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VOLUME II

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BIOENERGY CROPS

BY

Kavitha P.R

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SEMINAR REPORT

Submitted in partial fulfilment for the requirement of the course Agron.591

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The use of vegetable oil as fuel might seem of no importance in our times. However, such products can gain importance in the course of time and reach an equal status compared with today's petroleum and these coal-tar products

- Dr. Rudolf Diesel,1912

1. Introduction

India is richly endowed with non-conventional energy sources in the form of solar energy, wind energy, biomass, urban and industrial waste and more. These environmental friendly energy sources have low or compatible capital costs. In addition to this the depleting nature of fossil fuel resources, rising import bills for oil and coal and for managing pollution and environmental degradation confirms the need for renewable energy in the country.

With increasing use of fossil fuels, stronger threat to clean environment is being posed as burning of fossil fuels is associated with emissions like CO_2, CO, SO_2, NO_2. These emissions are the major gases causing air and hence environmental pollution. Despite this, fossil fuels continue as the major conventional energy source in meeting the faster increasing world energy demand. The harmful exhaust emissions from engines, rapid increase in the prices of petroleum products and uncertainties of their supply have jointly created renewed interest among researchers to search for suitable alternative fuels (Chaturvedi, 1995).

Energy, especially from fossil fuels, is a key ingredient for all sectors of a modern economy and plays a fundamental role in improving the quality of life in less developed economies. Energy crops could be used for multipurposes namely for energy, food, medicine and industrial uses, including paints, lubricants etc. The Botanical Survey of India has identified about 400 plants which yield vegetable oil. Among the 400 plant species 60 have the most potential and are important bioenergy crops. Bioenergy crops are fast growing crops grown for the specific purpose of producing energy from the resulting plant (OECD, 1984). Main advantageous environmental qualities include erosion control, soil organic matter build up and reduced fertilizer and pesticide requirement.

Bioenergy crop plants functioning as solar energy collectors and thermochemical energy storage system are the basis for biological systems that are expected to contribute renewable energy, help stabilize the rising levels of GHG (Table1) and mitigate the risk of global climate change (Parrish and Fike, 2005).

Biofuels are renewable liquid fuels coming from biological raw material and have been proved to be good substitutes for oil in the transportation sector. As such biofuels like ethanol and biodiesel are gaining worldwide acceptance as a solution for problems of environmental degradation, energy security, rural employment and agricultural economy. Biodiesel is a diesel fuel substitute produced from renewable source such as vegetable oils, animal fat and recycled cooking oils through transesterification process (Lele, 2006). The use of biofuel in conventional diesel engines results in substantial reduction of unburnt hydrocarbons, carbon monoxide and particulate matter. Also it is considered a clean fuel since it has almost no sulphur, aromatics and about 10% built-in oxygen which helps to burn fully (Achten et al.,2008). Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. The annual estimated potential of biodiesel is about 20 millon tonnes per annum. It is expected that country's energy demand would grow at an annual rate of 4.8% over the next couple of decade (Mohan *et al*, 2010).

2. Petroleum consumption in India

In 2001, India was ranked 8^{th} in the world in terms of energy demand, and consumption is expected to grow at 48 percent in the future (Sivanappan, 2006). India imports 72% of the oil used and there is a gradual increase in the import of crude oil and petroleum products year after year (Fig.1). Petroleum products consumption increased from 100mt from 2001-02 to 134mt in 2008-09

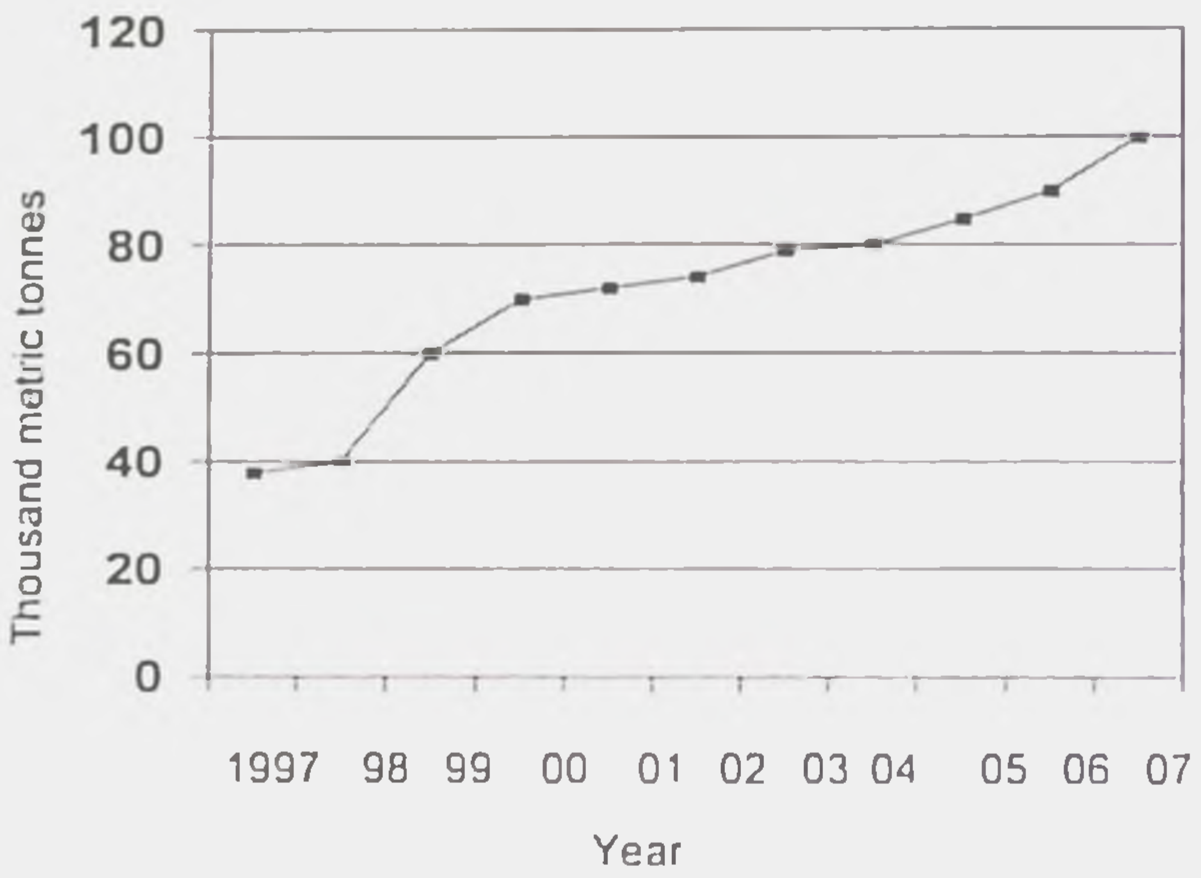

Fig 1 India's import of crude oil and petroleum products (Petroleum planning & analysis cell, 2009)

3. Energy scenario in India

Energy is the key input for technological, industrial and socio-economic development of a nation. The commercial sources of energy such as coal, fossil fuel, natural gas and electricity are extensively used, but these resources are finite. It is estimated that 246 mt of coal, 323.5 billion units of electricity, 25.9 mt of diesel oil and 8.7mt of kerosene are available in the country to meet the energy demand of various sectors (Maheshwari and Chaturvedi, 1997).

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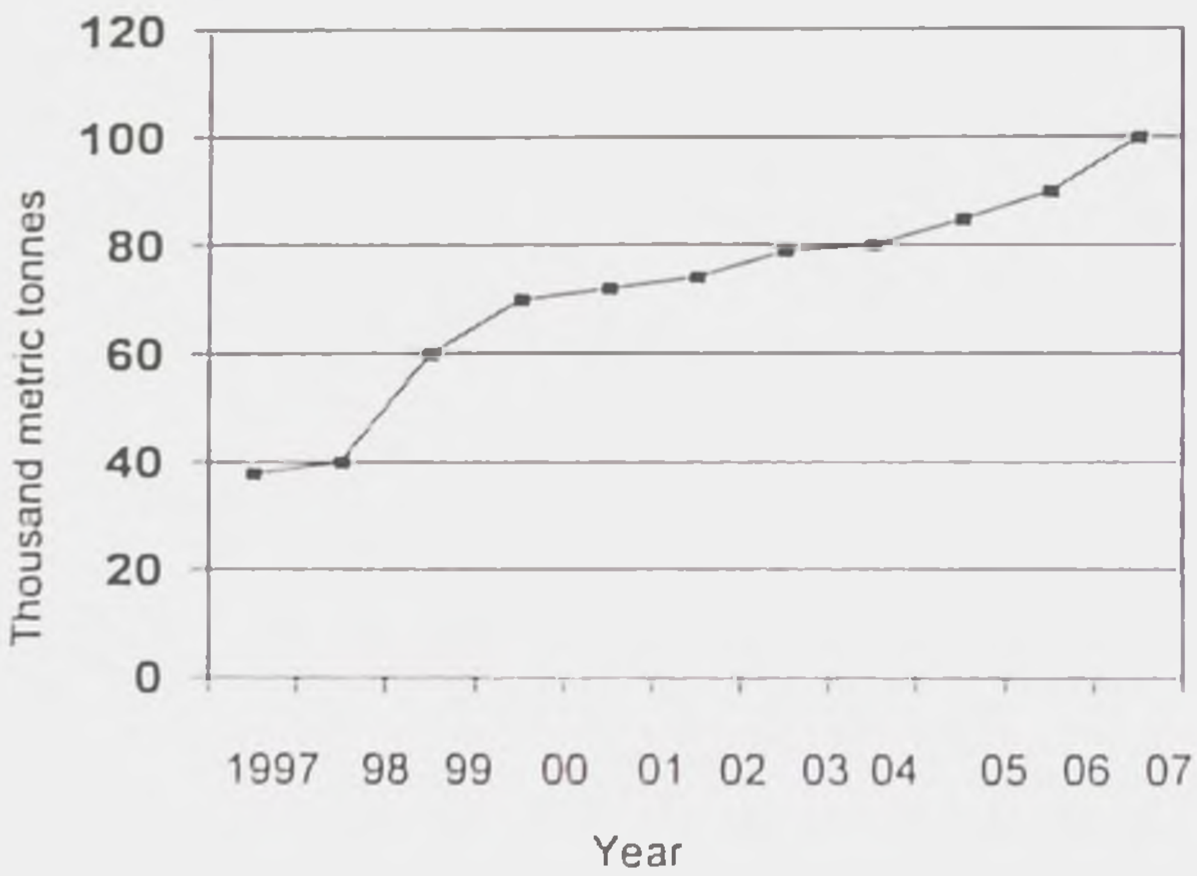

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Table 1. GHG savings by bioenergy crops

Crop	Annual ethanol yield (L/ha)	GHG savings(%)
Sugarcane	6800 - 8000	87 – 96
Corn	3100 - 4000	10 – 20
Switch grass	3100 - 7600	37 – 73

(Parrish and Fike, 2005)

3.1 Oil status in the world

The earth was originally endowed with about 2,000 billion barrels of oil. We have used about 1,000 billion barrels. As of 2004, we consumed about 28 billion barrels per year. If we consume at this rate, oil reserves would last only for 35 years(Bharadwaj *et al*.,2007).

4. Green energy sources

Green energy sources refer to various technologies used to meet the energy needs of society in ways that can continue indefinitely into the future without damaging or depleting natural resources.

The main categories of green energy include:

1.Wind energy
2.Solar energy
3.Fuel cell power
4.Ocean Current Energy Conversion System
5.Biofuels

4.1 Biofuels

Biofuels are alcohols, esters or other chemicals made from cellulose biomass, renewable sources such as fast growing trees, grass, aquatic plants including algae and waste products (Kumar, 2008).

The major advantage is that these sources are renewable. It qualifies for carbon credits through reduction of GHG emission. We get an additional income from byproduct utilization. There sources are pollution free. However, the production of energy from these sources are expensive. It can produce energy only under certain circumstances. For example to produce solar energy sufficient sunlight is required. These are less energy efficient also.

5. Classification of biofuels

5.1 First generation biofuels

First generation biofuels are the biofuels made from sugar (sugarcane,sugarbeet), starch (seeds or grains such as maize kernels) using conventional technology. The best known first-generation biofuel is ethanol made by fermenting sugar. With different fermentation organisms, other alcohols, like butanol can be obtained. Commercialization efforts for butanol are ongoing , while ethanol is already a well-established industry. Global production of first-generation bio-ethanol in 2006 was about 51 billion litres, with Brazil (sugar cane as a source) and the United States (maize as a source) each contributing 35 percent of the total (Table 3). China and India contributed 11 per cent to global ethanol production in 2006, and production levels were much lower in other countries with feedstocks that include cane, corn, and several other sugar or starch crops (sugar beets, wheat, potatoes). Many countries are expanding or contemplating expanding their first-generation ethanol production, with Brazil and the United States having by far the largest expansion plans. Ethanol production is expected to more than double between now and 2013 in Brazil and production capacity in the United States will double from the 2006 level once new plants currently under construction are completed. Such feedstocks which are important sources of human foods in India, will not be diverted for generation of biofuels because this will lead to food shortages and price rises in the country.

5.2 Steps in ethanol production

First the juice is extracted from the biomass. Then it is converted into sugar by enzymatic reaction. After conversion, it is transfered to the fermentation tank and a selected strain of yeast is added. Mixing is done and the fermentation proceeds for 2-3 days at 20-40^{0}C to produce an alcohol concentration of 8-10 percent . This mixture is distilled first to give 50-60 percent alcohol. The alcohol stream is redistilled to give a 95% product. The annual fuel ethanol production in the world is given in Table 2.

5.3 Second generation (2G) biofuels

The second generation biofuels are produced from the non-food crops, including cellulosic and lignocellulosic materials. We can use either non-edible residues of food crop (corn stalks) or non-edible whole plant biomass.

Second generation biofuel production processes can use a variety of non-food crops which have tremendous potential in India. These include waste biomass, the stalks of wheat, corn, wood, etc. There are certain advantages of 2G biofuels. They can be produced on degraded agricultural lands and processes are highly sustainable and ensure stable fuel supply. The 2G biofuels do not contaminate the ground water and help maintain cleaner rivers. Economically, they provide more energy per acre than food-based biofuels in India. Transesterification is the process involved in the production of biodiesel. Germany ranks first in biodiesel production, mainly from Rapeseed and sunflower. Top biodiesel producers are given in(Table 3).

Transesterification (Fig.2) is the chemical conversion of vegetable oil into biodiesel. It is also called alcoholysis. This process has been widely used to reduce the viscosity of triglycerides. Vegetable oil is chemically reacted with alcohol (methyl/ ethyl) in the presence of catalyst KOH at atmospheric pressure and at a temperature of about 60-70°C. The mixture at the end of reaction is allowed to settle. The lower glycerine layer is drawn off while the upper methyl ester layer is washed to remove entrained glycerine and is then processed further. The excess methanol is recovered by distillation and sent to a rectifying column for purification and recycled. The transesterification works well when the starting oil is of high quality. Biodiesel fuel made from vegetable oil are non toxic, biodegradable, renewable sources.

5.4 Third generation (3G) biofuels

The third generation biofuels are produced from algae. Algae are low input, high yield feedstock to produce biofuels in India. It produces 30 times more energy per acre than land crops such as soybeans. The interest in algae as a potential biofuel feedstock stems from two main features. Firstly, many algae species are remarkably efficient at photosynthesis, converting up to 6% of incident solar energy into biomass. Secondly, for a handful of these algae, much of this captured energy is stored in the form of plant oils (lipids) that can be extracted and processed into biodiesel (Singh *et al.*,2010).The production of algae for processing into biofuels has greater potentials in India because of availability of abundant solar energy. Further, high growth rates and near continuous harvesting which is possible with algae makes them a very important alternative energy resource for biodiesel in India. In USA the production technology for production of biodiesel from algae are already popularized, but the cost of production is very high which comes around Rs.500/litre. In India we are trying to reduce its cost @ 20/litre by using super strains of algae. In India, research work are progressing at Institute of Chemical Technology Matunga, Bombay.

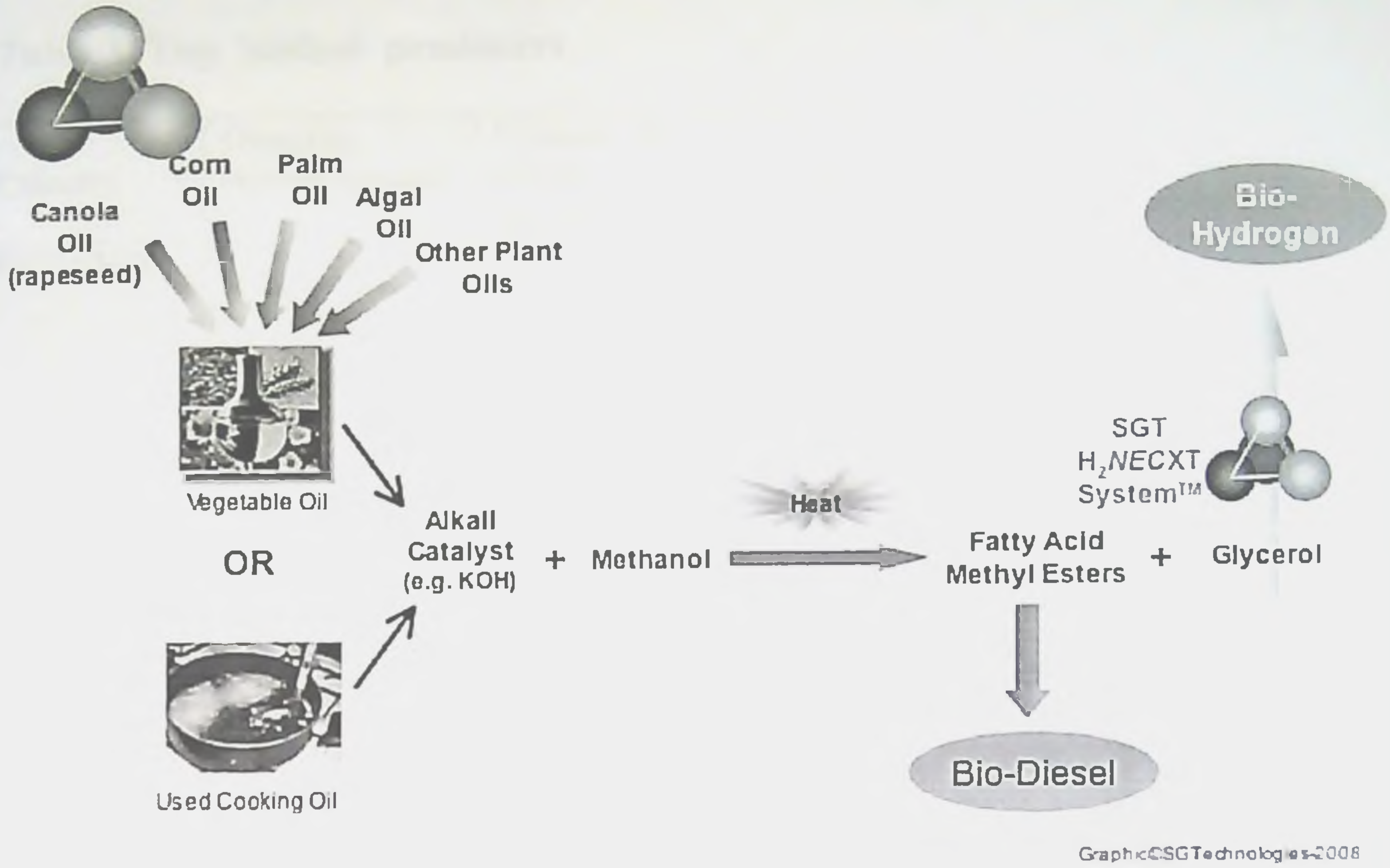

Fig. 2. Steps in transesterification

Table 2. Annual fuel ethanol production (Million gallons/year)

World rank	Country	2007	2008	2009
1	USA	6498	9000	10750
2	Brazil	5943	6053	7264
3	Europe	5943	6053	7264
4	China	486	501	541
5	Thailand	79	89	435
6	Canada	211	237	290
7	India	52	66	91
8	Colombia	74	79	83
9	Australia	26	26	56
10	**World total**	**14026**	**17916**	**20221**

(Licht, 2010)

Table 3. Top biofuel producers

Country	Ouantity (millon tonnes)	% share of world population	Crops
ETHANOL			
Brazil	15,110	37	Sugarcane
USA	13,390	33	Maize
China	3650	9	Maize, cereal grains
India	1750	4	Sugarcane
France	830	2	Sugar beet, Wheat
BIODIESEL			
Germany	1310	50	Rapeseed, Sunflower
France	440	17	Rapeseed
Italy	400	15	Sunflower, Rapeseed
US	95	4	Soya bean

(Soltani and Almodares, 2004)

6. Conventional bioenergy crops

6.1 Sugarcane (*Saccharum officinarum*)

Sugarcane is a tall perennial grass,native to warm temperate to tropical regions of South and South East Asia. They have stout, jointed, fibrous stalks that are rich in sugar, and measure two to six meters tall. Sugar cane products include table sugar, molasses, bagasse and ethanol. Total production is 55-60t/ha. From one ha of sugar cane yield around 4000 litres of ethanol /yr (Almeida, 2007).

Brazil is the biggest grower of sugarcane, which goes for sugar and ethanol for gasoline-ethanol blends (gasohol) for transportation fuel. Today, sugarcane is grown in over 110 countries. In 2009, an estimated 1,683 million metric tonnes, were produced worldwide which amounts to 22.4 percent of the total world agricultural production by weight. About 50% of production occurs in Brazil and India. In India, the states of utterpradesh (38.57 %), Maharashtra(17.76 %) and Karnataka (12.20 %) lead the nation in sugarcane production.

6.2 Sugar beet (*Beta vulgaris*)

It is a hardy perennial crop, that can be grown commercially in a wide variety of temperate climates. During its first growing season, it produces a large storage root whose dry mass is 15–20 percent sucrose by weight. Major advantages are lower cycle of crop production, higher yield, high tolerance of wide range of climatic variation, low water and fertilizer requirement compared to sugar cane. Yield potential is 60 t/ha.

Ethanol yield is about 6500 to 7000 L/ha (Devlin, 2009). Ethanol is produced through fermentation. It can also be used for preparation of beverages and sugarbeet syrup.

6.3 Cassava (*Manihot esculenta*)

It is a woody shrub, native to South America. Cassava is grown for its enlarged starch-filled roots, which contains the maximum concentration of starch on a dry weight basis among food crops. Fresh roots contain about 30% starch. Its yield is about 30 to 40 t /ha. Ethanol production from one tonne is about 200 to 280 L. It can be used for starch extraction and culinary purpose.

6.4 Sweet sorghum (*Sorghum bicolor*)

It is a drought tolerant crop, which is similar to grain sorghum with sugar rich stalks and a water-use efficient crop, has a very good potential as an alternative feed stock for ethanol production. Its origin is in Africa.

6.4.1 Comparative advantages of sweet sorghum over sugarcane

Growing period (about 4 months) and water requirement are four times lower than those of sugarcane (12 to 16 months). Cost of cultivation of sweet sorghum is three times lower than sugarcane. Suitable for mechanized crop production in sweet sorghum. The ethanol production process from sweet sorghum is eco-friendly compared to that from molasses. Ethanol burning quality is superior - less sulphur than from sugarcane and high octane rating.

6.4.2 Sweet sorghum based ethanol production

Stalks passed in series of two rollers. Juice yield to an extent of 40 percent of cane yield on weight basis. Juice pasteurized at 100^0C for 30 minutes. Enzyme added to breakdown starch to glucose. Yeast is added and allowed to ferment for 34 to 40 hours. Methane collected from spent wash, used as fuel in boiler. Molecular sieve used to convert rectified Spirit into fuel ethanol upto 99.8%. Ethanol yield is about 3200 L/ha (Reddy *et al*., 2005).

6.5 Corn (*Zea mays*)

Corn is the main feedstock for the production of ethanol fuel in USA. In order of world grain production, corn ranks second after wheat. It has a grain yield of 12t/ha/yr and ethanol yield is about 4500L/ha.

6.5.1 Production process of ethanol is by dry and wet milling

1) Dry milling

In the dry milling process the entire corn kernel is ground into flour to produce meal. The meal is then slurried by adding water and enzyme to convert starch to dextrose, a simple sugar. Ammonia is added to control the pH and as a nutrient for the yeast, which is added later. The mixture is processed at high-temperatures to reduce the bacteria levels after that cooled in fermenters. Yeast is added to convert sugar to ethanol .

The entire process takes between 40 to 50 hours, during which time the mash is kept cool and agitated in order to facilitate yeast activity. After the process is complete, everything is transferred to distillation columns where the ethanol is removed from the stillage. The remaining stillage then undergoes a different process to produce a highly nutritious livestock feed.

2) Wet milling

The process of wet milling takes the corn grain and steeps it in a dilute combination of sulfuric acid and water for 24 to 48 hours in order to separate the grain into many components. The slurry mix then goes through a series of grinders to separate out the corn germ. The remain process is same as that of dry milling. Corn oil is a by-product of this process and is extracted and sold.

6.6 Purging nut (*Jatropha curcas)*

It can be grown in wide range of soil (gravely, sandy, saline and rocky soils) and climatic conditions (from high temperature to light frost). Jatropha originated in Central America and was introduced in India by the Portuguese. There are number of species of Jatropha like *J.curcas*, *J.gossypifolia*, *J.glandulifera*, *J.multifida*, *J.nana* etc. Out of this *Jatropha curcas* is the potential oil yielding species. It is a photoinsensitive perennial plant, have a life span of 30 years. It can be established from seed and vegetatively from cuttings. The use of curcas oil as a source of fuel has primarily been investigated in Thailand (Dharmalingam and Palaniappan, 2008).

Jatropha plantation starts giving seed in a maximum period of two years after planting. Seed production ranges from about 0.4 t /ha in first year to over 5t/ha after 3 years, with approximately 30-40% oil. From 1t of seeds around 600 litres of biodiesel obtained and oil potential is around 1890L/ha/yr (Singh and Srivastava,2010). Biodiesel can be obtained by the process of transesterification (Figure 3).

Jatropha curcas is used as a pioneer species for reclamation of degraded lands in a country with a largest forest cover. Various parts of the plant are of medicinal value, its bark contains tannin and the plant has honey production potential. Being rich in nitrogen ,the seed is an excellent source of plant nutrients

6.6.1 Non-forest areas proposed for Jatropha cultivation

200 districts in 19 potential states have been identified on the basis of availability of wasteland, rural poverty ratio, below poverty line (BPL) census & agroclimatic conditions suitable for jatropha cultivation. Each district will be treated as a block and under each block 15000 ha jatropha plantation will be undertaken through farmers. It has

been proposed to provide green coverage to about 3 million ha of wasteland through plantation of jatropha in 200 identified districts over a period of 3 years .

6.6.2 Organisation for promotion of the production of Jatropha

1. Plant Bio-Set up in the year 2005. The company is engaged in the production of jatropha seeds. The company is located in Thirunelveli, Tamil Nadu. The company is into contract farming and it also develops nurseries for jatropha cultivation. The services offered by the company to growers in jatropha plantation includes consultancy work for soil testing, cultivation technology, nursery raising, seed marketing with association of best professionals.

2. Jatropha Vikas Sansthan

JVS came into existence during the year 2002-2003. They provide overall development techniques for the jatropha cultivation, supply of tested seeds and saplings of best varieties. JVS has stretched its area of functioning to north, east and southern ends of India.

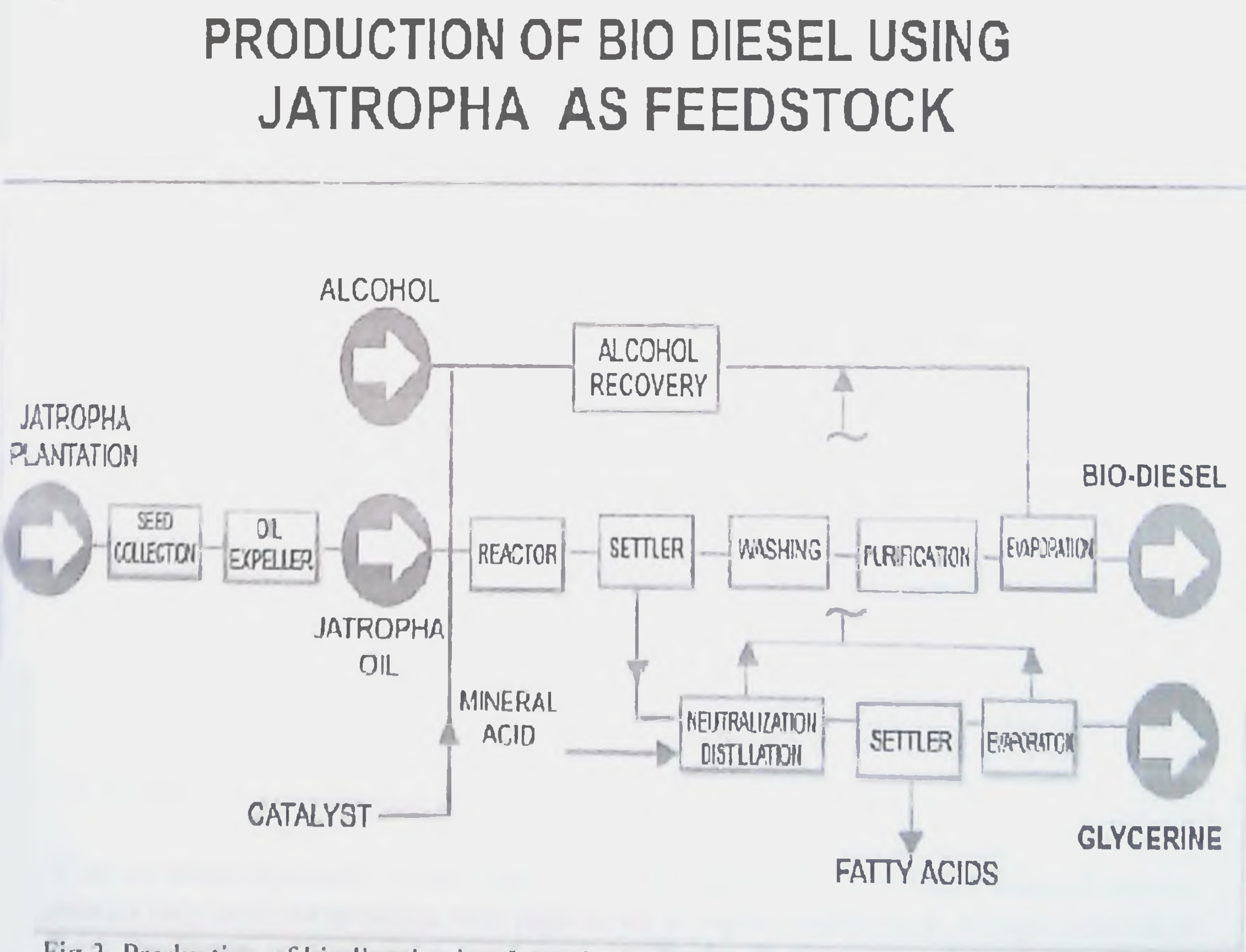

Fig 3. Production of biodiesel using Jatropha as feedstock

7. Emerging bioenergy crops

7.1 Switch grass *(Panicum virgatum)*

It is a warm season, perennial grass indigenous to Central and North America. It is widely adapted due to high biomass production, high photosynthetic efficiency and efficient use of water and nitrogen. Switch grass tolerates diverse growing condition, ranging from arid sites in the shortgrass prairie to brackish marshes. In southern range it grows to more than 3m in height. Deep vigorous root system, which may extend to depth of more than 3.5 m (Margarita *et al*, 2010). It reproduces both by seed and vegetatively.

Switch grass are classified as lignocellulosic crop, it is primarily the cellwall that are digested to form sugars, which can subsequently be fermented to produce liquid fuels. Developing lignocellulosic crops for energy require less intensive production techniques and poor quality land, there by avoiding competition with food production on better quality land. It is harvested with conventional equipment after the topgrowth has completely died back. It is done from mid-late October. Switch grass yield is around 10-25 t/ha/yr. Ethanol yield is about 13000L/ha/yr (Brejda *et al.*, 1998)

In addition to ethanol production, it would help reduce degradation of agricultural soils.

7.2 Elephant grass *(Miscanthus giganteus)*

Miscanthus has been trailed as a biofuel in Europe since the early 1980, native to subtropical and tropical regions of Africa & Southern Asia. It can grow to a heights of more than 3.5m in one growth season. The rapid growth, low mineral content and high biomass yield make it a favorite choice as a biofuel. It can tolerate brackish waters and utilize minimum amount of nutrient from the soil. It has high productive in yield, high ensilage capacity and low demand to soil fertility that makes it very cheap to produce. It is also a lignocellulosic crop. Miscanthus is spring-planted, and canes produced during the summer are harvested in winter. This growth pattern is repeated every year for the lifetime of the crop, which will be at least 15 years.

Using extensive cropping the yield makes 50-100t/ha/yr. Intensive approach is possible to achieve upto 400t/ha/yr. The top growth can be harvested 2yr after planting. Its annual yield can reach 25t/ha and fuel yield is about 12t/ha (Christian and Riche, 1998). The dry and leafless bamboo like stem is utilized as a solid fuel. Miscanthus has also excellent fibre properties for papermaking.

7.3 False flax (*Camelina sativa)*

It as an underexploited oilseed crop. It has an agronomic low input features and an unusual fatty acid composition with high levels of alpha linoleic acid & high cholesterol & brassicasterol content. Seed yield upto 2800kg/ha In the presence of omega-3-fatty acid makes its oil unique and nutrionally rich.

It is an annual plant with a maturity of 90-100 days, posses 35-40 % oil exhibiting a potential of 1400-1500L/ha/yr (Agarwal *et al.*, 2010). Cold pressed meal of camelina after oil extraction contain 10-14% oil by weight & protein with lower glucosinolate levels, making it is a desirable animal feed. The work was done in Uttarakhand, India to study the performance of Camelina under varing sowing dates (table.4). The result shows that maximum seed and oil yield obtained from plant sowing in september.

Table 4. Performance of *Camelina sativa* in a polyhouse under various sowing dates

Date of sowing	Plant height (cm)	Days to harvest	Branches/plant	Pods/ plant	Seeds/ pod	Seed yield/ plant	Seed yield (g/m2)
June 2009	47.25	82	11.4	185.4	9.40	0.865	120.2
July 2009	47.50	84	11.6	190.8	9.80	0.970	123.5
August 2009	50.75	86	12.4	201.0	11.20	1.245	136.4
Sept 2009	51.50	86	**12.8**	**203.0**	**13.75**	**1.400**	**150.1**

(Agarwal *et al.*, 2010)

7.3.1 Advantages

The crop has high oil content in the seed (40%) and ability to withstand low temperature to frost. It has high multiplication ratio and fit for crop rotation due to short life period.

7.4 Karanj (*Pongamia pinnata*)

It is a non edible oil producing tree legume native to tropical & subtropical regions of Asia. It is a drought resistant photo insensitive perennial plant, producing an average of 160 kg of seed/tree/yr. The seed of pongamia contain viscous, nonedible oil are a potential source of biodiesel. The seed contain around 30-40 percent oil. Oil made from seed known as honge oil. A single tree yield 9-90kg seed/tree, an yield potential of 900-9000kg seed/ha (Sujatha *et al.*, 2010).

Pongamia seed oil as a biofuel has physical property very similar to conventional diesel. It has no polyaromatic compounds & reduced toxic smoke& soot emission. A drastic reduction in sulphur content (<350ppm) & higher cetane number (>51) will be required in the petroleum diesel produced by refineries.

Juice from the plant as well as oil are antiseptic & resistant to pest. Used for making cart wheels, posts, agricultural implements. The press cake, remaining oil is extracted from seed used as poultry feed. The oil is used as lubricant, against human & animal skin disease.

7.5 Artichoke thistle/Cardoon (*Cynara cardunculus)*

It is a herbaceous species, most suitable for Southern European Countries. Cardoon requires a long, cool growing season, but it is frost sensitive. The oil extracted from the seed called artichoke oil and is similar to safflower & sunflower oil in composition & use. Cardoon has high biomass productivity stands around 20-30t of dry matter/ha. The plant contains oil bearing seeds that can be directly cold pressed to obtain oil suitable for biodiesel. Cardoon is propagated from stem portions having axial bud/suckers/seed.

The bulk of the biomass can either be used as a solid biofuel for the production of electricity & heat through direct combustion. Good crop for composting due to large amount of fibrous leaves & stalks.

7.6 Poplar/ Cotton wood

It is a deciduous flowering plant, native to Northern hemisphere. Poplar have very vigorous & invasive root system stretching upto 40m from the trees. Poplar used as an energy crop for biomass and biofuel, in energy forest systems due to high energy in-energy out ratio, large carbon mitigation potential & fast growth. The tree has ability to capture CO_2 from the atmosphere while improving the fast growth make it better renewable bioenergy resources (Hansen, 1993). The compound in the cellwall called lignin that contribute to plants structural strength ,but it hinders the extraction of cellulose, which is needed to make the fuel ethanol. In genetically modified hybrid poplar, lignin will not impede the release of cellulose for degradation into fermentable sugar, which then converted into ethanol.

Hybrid poplar could produce 320 liters of fuel/t of wood. It has a productivity of about 25t wood/ha (Hamzeh and Dayanandan,2004). Due to high tannic acid content, the bark is used for tanning leather. Also used for manufacture of paper. Logs from poplar provide a growing medium for shiitake mushroom.

7.7 Rape seed (*Brassica napus)*

Rapeseed oil was produced in the 19th century as a source of lubricant for steam engine. Rapeseed oil is used in the manufacture of biodiesel for powering motor vehicles. It is frequently combine with fossil fuel diesel in ratio from 2-20 percent biodiesel. It is the preferred oilstock for biodiesel production because it produces more oil per unit of land area than other oil seed crop. Rapeseed oil cake is used as a fertilizer. Biodiesel is produced through transesterification process. Yield is around 1150L/ha.

7.8 Duck weed *(Lemna gibba)*

It is a small floating perennial aquatic weed found worldwide & growing in thick, blanket like mat, slow moving, seen in nutrient rich waters. Its growth rate is very fast, less economic value, contain high amount of carbohydrate, cellulose and hemicellulose compared to several other aquatic plants. It yield 10-30 t dry matter/ha/yr.

Lemna gibba has wide spread distribution ranging from tropical humid climate to temperate areas. *Saccharomyces cereviceae* efficiently utilizes carbohydrates, cellulose & hemicellulose & converted into simple sugars, then to ethanol under oxygen limiting conditions. From 1kg dry weight can produce an average of 330ml of ethanol. Ethanol yield is about 20 percent & the efficiency of ethanol production comes around 25% (Sharma *et al.*, 2010)

The rapid growth of duckweed has application in bioremediation of polluted waters. Used for production of complex biopharmaceuticals. The meal is a good cattle feed.

7.9 Willow (*Salix herbacea)*

Willows form the genus *Salix*, around 400 species of deciduous tree and shrubs, found primarily on moist soils in cold and temperate regions of the Northern hemisphere. Willow is grown for biomass or biofuel, in energy forest systems, as a consequence of its high energy in-energy out ratio, large carbon mitigation potential and fast growth (Mola-Yudego and Aronsson, 2008). Large scale projects to support willow as an energy crop are already at commercial scale in Sweden, and in other countries there are being developed through initiatives such as the willow biomass project in the US and the Energy Coppice Project in the UK.

7.10 Blue Agave (*Agave tequilana)*

Agave, known for its use in the production of alcoholic beverages due to high proportion of sugars in the form of fructose. Grows chiefly in Mexico and the south-west of the United States, as well as tropical South America. Agave grows best in semi-arid regions where it will not likely come into conflict with food and feed production. Agave is a succulent with the ability to survive long periods of time without water. It is basic ingredient of tequila, a popular distilled spirit. The leaves can be beaten to make fibre (Dalton, 2005).

7.11 Jerusalem Artichoke (*Helianthus tuberosus)*

It is a herbaceous perennial plant, cultivated widely across the temperate zones. Tubers are an important source of fructose for industry. Crop yield is about 16-20t tubers/ha. It has a potential as a producer of ethanol fuel using inulin-adapted strain of yeast for fermentation. Ethanol fermentation of juice is done by the bacterium *Zymomons mobilis*. Acid hydrolysis at 80^0C for 40 minutes using concentrated H_2SO_4 gives maximum ethanol yield. It can yield more ethanol/ha than conventional crops used in alcohol production, but the major constraints are difficulty in harvesting as, tubers are irregularly shaped and difficult to store. The stalks and leaves can be used for silage.

8. Algae

Algae range from small, single celled organisms to multicellular organisms, some with fairly complex and differentiated form. Algae are usually found in damp places or bodies of water and thus are common in terrestrial as well as aquatic enviournment. Algae contain 2- 40 percent of lipids/oil by weight.

Algae grow rapidly and can have a high percentage of lipids, or oils which conventional petroleum refineries can convert into diesel fuel, a product known as green diesel. Like plants algae require primarily three components to grow that is sunlight, carbon dioxide and water. During photosynthesis, algae organisms use energy from the sun to combine water with CO_2 to create biomass. They can produce 30 times more oil per acre than alternatives such as rapeseed, palm, jatropha. As the slime grows, it makes a kind of vegetable oil, similar to the oil produced from sunflower seeds. Because algae can grow under severe conditions-extremes of temperature, pH and salinity, algae growing facilities can be built on arid coastal land unsuitable for conventional agriculture. Key technical challenges include identifying the strains with the highest oil content and growth rates and developing cost effective growing and harvesting methods.

The per unit area yield of oil from algae is estimated to be from between 47,500 to 1,87,500L/ha/yr, this is 7 to 31 times greater than the next best crop, palm oil (6010 litres). Production through transesterification process. In addition to its projected high yield, alga culture, unlike crop-based biofuels does not entail a decrease in food production, since it requires neither farmland nor fresh water.

8.1 Advantages of biodiesel from algae oil

Algae has high growth rate & certain strain can able to harvest continuously. High yield. Biofuel obtained from algae contains no sulphur, non-toxic and highly bio-degradable. Algae consume carbon dioxide as they grow, so they could be used to capture CO_2 from power stations and other industrial plant that would otherwise go into the atmosphere

9. Opportunities

It was estimated that around 55 mha waste land are reported in India. If this areas are effectively converted for the production of bioenergy crops that will reduces the dependency on other country for oil products. Now a days there is a high demand for bio-fuel due to more concerns about environment. 3G bio-fuels offer scope for further exploitation. Cost effective ethanol production from ligno-cellulose , it will increase the scope for selection of biomass.

9.1 Constraints

Competition with food markets is the major constrain. Ethanol supply is constrained by arable land availability. Competition with food production for land use could drive possible increase in both ethanol and food prices. Producing more biofuels from conventional feedstocks could conflict with conservation of biodiversity and for increased amounts of water, pesticides and fertilizers, thus raising sustainability issues. Ethanol recovery from feedstocks is less in conventional crop. Weak research work are there in this area.

10. Conclusion

The use of bioenergy offers significant opportunities for reducing green house gas emissions and for increasing energy security. However, an increase in bioenergy production can also put additional pressure on farmland and biodiversity as well as on soil and water resources. Hence, it is important to know how much bioenergy could technically be produced without increasing pressure on the environment (OECD, 1984).

Fuel security is one of the major concerns surrounding the use of biofuels. Biofuel feedstock production competes with food, fibre and timber for land, water and fertilizers (NRC, 1981). Transformation of biomass bound energy into a usable form of energy such as heat or liquid biofuel is not 100 percent efficient. However, second and third generation biofuels do not threaten food supplies. They hold promise for lower feedstock costs and substantial energy and environmental benefits.

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Discussion

1. What are the major algae used for biofuel extraction?

Botrycoccus braunii and *Chlorella vulgaris* are major algae used for biofuel extraction and extraction is mainly through transesterification process.

2. What are the major disadvantages of using algal strain for biofuel extraction?

Too much direct sunlight inhibit the growth of algae. Sometimes local species of algae overgrow the desired strain. Also overcrowding inhibit the growth.

3. What are the major difference between ethanol and biodiesel?

Ethanol is mainly produced from sugar and starch containing crops through fermentation process. Mainly food crops are involved in ethanol production. But in biodiesel production non edible vegetable oil by the process of transesterification .

4. What is the main difference between first and second generation biofuel?

The basic feedstocks for the production of first generation biofuels are seeds or grains such as wheat, which yields starch that is fermented into bioethanol . Such feedstocks which are important sources of human foods in India. The second generation biofuels are produced from the non-food crops, including cellulosic and lignocellulosic materials. Second generation biofuel production processes can use a variety of non-food crops which have tremendous potentials in India. These include waste biomass, the stalks of wheat, corn, wood, etc.

5. Mention the major companies involved in biofuel production?

1) Enhanced biofuel and technology- develops of multiple vegetable oil Biofuel technologies. EBT's headquarters are in London, UK and the company has a biofuel research and development centre in India.

2) Green Fuel Technologies - process harnesses photosynthesis to grow algae, capture CO_2 and produce high-energy biomass.Headquarter is in New York.

3) Aquaflow Bionomics Corporation- New Zealand-based, first company in the world to economically produce biofuel from wild algae harvested from open-air environments and to market it.

6. How these ethanol and biodiesel are used in engines?

In engines, ethanol and biodiesel are blended with conventional diesel and petroleum. We can normally go for 5%, 10% and 15% blending. If we go for 20% blending, some engine modification are necessary for using this.

Abstract

India produces only 30 percent of its annual crude oil requirement, which is nearly 105 Mt. Petroleum consumption increased from 100 Mt in 2001-02 to 134 Mt in 2008-09. Petroleum resources are finite and therefore searches for alternative sources are continuing all over the world.

Biofuels are alcohols, esters or other chemicals made from cellulose biomass, renewable sources such as fast growing trees, grass, aquatic plants including algae and waste products. Bioenergy crops can be grown for producing ethanol or biodiesel. Ethanol is a product of fermentation while vegetable oils/fats on transesterification are converted into their alkyl esters to produce biodiesel . Ethanol can be extracted from starchy crops such as corn, tubers like cassava and sugar yielding plants like sugarcane, sugarbeet and sweet sorghum (Kumar, 2008). Biodiesel is extracted from oil bearing crops like jatropha and rapeseed, and from aquatic plants including algae. Research is going on in many new sources like switch grass, miscanthus and jerusalem artichoke.

The use of bioenergy offers significant opportunities for reducing green house gas emissions and for increasing energy security. However, an increase in bioenergy production can also put additional pressure on farmland and biodiversity as well as on soil and water resources. Hence, it is important to know how much bioenergy could technically be produced without increasing pressure on the environment (OECD, 1984).

Fuel security is one of the major concerns surrounding the use of biofuels. Biofuel feedstock production competes with food, fibre and timber for land, water and fertilizers (NRC, 1981). Transformation of biomass bound energy into a usable form of energy such as heat or liquid biofuel is not 100 percent efficient. However, second and third generation biofuels do not threaten food supplies. They hold promise for lower feedstock costs and substantial energy and environmental benefits.

CARBON TRADING

BY

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2010-11-103

SEMINAR REPORT

Submitted in partial fulfilment for the requirement of the course Agron.591

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1. Introduction

Climate change is real and it has become one of the biggest threats that humanity is facing today. The main reason for this is the global warming due to increase in green house gases in the atmosphere. As a result of industrialisation there was a gradual build up of green house gases over the last century (Rao and Ramakrishna, 2004). It has been reported that mean global surface temperature over the century increased by 0.74^0C (IPCC, 2007). Since climate is closely related to human activities and economic development, there is a serious concern about its stability (Sinha *et al.*, 2000).

Several approaches are being adopted to reduce carbon emission to promote activities, which help to store and remove carbon from environment. These include the commitments of national governments to reduce emission through the 1992 United Nations Frame Work Convention on Climate Change (UNFCC) and its 1997 Kyoto Protocol. Per capita emissions in the industrialised countries are typically as much as ten times the average of developing countries. According to UNFCC, industrialised countries, which shall have the main responsibility to mitigate climate change, are listed as Annex I countries and the others as Non – Annex countries. Under Kyoto Protocol, emission caps where set for each Annex-I countries, and aims to reduce carbon dioxide level of 5.2 percent from 1990 level (IPCC, 2001).

Kyoto Protocol defines three flexibility mechanisms to meet their emission reduction commitments .The efforts made by governments to reduce carbon emission have made carbon a viable economic commodity. The Kyoto Protocol mechanisms has evolved into carbon trading mechanisms.

Carbon credits and carbon markets are components of national and international attempts to mitigate the growth in concentration of green house gases. To find a common unit for this commodity all green house gases are converted to carbon dioxide equivalents and are traded in carbon markets. The currency used in these markets is carbon credit. One carbon credit is equal to one tonne of carbon dioxide .Similar to trading of shares of companies and commodities in share markets we are trading carbon credits in carbon markets.

The market based measures have the greatest potential to attract profit – minded investors for climate – change mitigation. The main idea of market based mechanisms is to solve environmental problems in an economically efficient way. The market based measures are sometimes favoured due to ideological reasons, for example, the belief that government is not capable or efficient enough for providing solutions (Stavins, 1989). However, markets require clear price signals and a legal framework. Therefore, market based measures necessarily imply a role for the government. They would not thrive in an environment entirely free from regulation, where the government does not provide clear rules and frame – working conditions (Hans, 1989).

2. Background

The view that the human activities are likely responsible for most of the observed increase in global mean temperature since the mid -20th century is an accurate reflection of current scientific thinking (NRC, 2008). Everyday human activities release substantial amount of green house gases such as methane, carbon dioxide, nitrous oxide and halones to the atmosphere which contributes to global warming and consequently climate change.

2.1 Green House Effect

Earth receives 47 percentage of solar energy reaching the atmosphere .Water vapour, carbon dioxide and other green house gases play a major role in regulating the earths surface temperature. About 60 percentage of green house effect is caused by green house gases ,of which 36-37 percentage is caused by water vapour .The concentration of water vapour in the atmosphere is beyond the control of man .But man has direct effect on the emission of the other green house gases .

2.2 Green House Gases

Major green house gases included under Kyoto Protocol are carbon dioxide, methane, nitrousoxide and halones (sulphur hexafluoride, perflurocarbons and hydroflurocarbons). Among these green house gases carbon dioxide is responsible for 60 percent of green house effect, followed by methane (20%), nitrous oxide (6%) and halones (14%).

Each green house gas traps different amounts of heat and stays in atmosphere for different lengths of time. Studies use measures of Global Warming Potential (GWP) to compare between different green house gases (IPCC, 2000). Carbon dioxide is used as the benchmark gas, so all other gases are measured in carbon dioxide equivalence. Global Warming Potential of different green house gases is given in Table 1.

Table 1. Global Warming Potential of different green house gases

GHGs	GWP	ATMOSPHERIC LIFE (YEARS)
CO_2	1	100
CH_4	23	12
N_2O	289	114
HFC	142 to 11,700	1.4 to 260
PFC	6500 to 9200	10,000 to 50,000
SF_6	23,900	3200

(IPCC, 2001)

Global Warming Potential of methane is twenty three ,that means heat produced by one molecule of methane is equal to heat produced by twenty three molecules of carbon dioxide.

2.3 Global Warming

Global mean temperature is 14.7^0C. The increase in global temperature after 1900 is 0.74^0C, of which 0.5^0C has increased during the last fifteen years. If global temperature is increasing in this manner, by 2100, it may rise by 1.1^0C to 6.4^0C (IPCC, 2007)

2.4 Sector wise emission of green house gases

Among the different sectors the major part of the green house gases emission is contributed by energy supply sector (IPCC, 2007).(Table 2)

Table 2. Sector wise emission of green house gases

Sector	Emission (%)
Energy supply	26
Industry	19
Forestry	17
Agriculture	14
Transport	13
Residential and Commercial area	11

(IPCC, 2007)

3. Important world initiatives to combat climate change

1972 – International Conference on Human Environment.

The first conference on climate change was held at Stockholm in 1972, known as International Conference on Human Environment. It adopted the motto **"Only One Earth"** and declared **June 5, The World Environment Day.**

1987 – Brundtland Report

In 1987, World Commission on Environment and Development submitted the famous report **Our Common Future**. At that time Gro Harlem Brundtland was the chairperson, hence known as Brundtland Report. It produced the concept of sustainable development. There is a need for using sustainable development as a frame work for climate change policies.

1988 – Inter governmental Panel on Climate Change

According to the famous Brut land Report World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) formed **Inter governmental Panel on Climate Change.** The Inter governmental Panel on Climate Change was established with the mandate to provide relevant scientific data associated with human induced climate change , its potential impacts and options for adaptation and mitigation.

1992 – Earth Summit

In 1992, United Nations Conference for Environment and Development was held at Rio de Janerio, known as **Rio Summit**. It produced the famous international environmental treaty **"United Nations Frame Work Convention on Climate Change"**. This treaty divides the entire world countries in two, Annex I countries , which includes the developed countries and others as Non-Annex countries (UNFCC, 1992).

4. Kyoto Protocol

The Kyoto protocol is a protocol to the United Nations Frame Work Convention on Climate Change, aimed at fighting global warming was amended in 11 December 1997 at Kyoto in Japan. The treaty was opened for signature on 16 March 1998, and closed on 15 March 1999. The agreement came into force on 16 February 2005.As on July 2010, 191 states have signed and ratified the protocol.

4.1 Objectives

1. To assign mandatory targets for reduction of global emission of green house gases to signatory nations.
2. To stablise green house gases concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Kyoto Protocol is a legally binding commitment for developed countries to reduce green house gases emissions by an average of 5.2 percent relative to 1990's level. It must be achieved by 2008 – 2012. According to this Protocol developed countries has agreed on the stabilization of green house gases concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCC, 1992).

5. Kyoto Protocol Mechanisms

Kyoto Protocol defines three flexibility mechanisms to meet the emission reduction commitment of the Annex I countries (Fig. 1). These mechanisms has evolved into **carbon trading** mechanisms The climate change mitigation policies which do not minimize the cost are doomed to fail (Reddy and Assenza, 2009). The trading emission may be an instrument with the greatest potential in terms of climate – change mitigation. The idea of carbon trading has developed even before the Kyoto Protocol. The first emission trading schemes have been developed in the United States (Svendsen and Vesterdal, 2003). The most well known programme is the sulphur dioxide trading scheme established at the beginning of the 1990s to tackle acid rain. This system enables firms to buy and sell rights to emit sulphur dioxide in a manner equivalent to buying and selling currencies in a foreign exchange market. The fact that it combines both environmental and economic benefits makes it an attractive model for carbon trading systems. High penalities have prevented sources from violating the cap level – the maximum amount of allowable emissions.

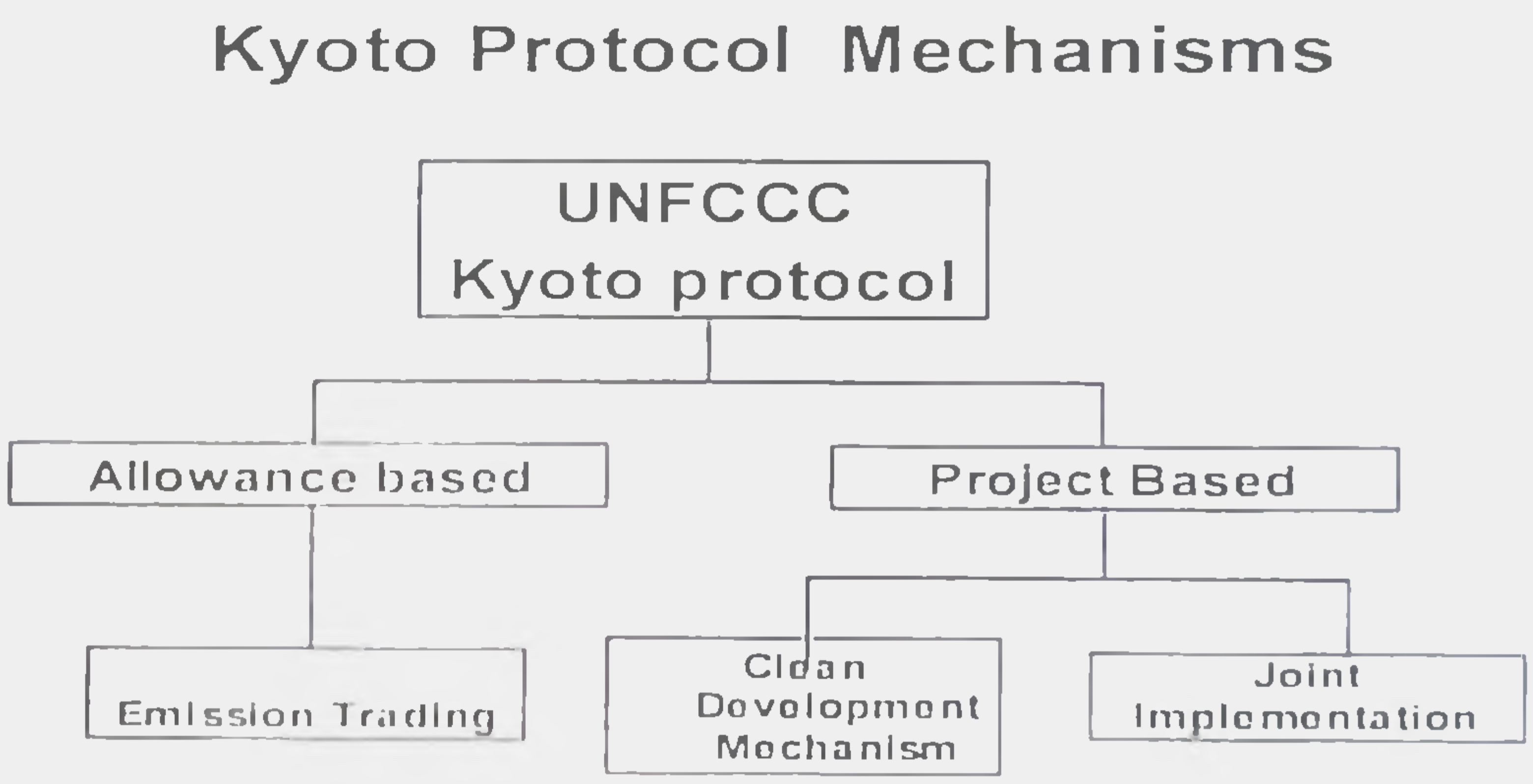

Fig. 1 Kyoto Protocol Mechanisms

5.1 Allowance based

Under allowance based mechanism comes the International Emission Trading. The countries have accepted certain targets for limiting or reducing green house gases emission. These targets are expressed as levels of allowed emissions or "assigned amounts".The allowed emissions are divided into units known as **"assigned amount units"** (AAUs). Assigned amount units are the trading units used in International Emission Trading. Under International Emissions Trading (IET) countries can trade in the international carbon credit market to cover their shortfall in Assigned amount units.

Countries with surplus units can sell them to countries that are exceeding their emission targets under Annex I of the Kyoto Protocol.

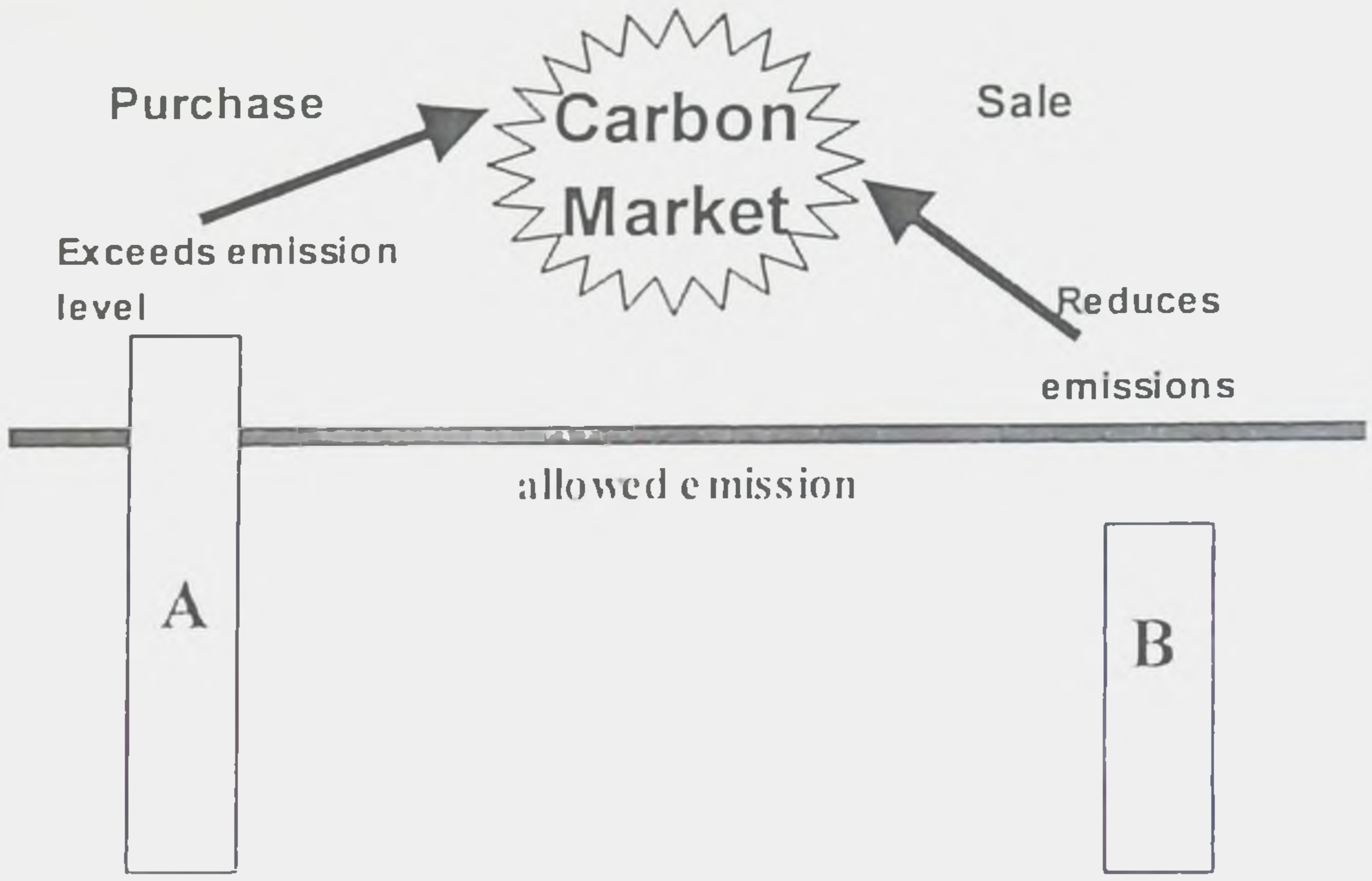

Fig. 2 Mechanism involved in International Emission Trading

For example, consider that A and B are two countries. If country A exceeds the emission level and country B reduces the emission, then country B can sell its assigned amount units in carbon market and country A can purchase AAUs from carbon market to meet its emission reduction target (Fig. 2).

5.2 Project based mechanisms

Project based mechanisms generate carbon credits from the projects. They are divided into two types.

1) Joint Implementation

2) Clean Development Mechanism

5.2.1 Joint Implementation

Joint Implementation is a project based mechanism which encourages participation of developed countries in reducing the green house gases emission. The trading unit is known as **Emission Reduction Units (ERUs)**.

1 ERU = 1 tonne of carbon dioxide

Joint Implementation allows a developed country to earn Emission Reduction Units from an emission – reduction project implementation in another country.

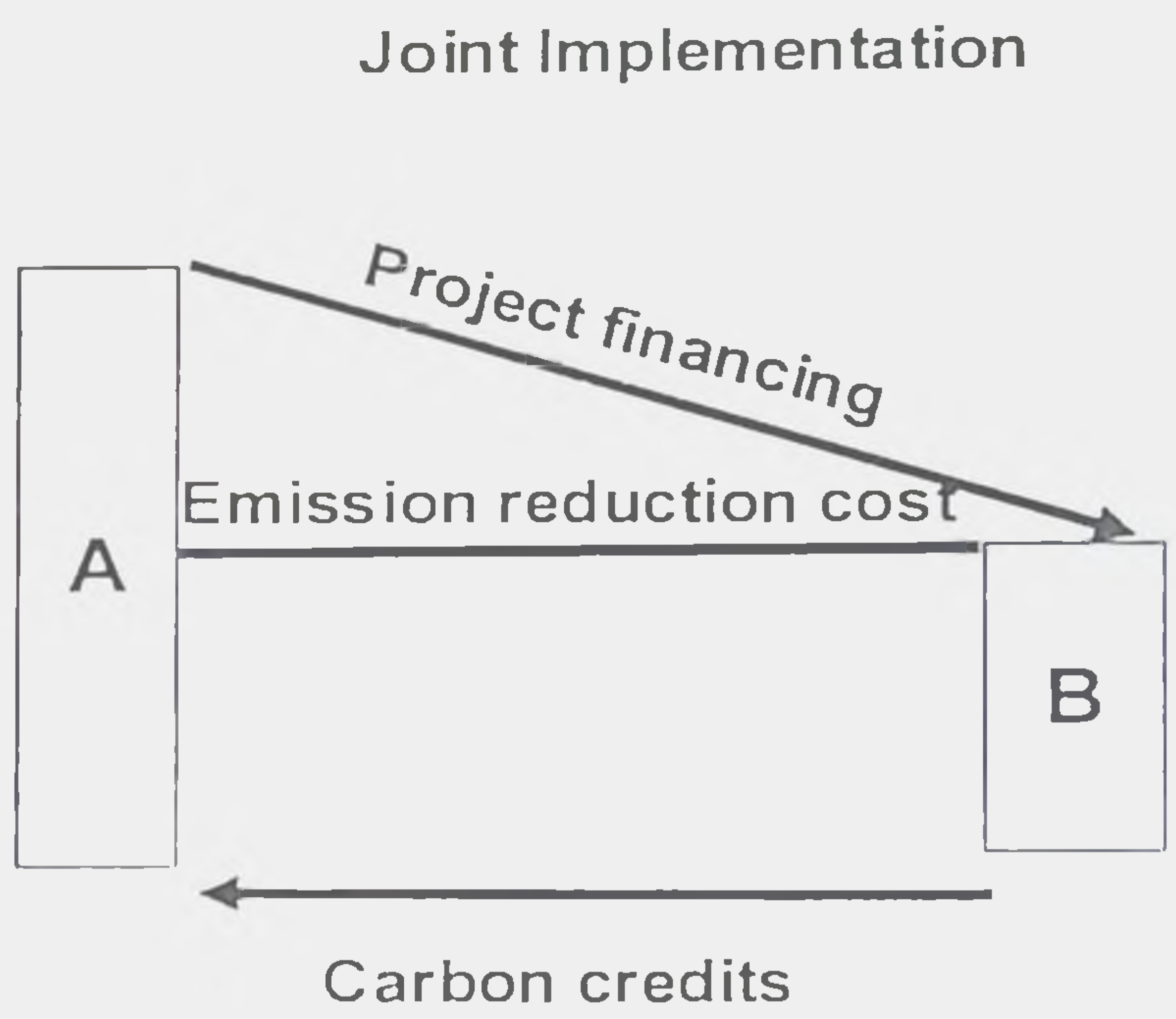

Fig. 3 Mechanism involved in Joint Implementation

For example, consider that A and B are two developed countries. If emission reduction cost of country A is more than that of country B , country A can implement a project in country B, in turn country B will provide carbon credits in the form of Emission Reduction Units (Fig. 3).

5.2.2 Clean Development Mechanism

The Clean Development Mechanism encourages the participation of Non-Annex countries that do not have green house gases emission reduction commitments under the Protocol. The Clean Development Mechanism envisages technology transfer and financial flow from developed countries to developing countries for environment – friendly projects that are in tune with the sustainable development needs of people in developing and least developed countries.

The Clean Development Mechanism (CDM) is defined in Article 12 of the Protocol. and is intended to meet two objectives:

(1) to assist parties not included in Annex I in achieving sustainable development through climate friendly technologies

(2) to assist parties included in Annex I in achieving compliance with their emission reduction commitments

The trading unit involved in Clean Development Mechanism is known as **Certified Emission Reductions (CER)**. One tonne of CO_2 (or its equivalent) that is prevented from releasing into the atmosphere (emission reduction) or removed from the atmosphere (sequestration), when certified by a designated operational entity is known as a CER.

$$1 \text{ CER} = 1 \text{ tonne of } CO_2$$

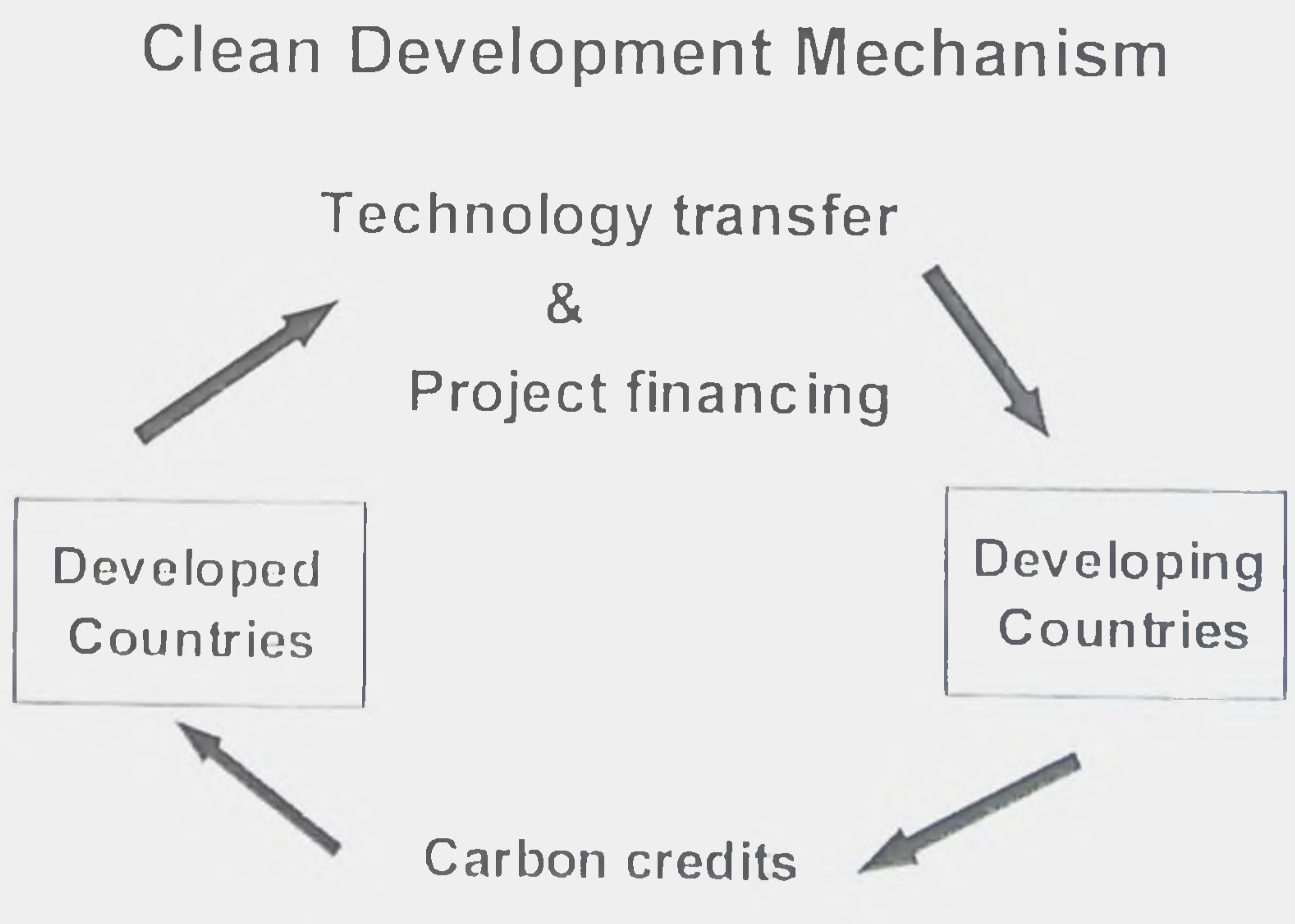

Fig. 4 Mechanism involved in Clean Development Mechanism

The developed countries will provied technology and implement a project in developing or least developed countries, inturn they will provide carbon credits in the form of Certified Emission Reductions (CER) (Fig. 4). Thus developed country can offset the carbon dioxide emission targets.

Types of Clean Development Mechanism projects

The concentration of green house gases in the atmosphere can be reduced either by reducing their emission or by capturing and storing them in plants.The capturing and storing of green house gases is known as carbon sequestration.The developed countries can implement projects based on these methods.The different types of projects includes :-

- Energy efficiency projects
- Transport
- Methane recovery projects
- Agro-projects
- Land use, and land use changes
- Industrial projects
- Cogeneration

Major part of the CDM projects are from renewable sources of energy. Percentage of CDM projects in each category is shown (Fig. 5).

Some CDM rules: (Seeberg – Elverfeldt,2010)

Additionality: Emission reductions or sequestration must be additional to any that would occur without the project. GHG emissions after the implementation of the project have to be lower than in the business as usual case.

Permanence: When accounting for credits, the length of the carbon storage and the risk of loss (natural or human disturbances, such as fire, flood or pest outbreak) are an important issue. Carbon is not stored indefinitely in forest biomass and soils, therefore, a separate temporary crediting system was developed for afforestation/reforestation (A/R) projects in which credits expire roughly between five and thirty years and can be renewed and resold.

Leakage: The unplanned, indirect emissions of GHGs, resulting from project activities. For example, if the afforestation of agricultural land leads to the migration of people who used to farm this land; and who then clear forest somewhere else.

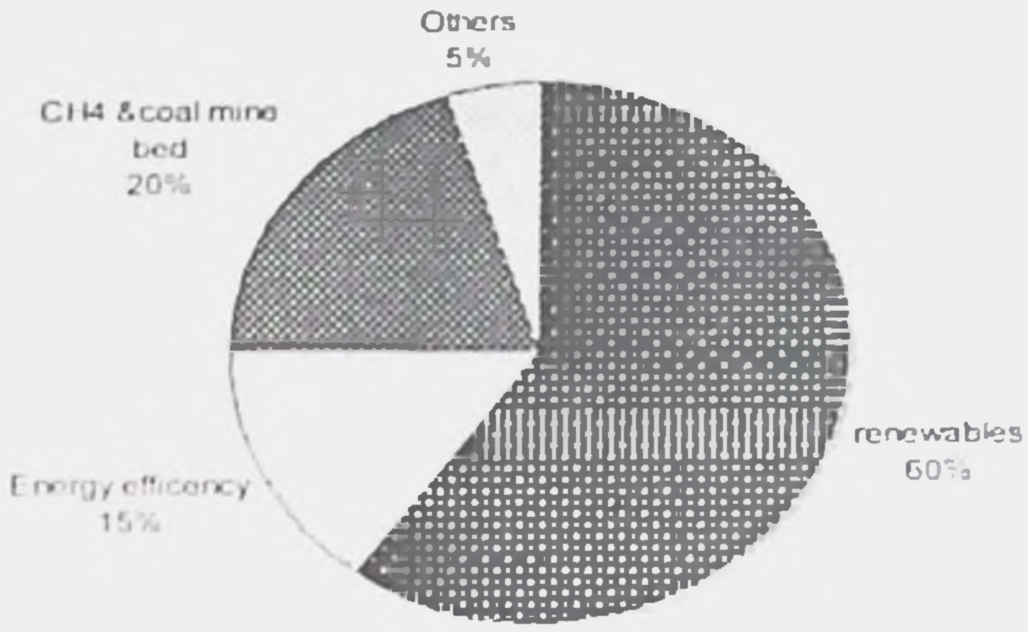

Fig. 5 Percentage of CDM projects in each category (World Bank, 2007)

To slow down climate change impacts, the emissions of GHGs need to be reduced immediately. Several activities in agriculture and forestry contribute to GHG emissions. Changing these and switching to new sustainable land management practices can support the uptake and the reduction of GHGs. Some agricultural activities can increase the amount of organic matter and carbon in the soil by using cover crops or reduce the emissions of methane through improving feeding practices. Sustainable forest management can avoid the destruction of forests and the release of CO2, and planting new trees sequesters more CO_2. Many of these practices also have additional potential benefits for the farming systems.

CDM project implementation steps

1) The project proponent (PP) prepare Project Design Document (PDD)
2) The PDD is validated by Designated Operational Entity (DOE)
3) The project should be approved by Designated National Authority (DNA)
4) Monitoring is done by PP
5) Certification /Verification is done by DOE
6) Issuance of Certified Emission Reductions by the Executive Board of UNFCC

Types of emission reduction activities in agriculture, forestry and other land uses

Forestry activities such as afforestation and reforestation, sustainable forest management, agroforestry, avoided deforestation/reducing emissions from deforestation and forest degradation (REDD).

Agricultural activities such as cropland and grazing land management, livestock management (improved feeding practices), peatland management and manure management.

Energy activities such as increasing the energy-efficiency at household or community level, sustainable biofuel production, and the employment of Integrated Food and Energy Systems.

Biodiversity enhancing activities such as watershed and soil management, biodiversity conservation.

6. Carbon Trading

Carbon Trading is a market based mechanism for mitigating the increase of CO_2 in the atmosphere. Carbon trading markets bring buyers and sellers of carbon credits together with standardized rules of trade. Any entity ,typically a business , that emits carbon dioxide to the atmosphere may have an interest or may be required by law to balance their emission through mechanism of carbon sequestration or reduction are potential buyers of carbon credits. The business entities those who reduce their carbon emission or the entities that manage agricultural land are potential sellers of carbon credits.

6.1 Carbon Markets

The carbon markets are a prominent part of the response to climate change and have an opportunity to demonstrate that they can be a credible and central tool for future climate mitigation (Singh, 2007).

6.1.1. Types of carbon markets

1. Regulatory compliance markets
2. Voluntary markets

1. **Regulatory compliance markets**

The three Kyoto Protocol mechanisms are very important for the regulatory market. Carbon credits are mainly purchased by **companies and governments** in regulatory compliance markets

2. **Voluntary markets**

On the voluntary market the trade of carbon credits is on a voluntary basis. Carbon credits on the voluntary markets are called Verified Emission Reductions. Voluntary carbon credits (VER) are mainly purchased by the private sector. The main task for private investors is to calculate the effects of green house gases regulations and carbon price sensitivities into the analysis of project economics (Weiss, 1990).

If an emission trading system is implemented at an international level, it could create strong demand for investment projects designed to reduce green house gases emissions. Private capital could be mobilized through this mechanism because green house gases reduction projects would yield credits that can be sold in the market. Firms that are able to reduce green house gases at a price below the trading price can make a profit out of mitigating climate change. In this way , climate change could become the basis for growing sector of business activity, ultimately developing into a major economic driving force in the coming decades.

The United Kingdom (UK) is the major buyer of carbon credits , and China is the potential seller , followed by India and Brazil. (Fig. 6), (Fig. 7).

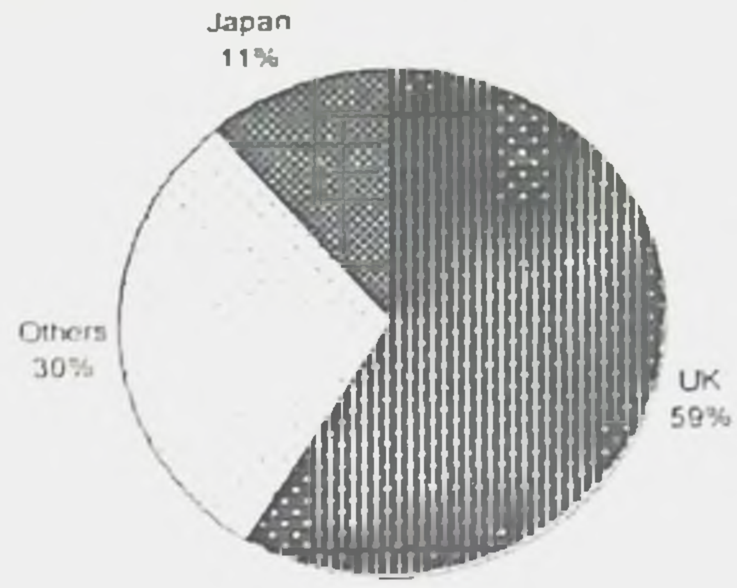

Fig. 6 Buyers of CDM and JI (World Bank, 2007)

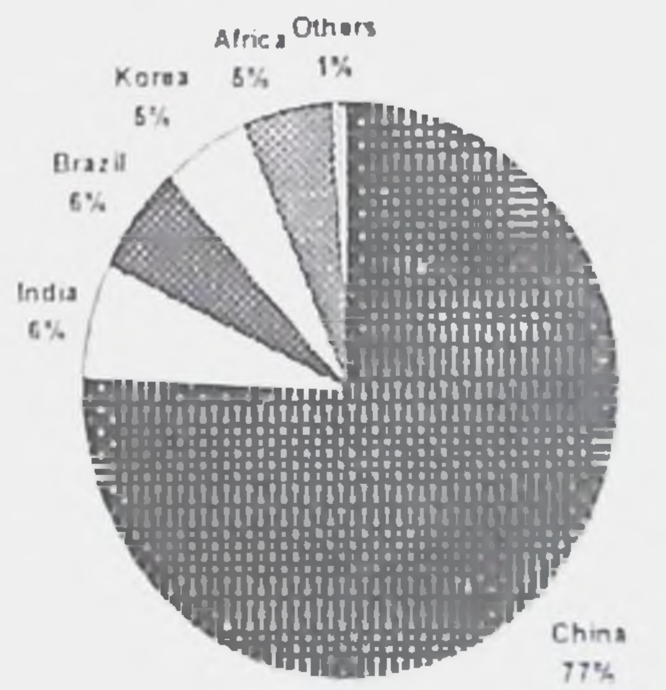

Fig. 7 Global CER supply country wise (World Bank, 2007)

6.2 Carbon Trading Exchanges

Climate exchanges have been established to provide a spot market in allowances, as well as futures and options market to help discover a market price and maintain liquidity. Carbon prices are normally quoted in Euros per tonne of carbon dioxide or its equivalent. Currently there are six exchanges trading in carbon allowances: the Chicago Climate Exchange, European Climate Exchange, NASDAQ OMX Commodities Europe, PowerNext, Commodity Exchange Bratislava and the European Energy Exchange. NASDAQ OMX Commodities Europe listed a contract to trade offsets generated by a CDM carbon project called Certified Emission Reductions (CERs). Many companies now engage in emissions abatement, offsetting, and sequestration programs to generate credits that can be sold on one of the exchanges. At least one private electronic market has been established in 2008: CantorCO$_2$e. Carbon credits at Commodity Exchange Bratislava are traded at special platform - Carbon place.

6.3. Carbon trading and rubber – A case study (Yogaratnam, 2007)

Under a Carbon trading arrangement, natural resource users who adopt and / or reintroduce land management technologies that store additional carbon in soil and vegetation compared to existing practices would be eligible to receive payments for the carbon those practices sequester. Two types of payments are anticipated, namely payments for C capture and C storage. Perennial tree crops as in the case of forest trees are known to function as natural "Sponges" for absorbing carbon dioxide from the atmosphere. Carbon sequestration is achieved through the uptake of carbon dioxide from the atmosphere and its conversion into cellulose and organic matter. Rubber tree behaves as a typical tropical rain forest tree that would at least function as efficient as forest trees in C sequestration.

Malaysian estimates indicates that mean annual leaf litter fall for a mature Hevea rubber ecosystem which included falling branches, twigs and fruits to be around 3.7 to 7.7 tonne/ha. Some preliminary studies done in Sri Lanka on biomass accumulation and carbon sequestration in rubber plantations from year 1 to year 33 when the trees are due for uprooting, indicates that total biomass accumulated in a tree at the age of 33 years is 1.8 Mg, which amounts is 963 Mg per hectare. This value is made up of biomass accumulated in fruits, leaves and fallen branches and trees uprooted at the end of the trees' economic life span of 33 years. The amount of carbon sequestered in one hectare of a 33 year-old stand is 596 mt, the major portion coming from the trunks and branches. The total amount of carbon sequestered in one hectare of rubber plantation made up of tree biomass, latex produced and contribution from leguminous cover crops amount to 680 mt. The possible credit revenue entitlement per hectare at the end of 33 years at the rate of U$ 12 per mt is about US$ 8160 Table 3.

Table 3. Carbon trading and rubber – A case study (Yogaratnam, 2007)

Total biomass accumulated in a tree at 33 years	1.8Mg
For 1ha	963Mg/ha
Amount of carbon sequestered in 1ha	596Mg
Amount of carbon sequestered in 1ha (latex and cover crops)	680Mg
Equivalent value in dollars	US $ 8160 (carbon credit @ US $ 12/Mg)

7. Indian Scenario

The ministry of Environment and Forests is the prime ministry for coordinating the climate change policy in India. India being non Annex I country has a large scope in carbon trade. Carbon like any other commodity has begun to trade on India's Multi Commodity Exchange and has become first exchange in Asia to trade carbon credits. India has generated approximately 30 million carbon credits.Indias market is growing faster than even information technology, bio technology BPO sector as 850 projects with a huge investment of Rs. 650,000 million are in pipeline. As per Prime Ministers Council on Climate Change, the revenue from 200 projects is estimated at Rs. 97 billion till 2012.

7.1 Favouring points for India

- India has high potential of generating carbon credits
- Wide spectrum of projects with different sizes
- Vast technical human resource
- Strong industrial base

Even though India is a largest beneficiary of carbon trading, it still does not have a proper policy for trading of carbon credits in market. So to unleash the true potential of carbon trading in India a special statue is to be created to govern the issues related to carbon credits.

8. Carbon Trading merits and demerits

8.1 Carbon trading merits

- Helps to meet the ultimate objectives of the Climate Change Convention
- A cleaner path for rapid economic development
- Assist developing countries in achieving sustainable development
- Flow of foreign investment
- Capacity building through CDM projects' development and implementation

8.2 Carbon trading demerits

- Lack of comprehensive global structure for trading
- Affects the economic development in developing & least developed countries
- Introduction of biofuel projects reduce the area under food grain production
- A lot of green house gases are emitted during project implementation

9. Conclusion

Nature has taken millions of years to capture and store the carbon as fossil fuel, but man has let it out in a few centuries. Man has opened the Pandora's Box and let out the evil but still there remains hope. Carbon trading provides excellent opportunities to reduce carbon emissions, especially that of industrialised countries. Climate negotiations will succeed only if developing countries are driven by development priorities, and if there are countries or groups of countries among them willing to take a leadership role to push the process forward. The issue of climate change should be approached at multiple levels through local and national development projects with an effort to establish cooperation mechanisms with an efficient sustainable development regime. It is hoped that viable policies of national governments along with better carbon trading mechanisms will help in achieving the goal of protection of the earth's climate.

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Discussion

1. Is there is any country which has not ratified the KyotoProtocol?

The most notable country who is yet to sign the Protocol is the United States, which is a party to UNFCCC.

2. What do you mean by Annex and Non Annex countries?

Annex I countries are industrialized countries and economies in transition, for example countries like Australia, Austria, Russian Federation, Ukraine, United Kingdom, and United States of America. A sub-group called Annex II countries are also there , who are developed countries which pay for costs of developing countries and include countries such as Australia, Austria, Belarus, Belgium, Bulgaria, Canada, the UK and the USA. The Non-Annex countries are developing countries, and they have no emission reduction targets.

3. What are the actions made in Copenhagen in relation to carbon trading?

The experts commented that the outcome of the Copenhagen climate summit was "disappointing". For example, the US President, Barack Obama has not proposed a target for US emissions cuts, it is the only obstacle to a strong climate agreement. Therefore, other countries did not support the convention of parties, and no more actions were made with regard to carbon trading.

4.What do you mean by energy supply sector?

The energy supply sector consists of a sequence of elaborate and complex processes for extracting energy resources, converting these into more desirable and suitable forms of energy, and delivering energy to places where the demand exists.

5. Why China is having more CER than India?

China has a strong industrial base compared to India, which provides more opportunities for hosting emission reduction projects than India.

6.What do you mean by co-generation ?

Co-generation is the sequential or simultaneous generation of multiple forms of useful energy in a single integrated system. For example, use of wasted heat from electric generation such as exhaust from gas turbines for industrial purpose or for heating .

7.How does watershed management earn CERs?

Watershed management activities are means of conserving the flora and fauna. The conservation of forest is a Clean Development Project. which can earn CERs.

8.Is there any exchange in India for carbon trading?

The Multi Commodity Exchange which has its base at Bombay is the exchange doing carbon trading in India. It is the Asia's first and largest carbon trading exchange.

9.Whether carbon trading is taking place in Kerala?

Yes. for example. the carbon credits. earned by around 16,000 farmers for their contribution towards controlling emission of greenhouse gases. are being traded now at Chicago Climate Exchange (CCX) providing them a small amount annually. It was an NGO. Anthyodaya. which pioneered the idea of carbon credit for farmers in the state. Anthyodaya functions as an aggregator of carbon emission offset credits for the CCX and pools the credits generated from the operation of biogas plants for sale in the exchange.

10.Is there any chance for carbon trading affecting food security?

Yes, converting land of agricultural land to forest and switching on to biofuel production at the expense of food grain production can affect food security.

11.What do you mean by leakage in CDM rules?

Leakage means, the unplanned, indirect emissions of GHGs. resulting from project activities. For example. if the afforestation of agricultural land leads to the migration of people who used to cultivate and who then clear forest somewhere else is a clear case of leakage.

Abstract

Climate change is one of the biggest threats humanity is facing today. It has been reported that the mean global surface temperature over the century increased by 0.74^0C (IPCC, 2007). The view that human activities are responsible for most of the observed increase in global mean temperature since the mid 20^{th} century is being accepted based on scientific facts (NRC, 2008). Everyday, human activities release substantial amount of green house gases such as methane, carbon dioxide, nitrous oxide and halones to the atmosphere which contributes to global warming and consequently, climate change.

Several approaches are being adopted to reduce carbon emission and to promote activities, which help to store and remove carbon from the environment. These include the commitments of national governments to reduce emission through the 1992 United Nations Framework Convention on Climate Change (UNFCC) and its 1997 Kyoto Protocol. Per-capita emissions in the industrialised countries are typically as much as ten times the average of developing countries. According to the protocol, industrialised countries, which have the main responsibility to mitigate climate change, are listed as Annex I countries and the others as Non-Annex countries. Under Kyoto Protocol, emission caps were set for each Annex-I country, and aims to reduce carbon dioxide level of 5.2 percent from 1990 level (IPCC, 2001).

Kyoto Protocol defines three flexibility mechanisms, International Emissions Trading (IET), Clean Development Mechanism (CDM) and Joint Implementation (JI), which can be used by Annex-I countries in meeting their emission reduction commitments. The efforts made by governments to reduce carbon emission have made carbon a valuable economic commodity. To find a common unit for this commodity all green house gases (GHGs) are converted to CO_2 equivalents, which are traded in carbon markets. The currency used in these markets is carbon credit, which is equivalent to one tonne of carbon dioxide emissions.

International Emissions Trading allows Annex-I countries to trade their emissions and to meet their emission reduction commitments at a reduced cost. Clean Development Mechanism and Joint Implementation are project-based mechanisms and they generate carbon credits through projects. Most of the CO_2 emission reductions are through renewable energy, energy efficiency and fuel switching projects. In agriculture, forestry and other land use sectors, different types of activities can help to reduce or avoid emission of greenhouse gases (Seeberg-Elverfeldt, 2010).

Carbon trading provides excellent opportunities to reduce carbon emissions, especially that of industrialised countries. It is hoped that viable policies of national governments along with better carbon trading mechanisms will help in achieving the goal of protection of the earth's climate.

BIOTECHNOLOGY APPLICATIONS IN WEED MANAGEMENT

BY

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SEMINAR REPORT

Submitted in partial fulfilment for the requirement of the course Agron.591

Valued

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1. Introduction

Weeds are the major constraints in crop production technology. About 45 percent of yield loss in crop production is caused solely due to weeds and a major share of cost of cultivation goes for weed control. Advances in biotechnology provide us alternative approaches in dealing with weed problems. Biotechnology is the application of biological organisms, systems, processes to provide desirable goods and services.

Agricultural biotechnology is the application of advanced concepts and techniques of biological sciences like recombinant DNA, genetic engineering, cell fusion, tissue culture etc that are relevant to specific agricultural programmes. During the nine-year period from 1996 to 2004, global area of transgenic/biotech crops increased more than 47 fold, from 1.7 mha in 1996 to 81 mha in 2004 and it reached 134 million hectares in 2009 (James,2009). Percent adoption of biotech crops in USA is given in Fig.2. This rate of adoption is one of the highest rates of crop technology adoption in agriculture and reflects the growing acceptance of biotech crops by farmers in both industrial and developing countries. The potential applications of biotechnology in addressing selected issues related to weed management and herbicide technology are quite promising. This comprises the use of bioherbicides mainly from microbial sources, use of naturally occurring herbicides of plant origin and their synthetic analogues, genetic improvement for crop tolerance to herbicides and decontamination of herbicide residues in soil using micro organisms. Of these applications, the widely exploited area is the breeding of crops having herbicide tolerance and pest tolerance.

2. Biotechnology / Genetic Engineering in Agriculture

Biotechnology played an important role in contributing various achievements in the field of agriculture. Some of them are a) improved crop yield b) adaptability to various environmental stresses c) increased nutritional qualities, taste, texture or appearance d) crop production technologies e) reduced dependence on fertilizers and agrochemicals f) synthesis of novel substances in plants. Tissue culture helped us in easy propagation in crops like pepper, garcinia, banana etc. Golden rice (with increased vitamin A content), Flavr savr tomato (improved shelf life) are examples for improved nutritional qualities and appearance. A plant gene, At-DBF2, from *Arabidopsis thaliana*, a tiny weed, was inserted into tomato and tobacco cells, the cells were able to withstand environmental stresses like salt, drought, cold and heat. Oilseeds can be modified to produce fatty acids for detergents, substitute fuels and petrochemicals. Potatoes, tomatoes, rice tobacco, lettuce, safflowers, and other plants have been genetically engineered to produce insulin and certain vaccines.

An analysis of the global area under GM crops during 2000 to 2010, shows an increasing trend in the area especially in the case of herbicide tolerant (HT) genetically modified crops. Globally, USA ranks first in area (64 mha) under GM crops followed by Brazil (21.4 mha) and Argentina (21.3 mha). In India, of the total area under cotton cultivation, 8.4 mha is under Bt cotton. Global area (country wise) of GM crops is given in Table 1. First HT soybean was released in Argentina in 1996. Trait wise area under GM crops is depicted in Fig.1. In USA, 100% area under soya and canola cultivation is herbicide tolerant varieties.

More than three-quarters (77%) of the 90 million hectares of soybean grown globally were biotech; for cotton, almost half (49%) of the 33 million hectares were biotech; for maize, over a quarter (26%) of the 158 million hectares grown globally were biotech; and finally for canola, 21% of the 31 million hectares were biotech.

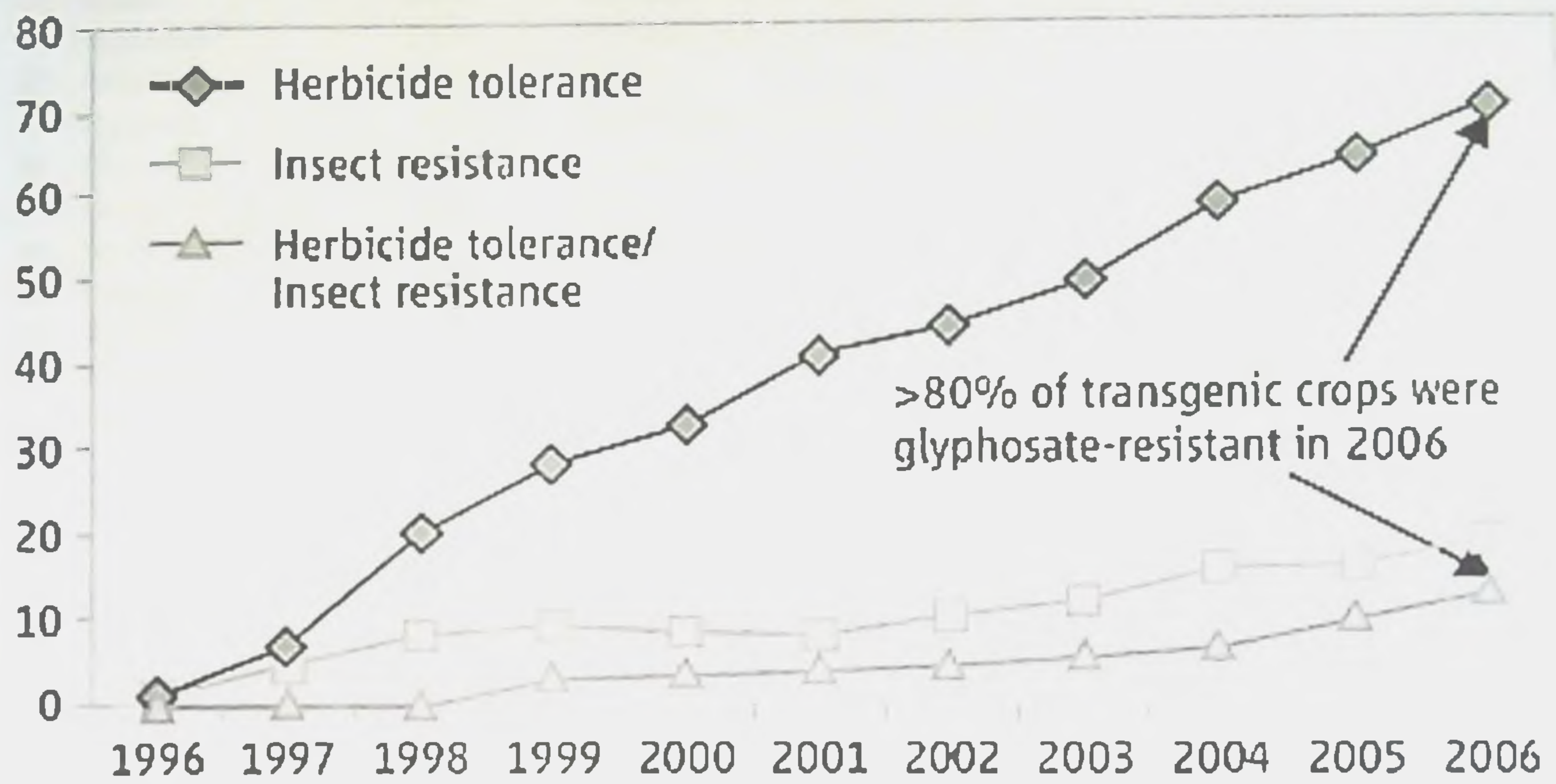


Fig 1. Trait wise area (%) under GM crops

(Service,2007)

Stacked products are an important feature of biotech crops and future trend, which meets the multiple needs of farmers and consumers, and these are now increasingly deployed by 11 countries of which 8 are developing countries. The new biotech maize, Smart Stax™, was released in the USA in 2010 with eight different genes coding for a total of three traits, two for pest resistance, (one for above ground pests and the other for underground pests) and herbicide tolerance. Biotech herbicide tolerant soybean continued to be the principal biotech crop in 2009, occupying 69.2 million hectares or 52% of global biotech area of 134 million hectares, followed by biotech maize, 41.7 million hectares at 31%, biotech cotton 16.1 million hectares at 12%, and biotech canola 6.4 million hectares at 5% of the global biotech crop area. Of the various companies producing GM crops, Monsanto's share is about 90 percent (Glyphosate tolerant soybean, corn, cotton, canola, sugar beet) and the remaining 10 percent by Bayer Crop Science , Syngenta, Du Pont etc.

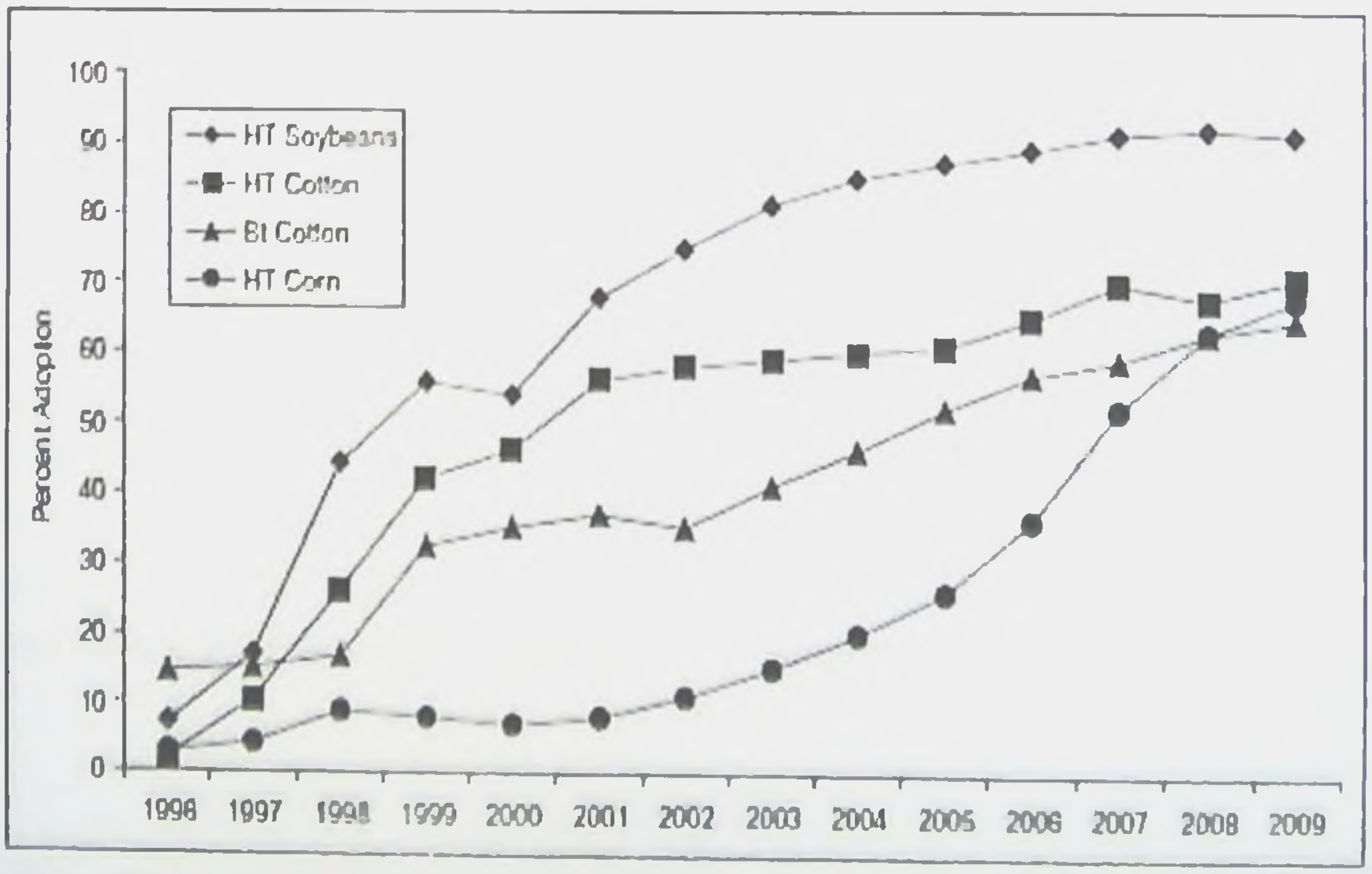
Table 1. Global Area of Biotech Crops in 2009: by Country (Million Hectares)

Rank	Country	Area (million hectares)	Biotech Crops
1*	USA*	64.0	Soybean, maize, cotton, canola, squash, papaya, alfalfa, sugarbeet
2*	Brazil*	21.4	Soybean, maize, cotton
3*	Argentina*	21.3	Soybean, maize, cotton
4*	India*	8.4	Cotton
5*	Canada*	8.2	Canola, maize, soybean, sugarbeet
6*	China*	3.7	Cotton, tomato, poplar, papaya, sweet pepper
7*	Paraguay*	2.2	Soybean
8*	South Africa*	2.1	Maize, soybean, cotton
9*	Uruguay*	0.8	Soybean, maize
10*	Bolivia*	0.8	Soybean
11*	Philippines*	0.5	Maize
12*	Australia*	0.2	Cotton, canola
13*	Burkina Faso*	0.1	Cotton
14*	Spain*	0.1	Maize
15*	Mexico*	0.1	Cotton, soybean
16	Chile	<0.1	Maize, soybean, canola
17	Colombia	<0.1	Cotton
18	Honduras	<0.1	Maize
19	Czech Republic	<0.1	Maize
20	Portugal	<0.1	Maize
21	Romania	<0.1	Maize
22	Poland	<0.1	Maize
23	Costa Rica	<0.1	Cotton, soybean
24	Egypt	<0.1	Maize
25	Slovakia	<0.1	Maize

* 15 biotech mega-countries growing 50,000 hectares, or more, of biotech crops

Source: Clive James, 2009.

Figure 2. Percent Adoption of Biotech Crops in the USA, 1996 to 2009.



Source: USDA's National Agricultural Statistics Service (NASS), 2009a.

3. Major Applications of Biotechnology in weed management

Applications of biotechnology in weed management can be grouped as:-

a) use of bioherbicides mainly from microbial sources

b) use of naturally occurring herbicides of plant origin and their synthetic analogues

c) genetic improvement for crop tolerance to herbicides and

d) decontamination of herbicide residues in soil using micro organisms.

Two major strategies for biocontrol of weeds include classical approach and biohericidal approach. Classical approach deals with introduction of an insect bioagent into weed population. For eg. Parthenium can be controlled by *Zygograma bicolorata* and *Cyrtobagous salviniae* and *Neochetina bruchii* controls Salvinia and Eichhornia, respectively.

3.1 Bioherbicide Approach

In bioherbicidal approach, various microbial bio-agents, usually a native pathogenous fungi or bacteria is cultured artificially and sprayed like a post-emergence herbicide on target weeds. Formulations of *Phytophthora palmivora* (De Vine®) as a selective mycoherbicide for the control of milk weed (*Morrenia odorata*) in citrus, and *Colletotrichum gloeosporioides* (Collego®) for the control of Northern joint vetch in rice and soybean, are now widely used in developed countries. Some of the commercialised bioherbicides are given in Table 2.

Kerala Agricultural University (KAU) has also contributed to this field. The herbicidal action of *Fusarium pallidoroseum* for the control of noxious aquatic weed *Eichhornia crassipes* was studied by Nazeema and Balakrishnan (1999) and application of five percent Cashew Nut Shell Liquid (CNSL) solution followed by five percent Wettable Powder (WP) of *Fusarium pallidoroseum* is being recommended for its effective control (KAU,2007). Abraham and Abraham (1999) reported that fungi like *Colletotrichum gloeosporioides*, *Alternaria alternata* and *Corynespora cassicola* are potential bioagents for the control of alien invasive weed *Mikania micrantha* (Mile-a-minute).

Criteria needed for a potential bioherbicide include fast growth and sporulation on artificial media, high virulency against target weed species, genetic stability, host specificity, broad tolerance range, prolific propagule production and poor dissemination. The main advantages of bioherbicides over chemical herbicides are their eco-friendly nature, high host specificity, lack of residue build up and absence of weed resistance development. Since they are host specific they lack broad spectrum action, which necessitates multiple applications. As they are microbes, they are mostly incompatible with other agrochemicals. Poor shelf life and restricted commercial potential (marketability) make their adoption difficult.

Table 2. **Commercialised bioherbicides**

Trade name of bioherbicide	Micro organism	Target weed
DeVine	*Phytophthora palmivora*	*Morrenia odorata* in citrus (milk weed, strangler vine)
Collego	*Colletotrichum gloeosporioides f. sp. aeschenomene*	*Aeschenomene virginica* (northern joint vetch) in rice , soybean
Casst	*Alternaria cassiae*	*Cassia obtusifolia* (sicklepod) in soybean, cotton
Biomal	*Colletotrichum gloeosporioides f.sp.malvae*	*Malva pusilla* (round leaved mallow)
Bipolaris	*Bipolaris sorghicola*	*Sorghum halapense* (Johnson grass)
Dr.Biosedge	*Puccinia canaliculata*	*Cyperus esculentus*

3.2 Naturally occurring herbicides and its synthetic analogues

Naturally occurring herbicides includes utilization of plant and microbial phytotoxins (allelochemicals) as herbicides. Of this, the first herbicide developed is 'Bialophos' a microbial product isolated from the fermentation broths of *Streptomyces hygroscopicus* and *S. viridichromogenes* and is marketed in Japan under the trade name 'Herbiace'. It exhibits strong herbicidal activity against a wide range of grasses and broad leaved weeds on foliar application. In sensitive plants Bialophos gets converted to phosphinothricin, a phytotoxic metabolite inhibiting the enzyme glutamine synthetase (GS) involved in ammonia assimilation and regulation of nitrogen metabolism. As a result, ammonia accumulation occurs and the plant dies. Anisomycin is effective against *Echinochloa crus-galli* and *Digitaria* sp. Some of the phytotoxins with allelopahtic effect are given in Table 3. Since these natural herbicides are limited in their selectivity and lack stability, another approach is the biorational synthesis of more stable and selective synthetic analogues of these natural compounds based on novel chemistries provided by allelochemicals and microbial toxins. Some of the commonly available synthetic analogues are given in Table 4. Glufosinate, a broad spectrum non-selective herbicide can be used for the controlling almost all weeds in a non-cropped situation. Methoxyphenone is marketed in Japan as a selective herbicide for the control of *Echinochloa crus-galli*. Picloram is a chlorinated derivative of fusaric acid produced by *Fusarium* sp. and it is used for the control of woody weeds. A study was conducted in USA to study the effect of Quinclorac for the control of *Sesbania herbacea*. The result showed 100 percent control when applied @ 0.56kg/ha at 4 weeks after treatment and was comparable with 2,4-D and propanil (Norsworthy *et al.*,2010).

Table 3. **Plant/Microbial toxins with herbicidal activity**

Phytotoxin	Source
Bialophos	*Streptomyces hygroscopicus, S.viridochromogenes*
Anisomycin	*Streptomyces* sp.
Caffeine, Trimethyl xanthine	Coffee plants
Juglone	Walnut
1,8 cineole	Eucalyptus, Cardamom
Cercosporin	*Cercospora* sp.
Moniliformin	*Fusarium moniliforme*
Tentoxin	*Alternaria alternata*

Table 4. **Synthetic analogues of natural compounds**

Natural product	Source	Synthetic Herbicide
Phosphinothricin	*Streptomyces viridochromogenes*	Glufosinate
Anisomycin	*Streptomyces* sp.	Methoxyphenone
Cineole	Eucalyptus	Cinmethylin
Fusaric acid	*Fusarium* sp.	Picloram
Moniliformin	*Fusarium moniliforme*	3,4-dibutoxy-monliformin
Quinolinic acid	*Nicotiana tabacum*	Quinclorac

(Hatzios,1987)

3.3 Genetic manipulation of crop tolerance to herbicides

Crop tolerance towards herbicides is the major area where application of biotechnology in the field of weed management has been widely exploited. The crops resistant to herbicides can be engineered genetically by four major approaches such as:-

1) classical plant breeding techniques and mutation breeding

2) *in vitro* mutant selection at the cell or tissue level

3) somatic hybridization

4) transfer of cloned genes into susceptible crops.

Classical plant breeding techniques involves selection of whole plants for tolerance and using those plants in a traditional breeding programme. Tracy-M, a metribuzin tolerant soybean cultivar developed by planting soybean in soil treated with metribuzin and survivors are used as parents for breeding. Maternally inherited trazine resistance has been transferred from weed *Brassica campestris* (bird's rape) to cultivated *Brassica napus* (canola) by back crossing followed by selection. Atrazine resistant canola (OAC Triton) is cultivated in Canada. Mutation breeding includes mutagenesis of seeds (EMS) followed by screening of seedlings for resistance. Tolerance to sulfonyl urea herbicide in soybean by mutation breeding was successfully done by Sebastian and Chaleff (1987). It takes many years to develop a plant with herbicide tolerance by standard selection techniques.

In *in vitro* mutant selection cells/tissues are cultured in the presence of herbicide concentration that is toxic to normal cells and the interaction between cells and inhibitors are studied. The regenerated plants with resistance are selected. Tobacco mutants showing tolerance to sulfonyl ureas has been isolated. Mutant selection by somatic hybridization is done by protoplast fusion, mainly applied in crops having sexual incompatibility. Protoplasts from different plants can be induced to fuse in culture, combining their genetic information to create a new hybrid (Skelsey,1984).

The direct transfer of cloned genes into cells of susceptible plants is the most powerful approach for genetically manipulating crop tolerance to herbicides (Hatzios,1987). Developments in biotechnology have led to successful gene transfer techniques like *Agrobacterium* mediated transfer, electroporation, microinjection, micro projectile bombardment. It is usually done by recombinant DNA technology using the vector *Agrobacterium tumefaciens* which contains the gene for inducing herbicide tolerance (Abraham *et al.*, 1993). In tobacco, using *Agrobacterium tumefaciens* as vector to express a mutant allele of *aro* A gene from *Salmonella* sp. coding for an enzyme 5-Enol Pyruvyl-Shikimate-3-Phosphate Synthase (EPSPS), caused a decreased affinity for glyphosate. But due to certain limitations like pathogenic nature of vector towards economic crops and limited host range of Ti plasmid (only dicots), now gene gun is used for gene transfer.

3.3.1. Mechanisms of crop tolerance/resistance

The various mechanisms of crop tolerance/resistance towards herbicides are.

- over production of target enzyme,
- introducing gene to produce the target site which is insensitive to herbicide
- metabolic detoxification of herbicide and
- by altered uptake and translocation.

Phosphinothricin (active ingredient in glufosinate) is a competitive inhibitor of glutamine synthetase (GS) enzyme of plants and bacteria. Synthetic phosphinothricin is marketed as Basta. Tobacco plants tolerant to phosphinothricin were developed by amplification of glutamine synthetase activity (Donn *et al.*,1984).

Another mechanism by which plants acquire resistance is by introducing a gene to produce the target site which is insensitive to herbicide. Usually triazines and urea derivatives are inhibitors of photosynthesis (chloroplast) inside plant system and they disrupt photosynthetic electron transport in photosystem II. So by introducing a mutant gene, we can make the target site insensitive to the applied herbicide. The mutant gene '*psb* A' from *Amaranthus hybridus* (weed) was introduced in tobacco using *Agrobacterium* Ti transformation technique and its protein product of nuclear *psb* A was identified in chloroplasts of transgenic tobacco, making them tolerant to herbicides (Cheung *et al.*,1988). Similarly sulfonyl ureas and imidazolinone herbicides inhibit acetolactate synthase (ALS) involved in biosynthesis of branched chain amino acids like valine, leucine and isoleucine. Mutant ALS genes encoding ALS resistance to these herbicides are found in yeast, bacteria and in plants (tobacco and *Arabidopsis*). Transgenic tobacco plants with mutant ALS gene from Arabidopsis tolerate herbicide concentrations four times that of typical field application (Mazur *et al.*,1987).

Corn is tolerant to atrazine because the enzyme glutathione -s - transferase (GST) inside corn binds with atrazine and converts it into detoxified form. Mixed function oxidases are involved in detoxification of 2,4-D in pea and dicamba in barley while 3 enzymes- super oxide disamutase, catalase and peroxidase are involved in resistance against paraquat. In metabolic detoxification, enzymes from plants and microbes are used to detoxify the applied herbicide before it inhibits a metabolic process. Propanil is a post emergent herbicide to control monocot weeds especially *Echinochloa* sp. in rice. But rice in spite of being a grass, it is not affected by propanil due the presence of enzyme aryl acyl amidase inside rice which convert propanil into its inactive form and *Echinochoa* having less concentration of enzyme is controlled by propanil. Some of the enzymes inside plants having the ability to degrade herbicides are presented in Table 5.

Table 5. **Herbicide detoxifying enzymes from plants**

Herbicide	**Enzyme**	**Plant source**
Atrazine, Alachlor	GST	Corn
Monuron, Diuron	N-demethylase	Cotton, Soybean
2,4-D	Hydroxylase	Peas, Cucumber
Arylamines	Peroxidase	Peas
Metribuzin, Acifluorfen	GST, Deaminase	Soybean
Metribuzin	N-glucosyl-transferase	Tomato
Propanil	Amidase	Rice
Chloramben	N-glucosyl-transferase	Soybean

(Hatzios,1987)

Since it is very difficult to isolate and transfer these enzymes from plants, microbes having such genes capable of degrading herbicides are now using widely (Table 6). The *bar* gene from *Streptomyces hygroscopicus* encoding for Phosphinothricin Acetyl Transferase (PAT) which convert phosphinothricin to non-toxic form has been engineered into tomato, tobacco and potato making them tolerant to glufosinate and bialophos. Similarly the *bxn* gene from *Klebsiella ozaenae* encoding for nitrilase enzyme convert bromoxynil (3,5-dibromo-4-hydroxy benzonitrile) to its inactive metabolite (3,5-dibromo-4-hydroxy benzoic acid).

Table 6. **Herbicides and its resistant genes**

Herbicide	**Resistant gene/enzyme**	**Gene source**
Glufosinate, Bialophos, Phosphinothricin	*Bar* (PAT- Phosphinothricin Acetyl Transferase)	*Streptomyces* sp., *Alcaligenes* sp.
Glyphosate	*aro* A (EPSPS)	*E.coli*, *Salmonella* sp.
Bromoxynil	*bxn* (Nitrilase)	*Klebsiella ozaenae*
Sulphonylurea, Imidazolinones	ALS (AcetoLactate Synthase)	*Nicotiana tabacum*

(Hatzios,1987)

In altered uptake and translocation mechanism of resistance, the herbicide is prevented from reaching the target site of action. Werner and Putnam (1980) reported tolerance of cucumber to atrazine is by modified translocation and vascular compartmentation.

3.3.2. Mechanism of tolerance in Round Up Ready crops

Glyphosate (Roundup) is a non-selective systemic herbicide which is a potent competitive inhibitor of the enzyme 5-Enol Pyruvyl-Shikimate-3-Phosphate Synthase (EPSPS) needed for the production of aromatic amino acids like phenyl alanine, tyrosine, tryptophan and there by protein synthesis inside plants. In Roundup ready crops like soybean, corn, canola etc. the tolerance is due to two mechnaisms 1) over production of the enzyme EPSPS within the transgenic plant 2) by transfering a gene coding for mutated, glyphosate resistant EPSPS. Glyphosate tolerant *Petunia hybrida* was produced by increasing EPSPS activity (40 fold) using CaMV 35 S as the promoter. Plants formed were tolerant for 0.8Kg/ha level of glyphosate. A mutant *aro* A gene coding for EPSPS insensitive to glyphosate has been isolated from microbes *E.coli* (Duncan *et al.*,1984), *Salmonella typhimurium* (Stalker *et al.*,1985) and a weed *Arabidopsis thaliana* (Klee *et al.*,1985). This was fused to promoters to permit expression in tobacco and tomato.

Similarly, herbicide tolerant rice was also produced. 'Liberty Link' rice tolerant to glufosinate, was produced by Aventis and 'Clear Field' tolerant to imidazolinone group of herbicides by BASF. Clear field is very successful in areas where weedy rice is a severe problem because on application of Newpath (imazethapyr), rice will survive and weedy rice will perish.

The last and final application of biotechnology is decontamination of herbicide residues in soil using micro organisms. It can be either by microbial degradation of herbicide residues or by the use of microbial herbicide safeners. Some of the microbes detoxifying herbicides in soil are given in Table7.

Table 7. **Herbicide detoxifying microbes in soil**

Herbicide	**Microbe**
2,4-D, MCPA	*Alcaligenes, Aspergillus*
Dalapon, Glyphosate	*Pseudomonas* sp.
Alachlor	*Rhizoctonia solani, Fusarium oxysporum*
Propanil	*Fusarium solani*
EPTC	*Arthrobacter* sp.

Herbicide safeners are those microbes with herbicide degrading genes in plasmid, so they are used as crop protectants. For example, herbicide injury to sugar beet is reduced by using bacterial fertilizer "Azotobacterin".

Though there are several benefits for GM crops, some of the risks associated are,

a) emergence of super weeds

b) excessive use of some herbicides

c) genetic contamination of non-GM crops and

d) threat to biodiversity

Super weeds are those weeds which show resistance towards a particular herbicide (Table 8). Now the common super weed species is *Amaranthus palmeri* (Palmer amaranth) resistant to glyphosate. There is also chance for out crossing with related weed species and they also acquire tolerance to herbicide.

Table 8. **Herbicide resistant weeds**

Common name	**Scientific name**	**Resistant herbicide/group**
Rigid rye grass	*Lolium rigidum*	Sulfonyl ureas
Smooth pig weed	*Amaranthus hybridus*	Triazines,Imidazolinones
Wild oats	*Avena fatua*	Fenoxaprop–p-ethyl, Diclofop-methyl
Redroot pig weed	*Amaranthus retroflexus*	Metribuzin
Common lambsquarters	*Chenopodium album*	Triazines
Green foxtail	*Setaria viridis*	Fenoxaprop–p-ethyl, Diclofop-methyl
Barnyard grass	*Echinochloa crus-galli*	Propanil
Goose grass	*Eleusine indica*	Dinitroanilines
Kochia	*Kochia scoparia*	Atrazine
Horseweed,Palmer amaranth	*Conyza canadesis, Amaranthus palmeri*	Glyphosate

4. Conclusion

Despite the continuing debate on biotech crops, millions of large and small farmers in both industrial and developing countries continue to increase their plantings of biotech crops by double-digit adoption growth rates every year since 1996, because of the significant multiple benefits biotech crops offer. This high rate of adoption is a strong vote of confidence in biotech crops. Today about 840 million people in the developing countries suffer from malnutrition and 1.3 billion are afflicted by poverty. Though there are certain risks associated with, biotechnology can make a vital contribution, but not a total solution, to global food, feed and fiber security and can also make a critically important contribution to alleviation of poverty, the most formidable challenge facing global society which has made a pledge to decrease poverty by half by 2015.

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Discussion

1. What is Picloram?

Picloram is the chlorinated derivative of fusaric acid, a synthetic analogue of natural phytotoxic chemical used for the control of woody weed plants.

2. Which are the weeds controlled by Glufosinate?

Chenopodium album (common lambsquarters), *Ambrosia artemisiifolia* (ragweed), *Digitaria sanguinalis* (large crab grass), Pig weed sp.

3. How the chloroplast is made insensitive to herbicides using *Agrobacterium* as vector?

The *psb* A mutant gene from *Amaranthus hybridus* was converted into a nuclear genome by fusing its coding region to transcription-regulation and transit peptide-encoding sequences of a nuclear gene. This chimeric constructs will be introduced to nuclear gene of tobacco using *Agrobacterium* Ti transformation sequences. The protein product of nuclear *psb* A was identified in chloroplasts of transgenic tobacco plants.

4. What is the reason for limited host range of *Agrobacterium*?

Agrobacterium tumefaciens is a gall inducing bacteria commonly used as a vector in genetic engineering. But it is mainly effective in dicots for gene transfer and its application is limited in monocots. As our main food crops are monocots, now gene gun is used for gene transfer in monocots (cereals).

5. How super weeds can be controlled?

Super weeds are those weeds which show resistance towards a particular herbicide. So by using a herbicide other than the herbicide to which the weed is resistant we can control super weeds. The weed *Amaranthus palmeri* (Palmer amaranth) is resistant to glyphosate. By using paraquat, a contact herbicide we can kill *Amaranthus* sp.

Abstract

Weeds have long been recognized as a major problem causing significant reduction in agricultural production. Several methods are being employed to overcome weed infestation in crop fields. Recent advances in agricultural biotechnology provide us with new options and alternative approaches in dealing with weed problems. The four major areas in the field of weed management technology where opportunities for the application of biotechnology exist are: development and use of bioherbicides, discovery and use of naturally occurring herbicides, genetic improvement of crop tolerance to herbicides and use of genetically engineered microbes for decontamination of herbicide residues.

In the bioherbicide approach, microbial plant pathogens are applied to target weeds. Fungi, bacteria and viruses offer great promise as bioherbicides. Formulations of *Phytophthora palmivora* (De Vine®) as a selective mycoherbicide for the control of milk weed (*Morrenia odorata*) in citrus, and *Colletotrichum gloeosporioides* (Collego®) for the control of Northern joint vetch in rice and soybean, are now widely used in developed countries. The herbicidal property of *Fusarium pallidoroseum* for the control of noxious aquatic weed *Eichhornia crassipes* was studied by Nazeema and Balakrishnan (1999) and 5% Cashew Nut Shell Liquid (CNSL) solution + 5% Wettable Powder of *Fusarium pallidoroseum* is being recommended for effective control (KAU, 2007). Abraham and Abraham (1999) reported that fungi like *Colletotrichum gloeosporioides*, *Alternaria alternata* and *Corynespora cassicola* are potential bioagents for the control of alien invasive weed *Mikania micrantha*.

Extensive research has demonstrated that several allelochemicals possess good herbicidal activity. Bialophos, a microbial product from *Streptomyces* sp., exhibits strong herbicidal activity against a wide spectrum of grass and broad leaved weeds. However, due to their limited selectivity, stable synthetic analogues were developed for commercial use. One such herbicide is the ammonium salt of glufosinate, marketed in India under the trade name Basta® (Bayer Crop Science).

Genetic improvement of crop tolerance to herbicides is an area where commercial exploitation of biotechnology has been very successful. The mechanisms of plant tolerance to herbicides vary with the plant and the herbicide. Approaches for development of herbicide resistant crops include classical plant breeding techniques, *in vitro* mutant selection from callus cultures, and transfer of cloned genes to susceptible crops. In the case of glyphosate, whose non-selective broad spectrum activity is due to inhibition of 5-Enol Pyruvyl-Shikimate-3-Phosphate Synthase (EPSPS) in Shikimic acid pathway of amino acid synthesis, tolerance in crops has been achieved by introducing cloned bacterial genes for altering the level/sensitivity of EPSPS. Of the total area under genetically modified crops in the world, 80% is occupied by herbicide tolerant crops such as Roundup Ready (RR) soybean, RR corn, RR canola, RR cotton and RR alfalfa (James, 2004). In the case of soybean and canola, the entire cultivated area is under herbicide tolerant GM varieties.

Apart from this, innovative future applications of genetically engineered microbes include microbial degradation of soil applied herbicides, microbial herbicide safeners and use of microbes as biocatalysts in the production of synthetic herbicides.

Though there are several benefits, emergence of super weeds, genetic contamination of non-GM crops, loss in biodiversity, human health related issues and excessive use of selected herbicides are some of the risks associated with this technology.

NON-FOOD USES OF FOOD CROPS

By

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(2010-11-106)

Seminar Report

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2011

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NON-FOOD USES OF FOOD CROPS

1. Introduction

There are many crops in the world which can be used for non-food purposes but of this only a few crops have been exploited commercially. It is due to various economical, technical and social constraints. People realize that if they depend only on food purpose of crops, they wont get much profit. Once upon a time, tapioca was the major food crop in Kerala but now its area is decreasing day by day. It is due to the less price that the farmer get by the sale of its product. In this context, if we increase the non-food use of tapioca then definitely its market demand will be increased and it will give more profit to the farmers. This will be a motivation for the farmer to produce more and thus we can prevent a crop from extinction. Thus non-food use of food crops is very important particularly at this time as the non-food use of food crops is increasing day by day.

I will be dealing with the non-food uses of certain important food crops of Kerala and South India.

1.1. Benefits of non-food use of food crops

- It exploits the potential use of the resources
- Allows new opportunities for crop rotation, diversification and enhances biodiversity
- Offers employment and also beneficial to environment
- Utilisation of waste lands

2. Rice

Rice is the most important food crop in the world. More than 40% of the people in the world consume rice as their major food. Apart from its use as food crop there are many non-food uses for this crop and the most important one is its medicinal uses. Njavara is a rice variety which is cultivated in Kerala exclusively for medicinal purpose. It is used in Panchakarma treatment where njavarakizhi and njavarathepu is practiced. Nutritionally also njavara rice is very much superior to other rice varieties.

2.1.Nutritional composition of Njavara and Jyothi

	Njavara (%)	Jyothi (%)
Carbohydrate	73.5	72.8
Protein	9.5	7.97
Thiamine	0.52	0.35
Riboflavin	0.071	0.052
Niacin	0.73	0.71

(Deepa *et. al.*,2008)

The crude methanolic extract from Njavara rice bran contains significantly high amount of polyphenolic compounds with superior antioxidant activity which will help in scavenging of free radicals including DPPH (1,1-diphenyl-2-picrylhydrazyl) and NO (nitrous oxide) (Rao *et. al.*,2010).

2.2.These are some of the rice varieties which is cultivated in India only for medicinal purpose.

Rice varieties	Medicinal uses
Gathuan	Rheumatism
Karhani	Paralysis
Baisoor	Headache, hemi crania & epilepsy
Nagkesar	Lung diseases
Maharaji	Tonic for woman after delivery
Bhejri	For early removal of placenta

(Oudhia,1999)

Apart from the medicinal use, rice has also many other non-food uses. The whole rice grain is filled in a vessel called 'Para' and used for religious purposes. The broken rice is used for making animal food and also used for brewing. Rice flour is also important. Some religious group use rice flour for drawing 'Kolam'.

Byproducts of rice

Rice has many by-products of which the most important is rice bran.

2.1.1. Rice bran

Rice bran constitutes about 10% of rough rice. It is generally used as animal feed.

2.2.These are some of the rice varieties which is cultivated in India only for medicinal purpose.

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2.3. Nutritional status of rice bran

Fat	18-24%
Dietary fibre	25%
Protein	14%
Carbohydrates	45%

2.1.1. Medicinal properties of rice bran oil

Rice bran oil contains high amount of gamma oryzanol which will improve the liver function. It also contain tocotrienol which lowers the cholesterol synthesis (Cheruvanky *et al.*,2003).

2.4.Comparison of RBO and other oils

	Vitamin E (ppm)	Oryzanol (ppm)	Total Natural Antioxidant (ppm)
Rice bran oil	1600	2500	4100
Coconut oil	2010	-	2010
Sunflower oil	670	-	670
Soybean oil	1150	-	1150
Palm oil	1170	-	1170

(Scavariello and Arellano, 1998)

RBO contains high free fatty acid and hence suitable for the manufacture of different types of soap.

2.1.2. Rice bran wax

It is the wax extracted from rice bran oil. It is used in paper industry, textile industry, printing ink etc. It can also be used as a substitute for carnauba wax.

De-oiled bran is a rich source of protein (17 to 20%) and can be used as animal feed. It can also be used as manure.

2.2. Rice Husk/Hull

Rice husk is generated during the first stage of milling. It is used for manufacturing activated charcoal, a catalyst for removal of colour, taste and odour in edible oil, foodstuffs and pharmaceuticals. It is also used as a plaster for soil stabilization.

Rice husk is used to retain soil moisture. It also absorbs moisture and prevent the caking of fertilizers. It can also be used as a fuel, both in the industry and household. Because of its high silica content, it is used in the ceramic industry for the preparation of glasses.

Rice hull ash contains about 92% silica and hence it is used as manure.

A study was conducted by Lakshmikanthan in 2000 in our college to study the effect of rice husk as a source of silica for rice. He found that the increase in yield when he applied rice husk was equivalent to the increase in yield when he applied fine silica.

2.5. Silica nutrition

Treatments	Panicle length (cm)		Panicle weight (g)		Chaff /panicle (No.)		Grain yield	
	K 52.5	K70.0	K 52.5	K70.0	K 52.5	K70.0	K 52.5	K70.0

Rice husk (Si 250)	23.1	23.0	2.3	2.7	14.0	11.0	5763	5823
Rice husk (Si 500)	23.3	22.8	3.3	3.2	12.0	17.7	6356	6507
Fine silica (Si 250)	22.3	23.2	2.6	3.0	12.0	12.7	5972	6094
Fine silica (Si 500)	23.8	22.8	3.2	3.3	15.0	13.7	6484	6577
Sodium silicate (Si 250)	24.2	22.9	3.0	3.0	17.7	17.0	6240	6290
Sodium silicate (Si 500)	21.7	22.5	3.2	3.7	14.0	14.7	6741	7306

(Lakshmikanthan, 2000)

2.3. Rice straw

Depending upon the variety, we get 2 to 8 tonnes of straw from one hectare. The most important use of rice straw is as animal feed. Since rice straw contains only very less quantity of nitrogen, it is enriched with urea. 4kg of urea is mixed with 100L of water for 100kg of rice straw. Spread the straw in layers in a container and sprinkle urea after each layer until the straw is about 30 cm from the top of the container. Then cover it with polythene sheet. Keep it for 2 weeks (KAU, 2007).

Ethanol can also be produced from rice straw using genetically engineered *Saccharomyces*. Genetically engineered *Saccharomyces* will hydrolyze both glucose and xylose unlike other microorganisms, which will hydrolyze only glucose. 50% increase in ethanol yield will be there (Jeffrins, 1999; Nancy *et. al*, 2003; Bera *et. al*,2009).

2.3.1. Rice straw wattles

It is a new product from the rice straw which is used for soil stabilization and controlling erosion.

Fig.2.1

2.3.2. Straw incorporation

A study was conducted by Rathish in 2010 in our college to find the effect of straw incorporation on rice grain yield. He found that the grain yield was very much higher for straw incorporation than cowdung incorporation or no organic manure.

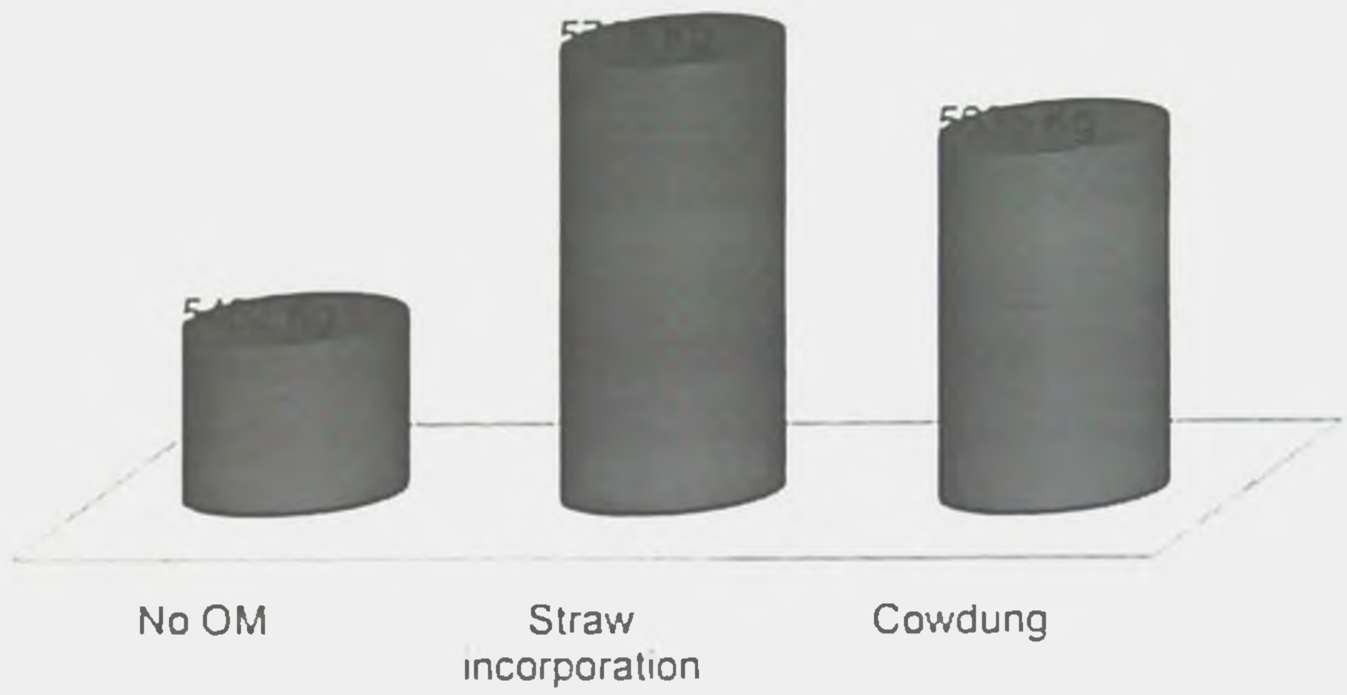

Fig. 2.2. Effect of straw incorporation on grain yield

Rice straw can also be used for thatching house especially in village areas.

2.3.3. Other uses of rice straw

- Handicrafts
- Hand made paper
- Hard board
- Packing material
- For ripening fruits
- As incubator

3. Coconut

Coconut is the most important oilseed crop of Kerala and also in the South India. It is called as 'Kalpavriksha' because each and every part of the tree can be used for one purpose or other.

3.1. Coconut husk

Coconut husk is used as a planting medium mainly for horticultural crops like orchids.

Husk burial is an important method of conserving soil moisture. It is done by taking trenches in the field and filling it with coconut husk with the convex side upwards till the half of the pit.

Fig. 3.1.

Mulching can also be done by putting coconut husk around the tree with the convex side upwards. This also helps in moisture conservation.

Fig. 3.2.

3.2. Coir

Coir is the most important product from coconut. It is made from coconut fibre. The most important product from coir is rope. It fetches a very good price in the market.

Coir geo-textile is another product from coir. It is used for controlling soil erosion mainly in slopy areas. It can be laid on slopy areas and planting can be done on it. It will prevent the soil from erosion till the crop establishes itself. There is no need to remove this after the crop establishment as it is biodegradable. Since soil erosion is a major problem especially in the slopy areas while clearing land for cultivation, the coir geo-textile is very useful.

Fig. 3.4

Coir log is another product similar to coir geo-textile. It is prepaed by filling coir fibre in a coir net. It is used to prevent erosion from stream banks.

Fig. 3.5

Coir is also used to produce beds and carpets which fetch a very good price in the market.

3.2.1. Coir Briquette

Another important product from coir fibre. It is used as a planting medium especially when cultivated in the terrace or in the desert. A hole is made in the briquette and it is kept in water overnight. On the next day it is taken out and used as a medium for planting. Only disadvantage is that over-irrigation should be avoided.

Fig. 3.6

3.2.2. Other fibre products

a. Fibre tray : It is used for planting seedlings that are to be transplanted

b. Fibre pots : It is used for planting seedlings that are to be transplanted and the advantage is that it is not needed to remove the pot while transplanting as it is biodegradable.

c. Fibre disc : It protect the plant root from direct

sunlight and prevent the water loss.

d. Fibre plant climber : It is used for trailing creepers.

3.3. Coconut shell

The most important product from coconut shell is activated charcoal. It is produced by the incomplete burning of coconut shell. It is used for removing impurities from drinking water and also to remove odour from edible items. Nowadays, the activated charcoal is having great demand in international market and the coconut development board is exporting it.

Many toys, jars, cups, handicrafts can also be prepared from coconut shell.

3.3.1. Coconut shell powder

It is produce by grinding coconut shell to finer particles. It is used as filler in synthetic resin glues. It can also be used to produce mosquito coils, agarbathis, etc.

3.4. Coconut leaves

Coconut leaves are mainly used for thatching houses and also for making fences. Baskets, brooms etc. can also be made from the leaf. Tender leaves are used for decoration during the auspicious occasions.

Compost can also be prepared from coconut leaves. Coconut leaves contain midrib which is very difficult to decompose. So it takes more time for forming compost. CPCRI has developed a technique for quicker composting where they add microorganism *Eudrillus eugineae*. Here the compost will be prepared within 45 days.

3.5. Coconut oil

There are many uses for coconut oil. The major non-food uses are,

- As it contain free fatty acids, it is used for preparing soaps, cosmetics & hair oils.
- Virgin oil is having medicinal properties as it prevents the formation of bad cholesterol and reduces the risk of heart attack.
- Bio fuel can also be prepared from it but it is not commercialized
- Oil cake is a very good source of protein and nutrients and hence can be used as cattle feed & manure

3.6. Coconut trunk

The coconut trunk is very strong and can be used for preparing furnitures. As it is very strong, it can be used to prepare bridges especially in the village areas. In many areas, the trunk is carved from inside and boats are prepared. Agriculturally also it is very important as it is used to prepare handle for hoe, pick axe etc. Many handicrafts can also be prepared from it.

3.7. Coconut flower

Medicinally coconut flower is very important as it is used to prepare 'pookularasayanam', which is used by women after delivery. It is also kept in 'Para' and used to adorn auspicious occasions. Beverage toddy is prepared from unopened spadix.

4. Banana

After mango, it is the most important fruit crop of India. Apart from its use as food crop, it is having many non-food uses also. The whole plant as such can be used for decorating buildings during auspicious occasions.

4.1. Fruit

Fruit is the most important part of the plant. The main product that we get from the fruit is starch which is industrially very important. The juice can be taken from it and can be used to prepare wine. After using the fruit, the banana peels can be used to prepare compost. It is nutritionally more rich than compost from the leaves (Pangnakorn, 2006).

Green bananas can be used as animal feed. It is mainly used for feeding pigs.

A good silage can be made from equal parts of chopped green bananas and grass, or from chopped green bananas mixed with 1.5% molasses and on such a diet, pigs tend to have less carcass fat (Stover and Simmonds, 1987).

4.2. Pseudostem

It is another important part of the plant. Fibre is extracted from the pseudostem. There are two types of fibre, coarse fibre and fine fibre. Coarse fibre are called manilla hemp and is used to prepare paper and rope and fine fibre is used to prepare clothes and high quality paper. The clothes prepared from banana fibre is of very high quality and fetches a very good price in the market. The national dress of Phillipines called 'Barong' is prepared from the banana fibre.

Fig.4.1

Pseudostem is having medicinal property also. It is used for curing kidney stone and also anaemia.

4.3. Leaves

- Used for making disposable plates.
- For thatching
- Wraping food
- Used for making cigarette papers and hats

'Kazhchakkula' is a form of value added banana bunch. Here the farmers will polish the banana bunch and make it into an attractive form. These are used as offering to the temple, especially in the Guruvayoor temple. It is generally done during the Onam season, where one bunch will cost about five hundred to two thousand rupees.

5. Tapioca

It is also called cassava. It is native to South America, but now it is cultivated world wide. Once upon a time , it was the staple food of Kerala. The most important product from cassava is biofuel.

5.1. Biofuel

It is produced from cassava chips. Two processes are there, wet milling and dry grinding. In both the processes, 3 steps are involved – liquifaction,fermentation and purification. From one tonne of dry cassava chips we will get about 333 litres of ethanol. The production cost of ethanol from cassava is very less compared to other sources of ethanol.

5.1. Estimated production costs of ethanol from various raw materials

Raw material	Cost of raw material (US$)	Ethanol Yield (Lt^{-1})	Production cost of ethanol (US$ L^{-1})
Molasses	37.5	260	0.144
Sugarcane	14.6	70	0.209
Sweet sorghum	10.0	70	0.143
Cassava	25.0	180	0.139
Maize	87.5	375	0.233
Rice	200.0	375	0.533

After extracting ethanol, the pulp is used for the production of biogas.

.2. Cassava starch

Starch is another important product of cassava. The main uses of cassava starch are,

- Used as adhesive
- In paper industry
- In textile industry for cloth printing and warp sizing
- It is incorporated into plastic to improve the biodegradability

- Added to concrete to reduce the set time
- Used as a stain remover

5.3. Animal feed

Cassava hay is produced at a young growth stage ie., at about three to four month stage. It is harvested at about 30–45 cm above ground and then it is sun-dried for about one to two days until it has a final dry matter of at least 85%. It is having very high crude protein content (20-27%) and condensed tannins (1.5-4% CP). It is used as a good roughage source for dairy, beef, buffalo, goats, and sheep by either direct feeding or as a protein source in the concentrate mixtures.

5.4. Biopesticide

Recently, a biopesticide has been developed by CTCRI. The Cyanogenic glucosides in tapioca is converted to biopesticide. They prepared this by grinding the cassava leaves, stems and roots with water and after filtering it in a special temperature. Eight liters of bio pesticide can be developed from one kg of tapioca leaves. It is available in the market by the name 'Nenma' which cost about twenty rupees per litre. They are claiming that it is more effective than furidan as it is having no health hazards or residual effects. It is effective against red palm weevil of coconut and pseudostem weevil of banana (Shanavas, 2010). As they have submitted application for patent, more information about this biopesticide is not available.

6. Sugarcane

Sugarcane is the most important sugar producing crop in the world. It is indigenous to tropical South Asia. The sugarcane mills produce three important by-products which is having many non-food uses. They are bagasse, pressmud and molasses.

Sugarcane , after crushing and squeezing, we will get sugarcane juice and bagasse. This juice after clarification with lime or gypsum, we will get clear juice and pressmud. This clear juice after evaporation, we will get sugar and molasses.

6.1. Sugarcane bagasse

There are many uses for sugarcane bagasse. They are,

- Fuel
- Cattle feed by mixing with molasses
- Paper industry
- Mulch
- Xylitol, which is a calorie free sugar is prepared using microorganism *Candida guilliermondii* . Xylitol can be consumed by diabetic patients and is gaining more popularity now. *Candida guilliermondii* uses bagasse as a carbon source and feed on it. After the metabolism, it will produce xylitol (Carvalho,2002).

6.2. Pressmud

Pressmud is used to produce 'Bioearth'. Bioearth is prepared by mixing pressmud with spentwash and keeping it for one month. It is also called biocompost. It contains - 25-30% organic carbon, 1.2-2.0% N, 1.5-2.0% P_2O_5 and 2.5-3.0% K_2O.

6.3. Molasses

- It is used to produce ethanol.
- Used as animal feed. Molasses, after extracting sugar is called blackstrap molasses and is used as cattle feed.
- Used as an additive for silage making.

For producing biofuel from molasses, a fermentation system for the continuous ethanol production from sucrose and molasses using *Saccharomyces cerevisiae* strain HAU-1 has been optimised (Sheaoran, 1998).

- It is having 11% more fermentation efficiency .

Sugarcane juice is used for preserving different food items.

.4. Sugar based products

6.4.1. Sucrose esters - Sucrose esters are obtained by linking sucrose with fatty acids derived from animal fats or vegetable oil.

- Can be made into mild, biodegradable detergents with inherent anti-bacterial properties.
- Widely used in the cosmetic industry.
- Used as emulsifiers and texturizing agents in the food industry

6.4.2. Sucrose epoxy - Sucrose is the main ingredient in new liquid epoxies that can bind wood, metal, glass, concrete and other materials.

6.4.3. Bioplastics – Bioplastics (Poly,3-hydroxyalkanoates), are produced from sucrose using microorganisms like Ralstonia, Azospirillum etc.

- Eco - friendly

7. Sorghum

Sorghum is the third most important grain crop of India. It is a crop suited to dry and arid climatic regions of our country. India is the largest producer of Sorghum in Asia.

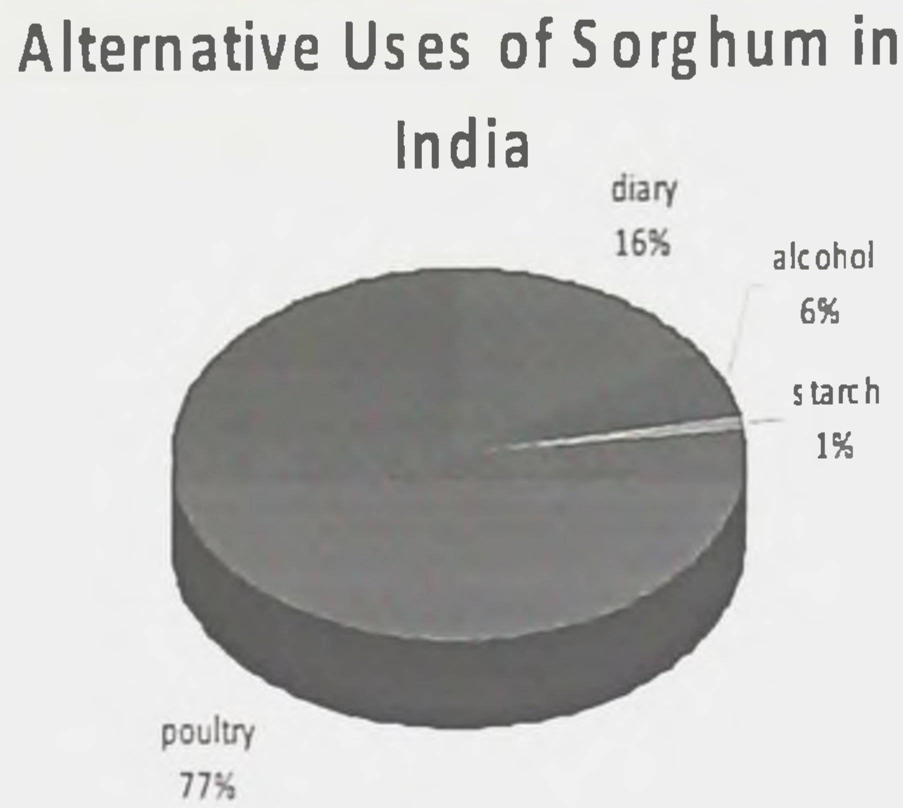

Fig. 7.1. (ICRISAT, 2002)

- In India, sorghum is mainly used as poultry feed and cattle feed. 10-15% of sorghum is added to the conventional poultry feed. It is more profitable than maize. The demand of sorghum is increasing as poultry sector is growing at the rate of 10% per annum.
- Sorghum is mainly used as animal feed in the northern India. Sorghum bagasse sprayed with 2% urea is good feed for animals. It is having good nutritive value and can be used for silage making

Main varieties used-Pusa Chari -1,JS 263, Pant Chari -3,4,5,CO 8,UP Chari -1,2 etc.

- Sorghum grains are used as fungal medium for mushroom production and also used for malting
- Ethanol can also be produced from sweet sorghum. Production of ethanol from sorghum is more profitable than from sugarcane

7.1.Comparison of sweet sorghum and sugarcane

Properties	Sugarcane	Sweet sorghum
Crop duration (months)	10 – 11	3.5 - 4
Sugar content (%)	11 – 13	9 - 11
Ethanol yield (Lt^{-1})	68 – 74	55 - 65
Water requirement (%)	100	30 - 36
Fertilizer requirement (%)	100	25

(ICRISAT, 2002)

8. Bajra

Bajra is the fourth most important grain crop of India. Similar to sorghum, bajra is also suited to dry and semi-arid climatic areas of our country.

- It is generally used as poultry feed and is included in 47-48% of the total conventional feed
- Although sorghum and bajra are excellent for producing silage, particularly in regions with dry spells, bajra can produce higher silage yields with higher protein and it is more succulent than sorghum and maize.

9. Maize

Maize is one of the most important cereals in the world. It is the fifth most important grain crop of India.

9.1. Biofuel

Yellow corn is used for producing biofuel. It is produced by dry milling and wet milling and corn oil is a byproduct of wet milling.

9.2. Fodder

Maize leaves are generally used. It has got good digestability and good nutrient content (25% crude fibre and 11% crude protein). Ganga 5, African tall, etc. are the major varieties used.

9.3. Corn starch

Corn starch is a major product from corn which has got many uses. They are.

- **Burn relief** - Mix cornstarch and water until a paste is made. Apply directly to sun burn and allow to dry.
- **Spray Starch** - Handy in an emergency when ironing - using a mix of one tablespoon of corn starch and two cups of cold water in a spray bottle, mix well and mist onto shirt collars and pants.
- **Perspiration Sponge** - A natural alternative to deodorants, mix 1 part baking soda with 6 parts cornstarch.
- **Dry Shampoo** - Sprinkle on pet or human hair and brush out.
- **Stain remover**
- It is also used in the production of porcelain part of spark plugs
- In the production of tires, corn starch is sprinkled on the molds before pouring the rubber, to prevent the rubber from sticking to the molds.

9.4. Other uses of maize

- Finely grounded corncobs are used as carriers for pesticides, fertilizers, vitamins, hand soaps and cosmetics.
- Tetrahydrofurfuryl alcohol is a resin developed from processing corncobs.
- Useful in the paint and varnish industry as solvents for dyes, resins, and lacquers
- Sorbitol produced from dextrose is used in the production of tooth paste

10. Conclusion

Non-food uses of food crops is increasing day by day. Biofuel, starch, compost, etc. are the major areas where most of the food crops are being used apart from its use as food. Coir geotextiles, coir mat, fibre, etc. are the new areas where food crops are being utilized. Now a days, microorganisms are also being utilized to exploit the full potential of the crops. Commercialization of alternative food, feed and industrial products is the best way to increase the market demand. Although these are some of the positive effects of food security, it is having some negative impact also. If more food crops are utilized for biofuel production or any other non-food purposes, then the food security will be affected especially at this time when the population is increasing at an alarming rate. So it should be judiciously used such that the food security is not affected.

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12. Discussion

- What is meant by carnauba wax?

  Carnauba wax is the wax obtained from the leaves of carnauba palm. This palm grows in the arid and semi arid climatic conditions of the world. The wax from this tree is used in the paper and textile industry.

- How we can increase the ethanol production using genetically engineered Saccharomyces?

  If we are using the conventional Saccharomyces, it will hydrolyze only the glucose present in the substrate. But if we are using genetically engineered Saccharomyces, it will hydrolyze both glucose and xylose. Thus the ethanol yield will increase to about 50 percent.

- How can we use coir pith briquette as a growing medium for plants?

  Take the coir pith briquette and dip it in a bucket of water overnight. Then take it and make a small hole at the centre. We can plant seedlings at this hole. Over-irrigation should be avoided.

- How can we prepare activated charcoal from coconut shell?

  Activated charcoal can be prepared from coconut shell by partial burning of the coconut shell. It absorbs toxic substance from edible items and fetches a good price in the international market.

- Which tapioca varieties are used to produce biopesticide?

Those tapioca varieties which has high content of HCN is used to produce biopesticide. All the local varieties of tapioca can be used for this purpose. Some improved varieties like H 97 can also be used.

- Which variety of banana is used to produce Kazhchakkula?

Changalikodan is the best variety which can be used to produce Kazhchakkula.

- How we can produce xylitol using microorganism *Candida guilliermondii*?

Candida guilliermondii uses sugarcane bagasse as its carbon source and feeds on it. This microorganism will convert the xylose in the bagasse to xylitol, which is a calorie free sugar and hence can be consumed by diabetic patients

13. Abstract

NON FOOD USES OF FOOD CROPS

Abstract

The range of crops which can be used for non food purposes is very large but in practice only a small amount of this potential is used on a commercial basis. The principal end products sought for non food use are carbohydrates, fats and fibres (Spelman, 1994).

Rice is the most important cereal crop in India. Several rice varieties have been identified which possess medicinal properties (Nanda and Agrawal, 2004). Njavara is an important medicinal rice in Kerala, used in panchakarma treatment. Rice bran and husk are the major by-products obtained during the processing of grain. Rice bran oil also has some medicinal properties. Rice straw, besides being used for feeding the cattle, can be incorporated in the field itself, which will enhance the productivity (Rathish, 2010).

Coconut, commonly known as 'Kalpavriksha' is highly valued for its non-food uses. Coconut husk is used as a growing medium for orchids, anthuriums etc. Husk burial is an important practice to conserve soil moisture. Coir produced from coconut husk is a major product which is used to make ropes, coir mats, beds etc. Coir geotextiles are widely used for soil conservation in slopy areas which is eco friendly. Coconut shell is used for making different products and the most important product is activated charcoal. Coconut leaf is mainly used for thatching and to make baskets, mats, hats, etc. Coconut oil is the main ingredient in soaps, cosmetics and hair oils. Oil cake is used as cattle feed. Biodiesel can be made from the coconut oil. Coconut trunk is useful for making furniture, boats, handicrafts etc.

Banana, one of the important fruit crops, also has wide uses. Banana plants along with bunches are used for ceremonial purposes. Banana bunches, especially Nendran, were offered as "Kazhchakkula" to the landlords during Onam festival and now these are offered to Lord Guruvayoorappan. Banana fibre is obtained from stem and leaves. Clothes from banana fibre is the national dress of Philippines, called "Barong". Banana starch is used for making glue and fruit juice for making alcohol. Silage can also be prepared from green banana (Stover and Simmonds, 1987).

Cassava is another important food crop having many non-food uses. Cassava starch is used as an adhesive and is having great use in paper and textile industry. Recently, a biopesticide extracted from tapioca leaves is found to be effective to control borer pests (Shanavas, 2010). Cassava hay is produced from young plants after sun drying and biofuel is another product.

Biofuel is the major product from sugarcane which is produced from the bagasse. Other important sugar based products include sucrose esters, sucrose epoxy and bioplastics. Pressmud is used to make compost. Molasses is widely used as an additive and also for alcohol preparation.

Sorghum, bajra and maize are the other important food crops which are used for making biofuel and also used as cattle feed. Starch extracted from maize has also got many uses.

The wider range of crops grown for non-food purposes will allow new opportunities for crop rotation and diversification, and thus potentially enhancing biodiversity. Non-food uses of food crops can also make a positive contribution to environmental protection and conservation. The rapid progress of new technologies such as biotechnology has provided a solution for a wide range of problems in using agricultural raw materials for non-food purposes.

SUSTAINABLE HERBAL FARMING

BY

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(2010-11-126)

MSc Agronomy

Valued

18.5

SEMINAR REPORT

Submitted in partial fulfillment of the requirement for the course

AGRON 591 - Seminar

Department of plant Pathology
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1. Introduction

For centuries onwards Kerala has marked its competency in treating almost all diseases using rare medicinal plants. The foothills of Western Ghats extending throughout the eastern boarders of Kerala are enriched with a rich biodiversity for valuable medicinal plants. Due to uncontrolled deforestation and other encroachment many of these biodiversity has been in the verge of extinct. Raw materials for ayurvedic medicines are adulterated due to the unavailability of required quality materials. Developing countries derive a significant part of their subsistence needs and income from gathered plant and animal products (Walter 2001). Gathering of high value products such as mushrooms (morels, matsutake, truffles), medicinal plants (ginseng, black cohosh, goldenseal) also continues in developed countries for cultural and economic reasons (Jones *et al.* 2002). By collecting the medicinal plants from the forest to meet the requirement of Ayurvedic drug industry is now seems to be impractical. Domestication and cultivation of these medicinal plants in the homestead gardens as well as in areas suitable for its cultivation is only the other alternative to cope with the demand. Increasing the number of medicinal plants species in cultivation would appear to be an important strategy for meeting a growing demand (Uniyal *et al.* 2000).

2. World scenario

It is well known that traditional medicines have been widely used all over the world for centuries. However, the extend and forms have varied. Majority of population worldwide has used traditional medicine at least once, mostly for minor or chronic ailments. Botanical drug products and raw material is growing at an annual growth rate between 5 to 15%. Globally, over one and half million practioners use traditional medicine in preventive and curative applications.

3. Indian scenario

India has one of the richest traditional medicine cultures in the world. Nearly 8000 species have been for long known and used for their medicinal properties. Millions of households, particularly in rural areas, use medicinal plants for self-medication, for preventive and curative applications. The Government of India has identified medicinal plants as one of the thrust areas, and various programmes have been initiated for conservation of medicinal plants found in the forests and protected areas as well as cultivation of these plants in the degraded forest areas. Medicinal Plants Conservation Areas have been established in the southern states of Kerala, Tamil Nadu and Karnataka and Medicinal plants conservation network for in situ conservation.

The domestic market for ayurvedic, herbal and plant based products is estimated to be around Rs. 3000 crores, growing at 15-20 percent per acre. The crude drugs and extracts are used by Pharmaceutical industry for production of OTC products, ethical formulations as well as traditional and home remedies. There are estimated to be over 7800 manufacturing units in India, the major players being Kottakal Arya Vaidyashala, Dabur, Himalaya, Zandu and Baidyanath. Most of this leading producers are not leading exporters in India.USA is the single largest export destination for Indian medicinal plants or products, accounting for almost 50 percent of total exports.

4. Kerala scenario

Kerala possess all the three kinds of biomes, namely hills, plateaus and coasts, making it a biodiversity hotspot having a rich source of medicinal plants. Almost 70 per cent of the medicinal plants used in the formulation of Ayurvedic remedies are native to Kerala. India's premier learning institutions imparting Ayurvedic education are in Kerala. Kerala has the largest pool of qualified and committed Ayurveda doctors and experienced therapists. Almost all the hotels and resorts in the state have Ayurveda centres, run by authentic and traditional Ayurveda institutions, making health tourism a unique selling proposition of the state. Kerala is the only state in the country where Ayurveda is practiced in its purest form. More than 50 tonnes of medicinal plants are required for meeting the demand of ayurvedic industries of Kerala annually (Skaria *et al.*, 2009). The demand for ayurvedic medicine is growing at a compound rate of 10 – 23 percent per annum in Kerala.(Monish Jose, 2010). The annual demand of medicinal plants is growing at a rate of 12-15 percent, but still the demand and supply are mismatching. At the same time, medicinal plants biodiversity in the forest is under threat due to collection from the wild. As a result the raw drugs are adulterated with poor quality types. In order to conserve the biodiversity and to increase the supply of quality raw material herbal farming is the possible way.

5. Herbal farming

Generally the terms "medicinal plants" and "herbs" are used interchangeably. Herbs include plant ,aerial such as leaves, flower, seed, stem, wood, bark, roots, rhizomes or other plant parts, which may be entire fragmented or powdered. Based on the definition it can be inferred that medicinal plants are in fact herbs, which are used for preparation of traditional medicinal products. Herbal farming is the scientific and systematic cultivation medicinal plants. The main objective of the herbal farming is the production of uniform quality medicinal plants which are easily accessible. For sustainable herbal farming several factors should be considered such as choice of crop and varieties, season and date of planting, selection of planting material, depth of planting, method of planting, spacing, light intensity, nutrient management, stress, time of harvesting, primary processing and storage *etc*. are some of them.

6. Factors influencing herbal farming

6.1. Choice of crop, varieties and planting material

Considering herbal farming the choice of crop and varieties are important. It depends on the market demand of the crop, purpose for which the crop is cultivated as well as the area of cultivation. National Medicinal Plant Board had suggested a list of medicinal plants which are suitable for cultivation under Kerala conditions. Crops like *Adathoda beddomei, Kaempferia galanga, Holostemma adakodien, Plumbago rosea, Indigofera tintoria, Bacopa monnieri, Aloe vera, Acorus calamus, Coleus vetiveroides etc* are some of them.

Due to low holding size and non availability of land homestead farming is the unique feature in Kerala. The important advantage of cultivation of medicinal plants in homestead is the ease of their incorporation in existing cropping system. This is due to the availability of large number of species, choice of plant type and their suitability to grow indifferent eco-physical conditions. Medicinal plants are suitable as inter crops in plantations. *Piper longum, Kaemferia galanga, Pogostemon patchouli* are suitable inter crops in coconut gardens ,were *Plumbago roseea and Rauvolfia serpentina* are suitable for inter cropping in rubber plantations (KAU, 2009). According to Ajithkumar (2009) *Kaempferia galanga, Zingiber officinale, Ocimum sanctum, Adathoda beddomei, Curcuma longa, Curcuma aromatica, Maranta arundinaceae, Coleus aromaticus, Saraca asoca* and *Azadiracta indica* are suitable for homestead farming system.

Generally in medicinal plants cultivation farmers prefer the local varieties. High yielding improved varieties are also available. For sustainability in the herbal farm suitable high yielding variety should be selected for cultivation. Depending on the climatic conditions of the field the performance of the varieties varies. Viswam is a *Piper longum* variety released from All India Co ordinate Research Project on Medicinal and Aromatic Plants, College of Horticulture. Kasthuri and Rjani are *Kampferia galanga* varieties, Vasika and Ajagandhi are *Adathoda vassica* varieties, Mridula and Agni are *Plumbago rosea* varieties Jeeva is a *Holostema-ada-kodien* variety. All these varieties are released from Dept of Plantation Crops, College of Horticulture.

Depending upon the medicinal plants different types of planting materials are used. Rooted stem cuttings are used crops such as *Plumbago rosea, Adathoda beddomi, Piper longum, Coleus amboniсus etc.* were in crops like *Indigofera tinctoria, Ocimum sanctum, Saraca asoca, Aegel marmelos etc.* seeds are used as propagules. *Kaemferia galanga, Curcuma longa, Maranta arundinacea etc* are propagated by rhizomes.

6.2. Time of planting

The yields of medicinal plants are estimated by assessing the quantity as well as quality of the produce. For getting good yield and quality it is important to plant the propagule at correct time. Latha (2010) reported the time of planting have an effect on the yield and quality of *Sida cordifolia*. During the experiment propagules were planted in the field at different months of May, June and July and the fresh yield (kg/ha) obtained were 657.52, 604.08 and 284.47 whereas the ephedrine content(%), which is the quality component, were 0.010, 0.005 and 0.004 respectively. This data infers that maximum yield and quality was obtained for the crop which was planted in the month of May.

Table 1.Effect of time of planting on yield and quality of *Sida cordifolia*

Treatments	Fresh yield (kg/ha)	Dry yield (kg/ha)	Ephedrine content (%)
Time of planting			
May	**657.52**	**488.12**	**0.010**
June	604.08	336.62	0.005
July	284.47	217.21	0.004
CD (0.05)	128.80	100.73	0.001

To achieve sustainability in herbal farming time of planting should be considered depending on the crop and varieties.

Withania somnifera is an important medicinal plant cultivated in the dry tracts of north India. It is commonly known as Aswagandha. According to Chouhan (2008) the yield and quality of the crop is influenced by the date of planting. During the experiment

Table 2. Effect of date of planting on the yield and quality of *Withania somnifera*

Date of sowing	Dry root weight (q/ha)	Total alkaloid content
1st week of September	11.26	4.447
3rd week of September	14.49	5.804
1st week of October	**16.48**	**5.787**
CD(0.050)	0.51	0.251

the seeds of the crop were sown at three different dates of 1st week of September, 3rd week of September and 1st week of October. Maximum yield of 16.48 q/ha and highest total alkaloid content (%) of 5.787 was obtained from the crop sown at 1st week of October. Date of planting influence the yield and quality of medicinal plants and it depends on the crop and varieties used.

6.3. Days to sprout and sprouting percentage

The irregularand low germination is the main problem in the propagation of many medicinal plants (Koppad and Umarbhadsha., 2006). Selection of planting material influences the days of sprout and sprouting percentage of medicinal plant. Shina (1996) reported that the sprouting percentage and days to sprout are influenced by the type of propagule used.Different types of propagules used in the experiment were main root cutting planted vertically, main root cutting planted horizontally, root stumps, vine cuttings planted vertically. Among the various propagules used main root cuttings which were planted vertically showed highest sprouting percentage of 60 and 6 days of sprout. Observations of field experiment revealed that 84 – 88 per cent of 5cm long main root cuttings planted vertically established within the first week of planting. So choice of suitable planting material influences the time taken for the sprout initiation and the crop establishment. Good crop establishment favours the crop yield and quality

Table 3. Influence of propagule on days of sprout and sprouting percentage in *Hemidesmus indicus*

Treatments	Days to sprout (DAP)	Sprouting percentage (%)
Main root cuttings (5 cm) planted vertically	6	60
Main root cuttings (5 cm) planted horizontally	6	40
Root stumps (5cm)	5	40
Vine cuttings planted vertically (5 cm)	-	0

6.4. Depth of planting

Depth of planting influences the yield and quality of medicinal plants. An experiment conducted in Dept of Agronomy of College of Horticulture reveals that in all the accessions of *Kaemferia galanga* such as *Echippara*, *Vellanikkara* and *Thodupuzha* which were planted at two depths of 10 cm and 20 cm ,*Echippara* accession when planted at 10 cm was found to be giving higher fresh rhizome yield and oleoresin content.

Table 4. Fresh rhizome yield and oleoresin content of *Kaempferia galanga* as influenced by the depth of planting

Accessions	10 cm depth		20 cm depth	
	Fresh rhizome yield (t/ha)	Oleoresin content (%)	Fresh rhizome yield (t/ha)	Oleoresin content (%)
Echippara	**5.07**	**5.43**	4.53	4.90
Vellanikkara	4.25	4.55	3.62	4.30
Thodupuzha	7.08	3.44	6.40	3.30

6.5. Planting method

Among the different species of *Plumbago, Plumbago rosea* is a commercially cultivated species in coconut gardens. Here the roots are the economic parts. Menon (1999) reported that among the different planting methods such as ridge and furrow, flat bed, mound and pit followed by mounds, flat beds were found to be better for high root weight followed by mound method.

Table 5. Effect of planting method on yield and quality in *Plumbago rosea*

Planting methods	Shoot weight (t/ha)	Root weight (t/ha)	Purified Plumbagin content (%)
Ridge and furrow	3.99	5.55	0.32
Flat bed	5.35	**5.99**	**0.33**
Mound	5.29	**5.85**	**0.35**
Pit followed by mound	5.67	5.76	0.32
CD (0.05)	NS	NS	-

6.6. Spacing

Spacing influences the yield and quality of medicinal plants. High density planting is preferred mainly in medicinal plants. Joy (2003) reported that in *Curculigo* *orchioides* which is commonly known as *Nilappana*, lower spacing of 10 cm x 10 cm was found to be optimum for higher rhizome yield as well as curculigoside content.

Table 6. Effect of spacing on yield and quality of *Curculig orchioides*

Spacing (cm)	Fresh rhizome yield (kg/ha)	Dry rhizome yield (kg/ha)	Curculigoside (%)
10 x 10	1896	796	0.093
20 x10	1137	499	0.097
20 x 20	648	259	0.084
30 x 20	353	146	0.083
CD (0.05)	110	28	-

6.7. Light intensity and shade

Intensity of light influences the yield and quality of medicinal plants. In *Curculigo orchioides* also shade was found to be a favourable factor for better yield as well as quality. Among the different shade levels tried in the experiment, 25 per cent was found to be optimum for rhizome yield as well as quality.

Table 7. Effect of planting method and light intensity on yield and quality of *Plumbago rosea*

Planting methods	Root weight (t/ha)		Purified plumbagin content (%)	
	Shade	Open	Shade	Open
Ridge and furrow	4.60	6.50	0.23	0.35
Flat bed	5.91	6.07	0.33	0.34
Mound	4.97	6.68	0.36	0.35
Pit followed by mound	5.09	6.44	0.37	0.27
CD (0.05)	0.70	NS	-	-

6.8. Shade

Proper shade influences better performance of medicinal plants. It is as much important as light intensity. The requirement of shade depends on the nature and habitat of the crop. Mild shade intensity of 25% is ideal for maximum fresh and dry herbage yield (Palanikumar and Jessykutty, 2007)

Table 8. Effect of shade on yield and quality of *Curculigo orchioides*

Shade (%)	Curculigoside (%)	Fresh rhizome yield (t/ha)	Dry rhizome yield (t/ha)
0	0.000	420	129
25	0.137	1482	643
50	0.094	965	419
75	0.125	1166	509
CD (0.05)	-	134	34

In *Curculigo orchioides* shade was found to be a favourable factor for yield as well as quality. In an experiment conducted, different shade levels of 1, 25, 50 and 75 were tried. Among the different shade levels tried 25 % shade was found to be optimum for better rhizome yield as well as curculigoside content.

Another experiment was conducted with *Kaempferia galanga* which is commonly called as Kacholam. In this experiment different ecotypes of Kacholam was grown in coconut garden under two different shade levels of 70 % and 50 %. The rhizome yield was maximum under 50% shade.

Crops like *Plumbago rosea, Kampferia galanga* and *Curculigo orchioides* are shade tolerant and can be cultivated as intercrop in coconut gardens. But when coming to *Sida cordifolia* there was a threefold increase in root weight and a fivefold increase in Ephedrine content under open situation. So *Sida sp* prefers open condition for higher yield and Ephedrine content.

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Table 9. Effect of shade on yield and quality of *Sida cordifolia*

Characters	Open	Shade
Dry matter production (g/pl)	42.51	16.74
Fresh root weight (g/pl)	9.33	3.37
Dry root weight (g/pl)	6.30	2.22
Ephedrine content (%)	0.013	0.002

6.9. Nutrient Management

Nutrient management is another important factor in herbal farming. The growth promoting effect of FYM as a source of plant nutrients and humus, which improves the soil physical condition by increasing its capacity to absorb water and to store it, enhances the aeration and by favoring microbial activity is well established. Addition of any form of organics has been found to improve the soil health, buffering capacity, water retention capacity, chelation, release of micronutrients, microbiological process, etc.,(Saravana Pandian et al., 2005).

Effect of Bioagents and soil amendments on yield and quality of Pachouli

Among the different bioagents and soil amendment used in *Pachouli* Trichoderma was found to be effective for leaf as well as oil yield when applied along with FYM and fertilizer. Soil amendments and bioagents were also applied in combination. In this treatement fresh leaf yield and oil content was obtained maximum with the application of neem cake and Pseudomonas along with FYM and fertilizers. Combined application of Azospirillum and AMF was found to be more effective for higher herbage yield and essential oil content over their sole application in medicinal plants (Manjnatha *et al.*, 2009)

Table.10 Effect of FYM and fertilizer on yield and quality of *Curculigo orchiodes*

Treatment	**Rhizome yield (kg/ha)**		**Curculigoside (%)**
	Fresh	Dry	
FYM (t/ha)			
10	405	151	7.232
20	518	201	7.266
30	490	191	9.154
CD (0.05)	21.152	7.221	-
FYM @ 20 t/ha : Fertiliser N			
100:0	448	167	7.417
75:25	736	293	8.033
50:50	567	222	7.480
25:75	340	130	8.163
0:100	363	135	8.327
CD (0.05)	21.152	9.322	-

Joy (2003) reported that in *C orchioides* when FYM was applied at different doses in which 20t/ha was found to be maximum for rhizome yield and curculigoside content was maximum obtained at the rate of 30 t/ha. When it was substituted with inorganic fertilizer with different proportion it was found that 75% of FYM and 25% as N fertilizer gave higher rhizome yield and comparable curculigoside content.

Njavara is an important medicinal rice variety cultivated in Kerala. Its medicinal property is due to the presence of amino acid. The grain yield and amino acid content was higher at 50% substitution of organic manure with inorganic fertilizers. *Bacopa moneri* is cultivated in marshy and water logged wet lands. It is commonly known as *Brahmi*. Latha (2010) reported that among different source of organic manure Coirpith compost was a better source for higher biomass yield and bacoside content. In case of biofertilisers the combined application of azospirillum and PSB was more effective in yield and quality. The interaction effect showed that the combined application of coirpith compost with biofertilizer was better for higher yield and bacoside content in *Brahmi.*

6.10. Stress

Under stressed condition medicinal plant produces secondary metabolites as a defense mechanism. These secondary metabolites are responsible for its medicinal properties. So stress is an important factor for the quantity and quality development in medicinal plants. Menon (1999) reported the effect of stress on the yield and quality development in Njavara, which is a medicinal rice variety. During this experiment Njavara rice was cultivated under three different conditions which included wetland, open upland and 50 – 70 % shaded upland. The yield obtained was maximum under wetland situation and lowest under 50 – 70 % shaded upland. But when coming to total amino acid content which is the quality component of Njavara rice it was found that maximum content was noticed in coconut garden followed by open uplands. In coconut garden light intensity and soil moisture are the two limiting factors which influence the yield and quality. Quality was found to be better.

Table 11. Yield of Njavara under different systems of cultivation

Type	Grain yield (kg/ha)
Wet land	2401
Open upland	841
With 50-70 % shaded upland	684

Jaleel (2009) reported the effect of water stress on the yield and quality of *Withania somnifera*, which is commonly known as *Aswagandha*. In the experiment the crop was irrigated at different drought interval days (DID). Maximum percentage of ascorbic acid, reduced glutathione and tochopherol was obtained at 20 DID. This experiment indicates the importance of stress on yield and quality of medicinal plants. For the sustainability of medicinal plant cultivation stress factor also should considered.

6.11. Stage of harvest

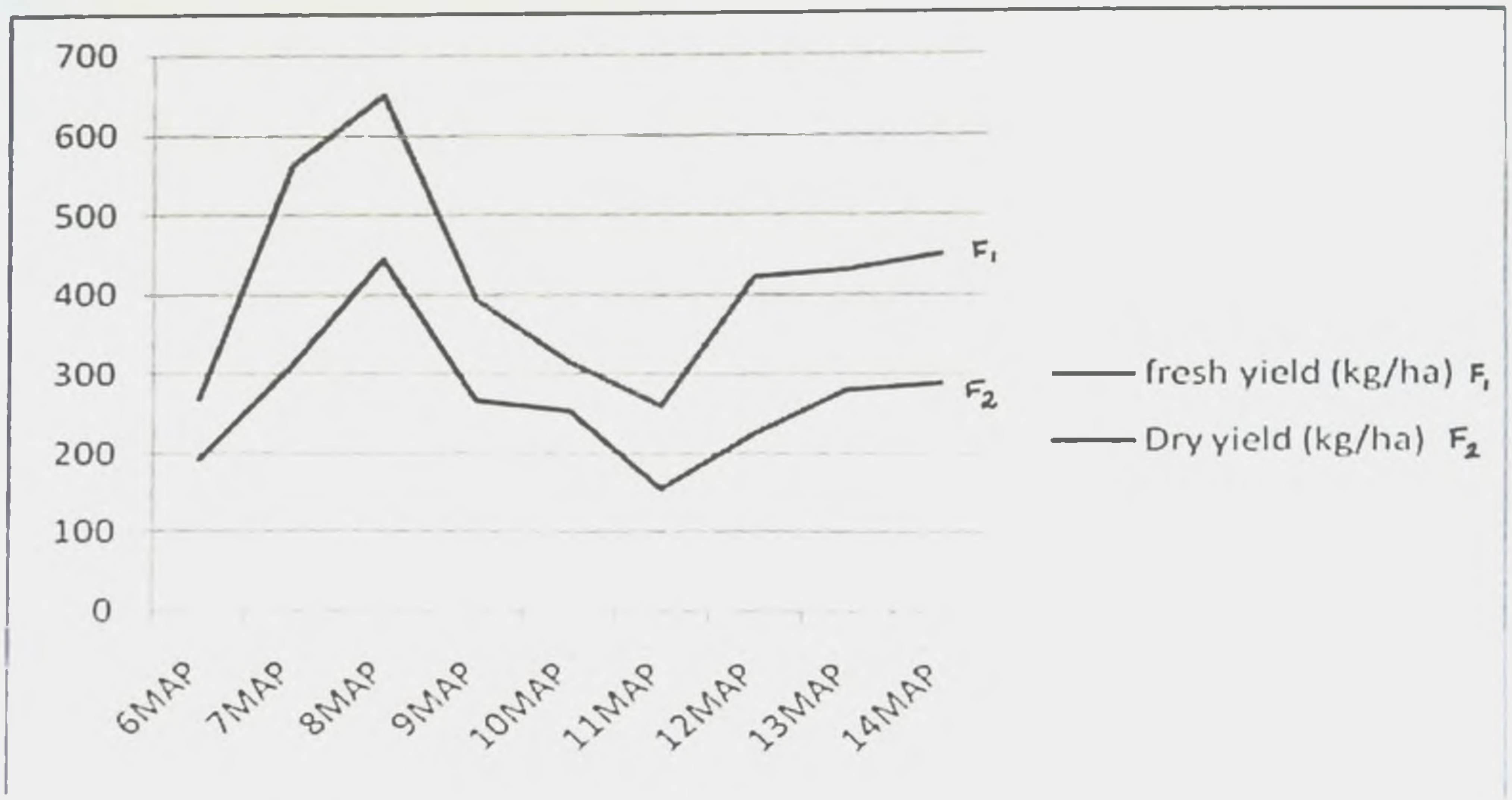
Seasons influence the time of harvesting in medicinal plants as any other crops. The chemical constituents in the plant parts impart medicinal qualities to the crop. Nature and quality of chemical constituents vary with season. So harvesting at optimum stage is important in medicinal plants. Harvesting should be done at correct stage of maximum yield and highest content of active principle.

Menon (1999) reported maximum yield and Plumbagine content in *Plumbago rosea* when the crop was harvested at 18 months after planting.

Table 12.Plumbagine content in the roots of *Plimbago rosea* at different stages of harvest

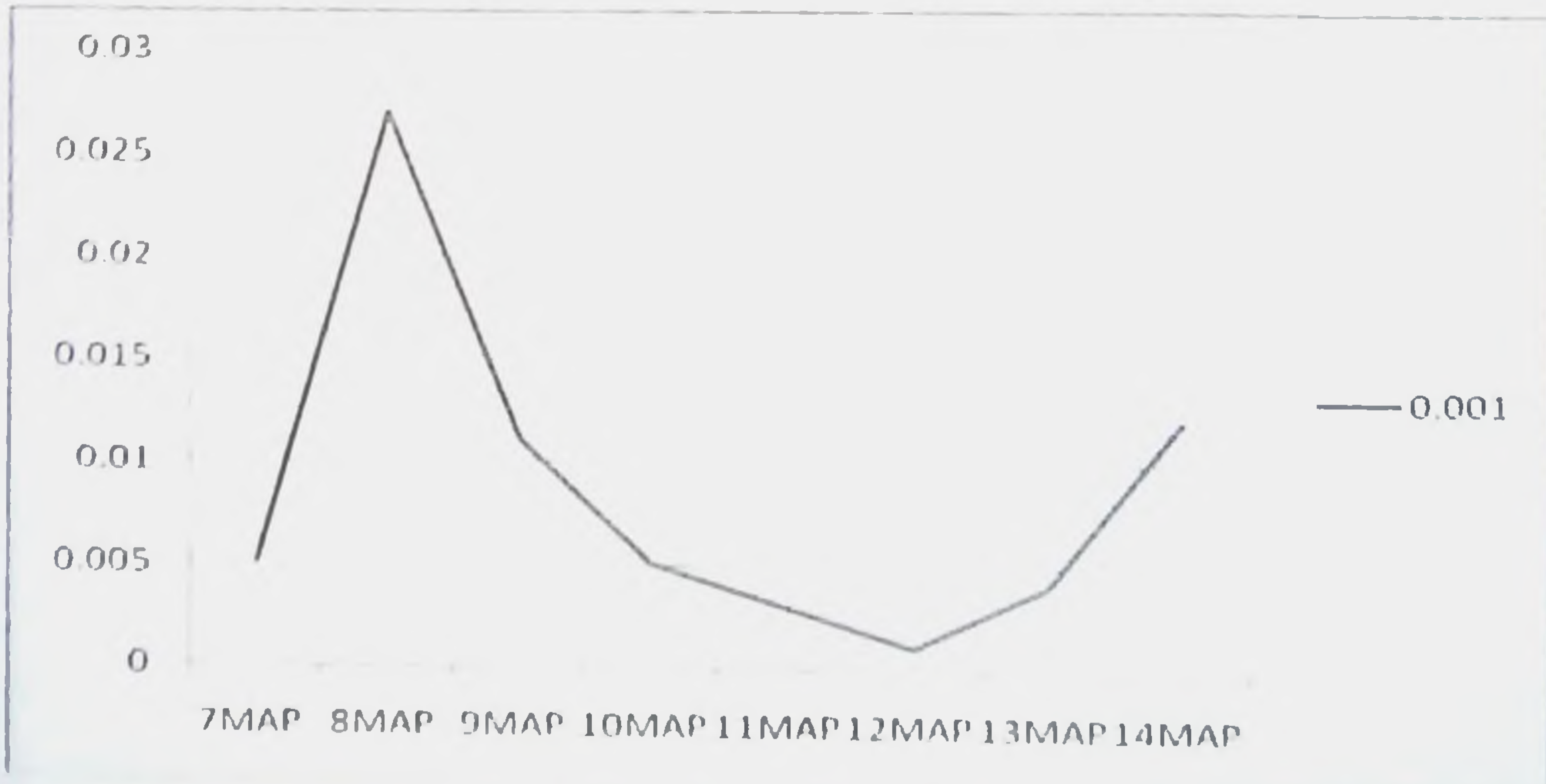
Stages of harvest (MAP)	Yield (t/ha)	Plumbagin content (%)
6	2.06	1.12
8	3.08	0.82
10	3.42	1.17
12	5.77	1.14
14	6.64	0.69
16	7.55	1.40
18	**8.42**	**1.72**

Fig 1.Effect of time of harvest on yield of *Sida cordifolia*



Latha (2010) reported that maximum fresh and dry yield of *Sida cordifolia* was obtained when it was harvested at 8 MAP.

Fig 2. Effect of time of harvest on Ephedrine content in *Sida cordifolia*



Maximum ephedrine content was found when harvested at 8 MAP. Ephedrine content was found to be decreasing with the delay in harvesting and slightly increasing at the time of new flesh emergence with the onset of rain.

6.12. Primary processing and storage

Primary processing and storage are very much important in medicinal plants. It helps the farmer to store the produce after processing for a prolonged period. Farmers can also fetch good price for the produce at lean period or at high demand. The major problem under storage of medicinal plants is fungal attack due to insufficient drying, rodent attack and contamination and decaying due unhygienic storage *etc* .storing the produce under correct driage will help to reduce those problems. The requirement of driage percentage for better storage depends on various plant species

Sujatha (2002) reported the effect of various storage method on quality of *Adathoda vassica*, which is an important medicinal plant used for extraction of vascicine. Vacsicine is the chemical component which imparts medicinal property to the crop. The effect of various storage methods on the preservation and retention of quality and quantity of vacsicine was studied with the experiment.

Table 13. Effect of different storage condition on Vasicine content in *Adathoda zeylanica*

Storage methods	Days after storage			
	0	45	90	150
Open storage of dried product	1.25	0.72	0.48	0.13
Dried chopped material in gunny bags	1.25	0.72	0.66	0.54
Dried chopped material in gunny bags and neem leaf	1.25	0.77	0.68	0.52
Dried chopped material in 250 gauge polythene bag	**1.25**	**1.06**	**1.05**	**1.03**
Powdered material in plastic container	1.25	1.03	0.90	0.82
Powdered material in 250 gauge polythene bag	1.25	1.02	1.02	1.00
Powder in steel container	1.25	1.09	0.99	0.90

From the experiment it was inferred that copped dried material when kept in 250 gauge poythene bag retained maximum vasicine content even after 150 days of harvest.

These are some of the important factors to be considered while going for herbal farming. Depending upon the crop, habitat, adaptation etc influence of these factors may change. For making an herbal farm sustainable consideration of these factors are important. Harvest of the crop at correct stage give good quality produce, but wastage of the economic parts during harvesting is a major problem in herbal farming. Apart following these factors care should be taken to reduce such wastages for making the farm sustainable. For reducing such losses certain special methods of cultivation can be practiced. Eg. Poly bag cultivation

7. Marketing

In Kerala marketing of medicinal plants are done primarily through commission agents and traders. Cultivators, gatherers from non forest areas, dealers outside the state, tribes and illegal collectors do business with the commission agents. The bulk of the material is sold to the traders. Major portion of the profit is taken by the traders. Traders are well versed with facilities of huge warehouses for storage and value addition. They can fetch good price for the produce at the time of high demand.

Marketing is a major problem for the farmers and hence they are reluctant to cultivate medicinal plants on commercial scale. Farmers find it difficult to sell their products in reasonable price prevailing in the market. This is due to unorganized market facilities prevailing in the state. There is no declared market for raw drugs and fresh picks. The traders are reluctant to reveal the source of plant. All these will force the farmers to sell their produce in a non competitive price. To a small extend these problems can be addressed by some of the pharmaceutical companies through contract farming.

Contract farming is a pre determined agreement between the farmer and pharmaceutical company about the quantity and quality of the produce. The companies may give subsidy for the cultivation of the crop and through buy-back system they will procure the produce for drug manufacturing. Oushadi, Kottakal Arya Vaidyashala, Nagarjuna, Dabur etc do contract farming in India.

Table 14. List of drug manufacturing units in Kerala

Sl No	Drug manufacturing units
1	Kottakkal Arya Vaidyasala ,Malappuram
2	Arya Vaidya Pharmacy (Coimbatore) Ltd, Palakkad
3	Nagarjuna Herbal Concentrates,Thodupuzha
4	Vaidyaratnam Oushadasala, Thrissur
5	Oushadhi, Thrissur
6	Kerala Ayurvedic Pharmacy, Thrissur
7	Sitaram Ayurveda Pharmacy, Thrissur
8	Kandamkulathil, Thrissur
9	Thaikaattu moos ETM oushada(Ind) Ltd, Thrissur
10	Santhigiri Ayurveda and Sidha Thiruvananthapuram

Source : (Kerala Ayurvedic Medicine Manufacturers Association, 2008)

8. Value addition

Value addition and diversification of the products helps the farmers to fetch good price in the market. This is another alternative approach to make the herbal farm sustainable. It is an additional source of income generation and open new arenas of livelihood improvement. Value addition includes product diversification like health products, food products, nutraceuticals, food flavours, natural dyes, pestivides, cosmetics, aroma therapy etc. AICRP on Medicinal and Aromatic plants working in College of Horticulture have developed several value added products. These products get good price in the market than those sold in the fresh form. Naruneendi syrup, Dantapala oil, Adalodaka choornam, Kesaraksha hair oil, Kesasudhi herbal shampoo etc are some of the products.

9. Sustainability in herbal farm

Women can play a prominent role in herbal farming and value addition. In Kerala Kudumbasree unit is an organized sector among women. They can enter in to a contract with pharmaceutical agencies. They can collect the material harvested by individual house hold and sell the produce through there co- operative societies. The can also enter into micro enterprises like processing, extraction of the herbal extracts etc, without marketing in raw form.

10. Exporting herbal products

Medicinal plants and herbal products have got a wide acceptance in the outside world. Farmers get premium price for their products from foreign markets. They can also make trade agreements with the pharmaceutical agencies in other countries. Organized farming and export are practiced in many parts of the country. For exporting the medicinal plants and products, farmers should follow the guidelines put forward by WHO.

WHO have given guidelines for collection and cultivation of medicinal plants and manufacturing of herbal medicines. This includes Good Agricultural Practices (GAP), Good Collection Practices (GCP) and Good Manufacturing Practices (GMP). Under herbal farming Good Agricultural Practices (GAP) is the major concern.

11. Good Agricultural Practices (GAP)

The major factors under Good Agricultural Practices (GAP) included site selection, ecological environment, climate, soil and nutrient management, irrigation and drainage, plant maintenance and protection, harvest and post harvest processing.

12. Conclusion

Sustainable herbal farming helps us to conserve the precious endangered medicinal plants in our ecosystem. Herbal farming provides the steady supply of quality raw materials in its fresh form and also for the preparation of medicinal preparations. Homestead farming and value addition of herbal products provides the households a new source of income which will improve the standard of living. Organized cultivation and marketing can search out new arenas for marketing. Establishing small processing units will help to product diversification and fetching premium price for the produce

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14. Discussion

14.1. What is meant by Nutraceuticals?

Nutraceuticals are processed medicinal products. They are prepared after value addition of the medicinal herbs. These include any materials which are considered as food or a part of food that provides medicinal or health benefits. Consumption of nutraceuticals daily prevents the diseases and also provides health.

14.2 What is the relevance of the word 'sustainability'?

Above discussed various factors should be considered when we plan to start a herbal farm. The major concern is the economic sustainability of the farm than the crop sustainability. In this regard value addition, exporting of the processed products and co operative cultivation of the crops are important thing to be considered.

14.3 What is your suggestion to the farmer regarding the shade adjustment in the cropped field, while going for a medicinal plant as an intercrop?

Shade tolerant crop and their varieties perform better in such conditions. I would suggest for crop selection than shade level adjustment.

14.4 Explain the polybag cultivation?

In many of the medicinal plants roots are the officinal parts. Harvesting of these crops is labour intensive and most of the roots will be damaged while harvested by hand pulling. The damage of the roots leads to decaying of the portion, pest and disease infestation at storage, reduction in shelf life etc. Blemished roots will get only lower price in the market. In polybag cultivation half of the polybags are filled with potting mixture. These bags are kept in 15 cm deep pits at a distance of 1 ft. the bags are planted with 2 rooted seedlings, bamboo splits are used as a support to the polybags. Organic manuring is done twice at 6 moths intervals. Harvesting is done after 2 years. Roots are extracted after tearing the polybags. No root will get damaged at the time of harvesting. Wastage of the crop during harvesting can be reduced to an extent.

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COLLEGE OF HORTICULTURE, VELLANIKKARA
Agron. 591- Masters Seminar

Name of the student: Varun kumar A.V.
Admission No : 2010-11-126

Venue: Seminar Hall
Date : 13-05-2011
Time : 10.00 am

SUSTAINABLE HERBAL FARMING

ABSTRACT

Kerala is considered as the home land of ayurvedic treatments. Due to uncontrolled deforestation and destructive collection, the biodiversity of medicinal plants is under threat. The raw materials required for the preparation of ayurvedic drugs are often adulterated due to the unavailability of quality materials. Domestication and commercialisation of medicinal plants is an approach to ensure the supply of quality raw materials.

In India, 70 per cent of the population use traditional medicines. The annual demand of botanical raw drugs in the country was 320 million tons in 2007-08 (Ved and Goraya, 2008). About 90 per cent of the requirement of the medicinal plants is procured from the wild and cultivation accounts for only 10 per cent of the supply in active trade. As a result, the demand and supply of medicinal plants are mismatching and this gap can be filled through herbal farming. Herbal farming is the scientific and systematic cultivation of herbs, which include plant materials such as leaves, flowers, fruits, seeds, stems, wood, bark, roots, rhizomes or other plant parts which may be used as entire, fragmented or powdered.

Homestead farming is a unique system prevalent in Kerala and the medicinal plants can be easily incorporated in this system. According to Ajithkumar (2009) *Kaempferia galanga, Zingiber officinale, Ocimum sanctum, Adathoda beddomei, Curcuma longa, Curcuma aromatica, Maranta arundinaceae, Coleus aromaticus, Saraca asoca* and *Azadiracta indica* are suitable for homestead farming system. The major factors influencing the yield and quality of medicinal plants are choice of crop and variety, spacing, light intensity, nutrient management, stress, stage of harvest, primary processing and storage. Selection of crops depend on the soil characteristics, system of cultivation and market demand.

In medicinal plants several factors influence both yield and quality. Closer spacing was found to be better for higher yield and quality in *Curculigo orcheoides* (Joy, 2003). Combined application of coir pith compost with Azospirillum and phosphorus solubilising bacteria gave higher yield and bacoside content in *Bacopa monnieri* (Latha and Radhakrishnan, 2010). The antioxidant content of *Withania somnifera* increased under water stress situation compared to irrigated condition (Jaleel, 2009).

Many farmers consider the cultivation of medicinal plants uneconomical. As there is no organised market for the raw drugs or the fresh picks, farmers find it difficult to sell their

How safe are the herbicides we use in Kerala?

By

RAJEES P. C.
(2010-11-130)

Seminar Report

Submitted in partial fulfillment for the requirement of the course
AGRON. 591 Seminar

DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA- 680656
THRISSUR

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How safe are the herbicides we use in Kerala?

1. Introduction

Herbicides are chemicals used to kill the herbs or we can say weeds, because majority of the weeds are herbs. From the following table it is clear that the insecticide and fungicide use is decreasing year after year where us the herbicide uses is having an increasing trend.

Pesticide Group	95-96	97-98	00-01	02-03	04-05
Insecticide	38.788	33.379	26.756	28.197	25.929
Fungicide	10.653	10.054	8.307	10.712	6.397
Herbicide	6.040	7.103	7.299	7.364	7.857
Others	5.869	1.703	1.222	1.398	1.660

Tab.1: Pesticide consumption in India (NCIPM, 2005)

Coming to world scenario, out of the total pesticides, herbicide use is 43%, insecticide use is 33% and fungicide use is only 17%. The increased use of herbicide is due to application of herbicides before the crop for minimum tillage practices in most of the developed countries. In Kerala, herbicide use increased from 6% to 10% during the period of 2007-2010.

The erratic and continuous use of herbicides may create toxicity problems to crops, residual effect in soil, toxicity to aquatic flora and fauna and finally to the human beings. Recently some of the pesticides including herbicides are banned in Kerala. So we should know what are all the things taking place when an herbicide is applied to the environment.

2. Common herbicides in Kerala

- Paraquat is a contact herbicide famous under the trade name gramoxone. It is a bipyridillium compound with broad spectrum action. Mode of action is by inhibiting photosystem-I of photosynthesis. The recommended dosage is 0.4 kg ai/ha.
- 2, 4-D is a systemic post emergent herbicide known under the trade name fernoxone. It is a selective killer of broad leaved weeds and sedges. The mode of action is by increasing biosynthesis of ethylene causing uncontrolled cell division and so damages the vascular tissue. The typical symptom shown by the weeds to 2, 4-D is "epinasty syndrome". It is the twisting and bending of tender parts of the plant. The recommended dosage is 0.5-1 kg ai/ha.
- Glyphosate is an organophosphorus systemic broad spectrum herbicide famous under the trade name roundup. Mode of action is by inhibiting EPSP synthase, which is an enzyme responsible for the production of essential amino acids in shikimic acid pathway. The typical symptom shown by the weed is "witches broom appearance". It is the characteristic discolouration followed by yellowing and drying of plants. Roundup is produced by the company Monsanto. They were having patent up to 2000, after which another companies also started producing glyphoste under the trade names like glycel, weed off. One of the major impacts of biotechnology was the introduction of roundup ready crops by Monsanto. They produced roundup ready soybean, canola and maize. Every year area under these crops is increasing. The recommended dosage is 0.8 kg ai/ha.

- Oxyfluorfen is a selective contact pre emergent herbicide commonly used under the name goal. It is a diphenyl ether compound and is specifically recommended for dry sown rice. The mode of action is by inhibiting protoporphyrinogen oxidase leading to cell membrane damage. The recommended dosage is 0.15 kg ai/ha.
- Cyhalofop butyl is a selective systemic post emergent herbicide known under the trade name clincher. Mode of action is by inhibiting Acetyl CoA and thereby inhibiting the lipid synthesis. Echinochloa is the major weed in the rice fields of Kerala. It can be effectively controlled by this herbicide. The recommended dosage is 0.08 kg ai/ha.
- Diuron is a pre emergent selective urea substituted herbicide. Mode of action is by inhibiting hill reaction of photosynthesis. The recommended dosage is 1.0 kg ai/ha.

- Pendimethalin is a pre emergent selective herbicide known under the trade name stomp. It is a dinitro aniline compound and the mode of action is by inhibiting mitosis and cell division. It is a seedling root growth inhibitor widely used in rice fields and also used in vegetables. It is effective against *Cuscutta sp*. But the drawback is it is having high price in the market. The recommended dosage is 1.5 kg ai/ha.
- Butachlor and Pretilachlor are selective systemic pre emergent herbicides famous under the trade names machete and rifit respectively. These are chloro acetamide compounds inhibiting the mitosis and cell division and thereby inhibiting seedling shoot growth. The recommended dosage are 1.5 & 0.75 kg ai/ha respectively.
- Nominee gold is the leading herbicide used in rice fields of Kerala. The chemical is bispyribac sodium and is a selective systemic post emergent herbicide. It can effectively control grasses, broad leaved weeds and sedges, but the weed *Leptochloa chinensis* is found to be resistant against nominee gold. That can be controlled by spraying clincher. Mode of action is by inhibiting ALS (Aceto Lactate Synthase) pathway. The recommended dosage is 30 g ai/ha.

3. Herbicides for major crops in Kerala

Rice is the crop in which herbicide usage is maximum. The pre emergent herbicides used are Butachlor, pretilachlor, oxyfluorfen and pendimethalin. Care should be taken to drain the field while applying the herbicides and flood the field with thin film of water for the next few days. Post emergent herbicides used are 2,4-D, nominee gold and almix. Almix is the combination of chlorimuron ethyl and metsulfuron methyl, which is effective in controlling marselia. It is recommended at 4 g ai/ha. Nominee gold is used to control all types of weeds.

The herbicides used in the plantation crops like coconut, coffee, cardamom, cashew and rubber are paraquat and glyphosate. In banana and pineapple pre emergent herbicides like diuron and oxyfluorfen are used, while the post emergent herbicides used are paraquat and glyphosate.

Herbicide classification based on toxicity level

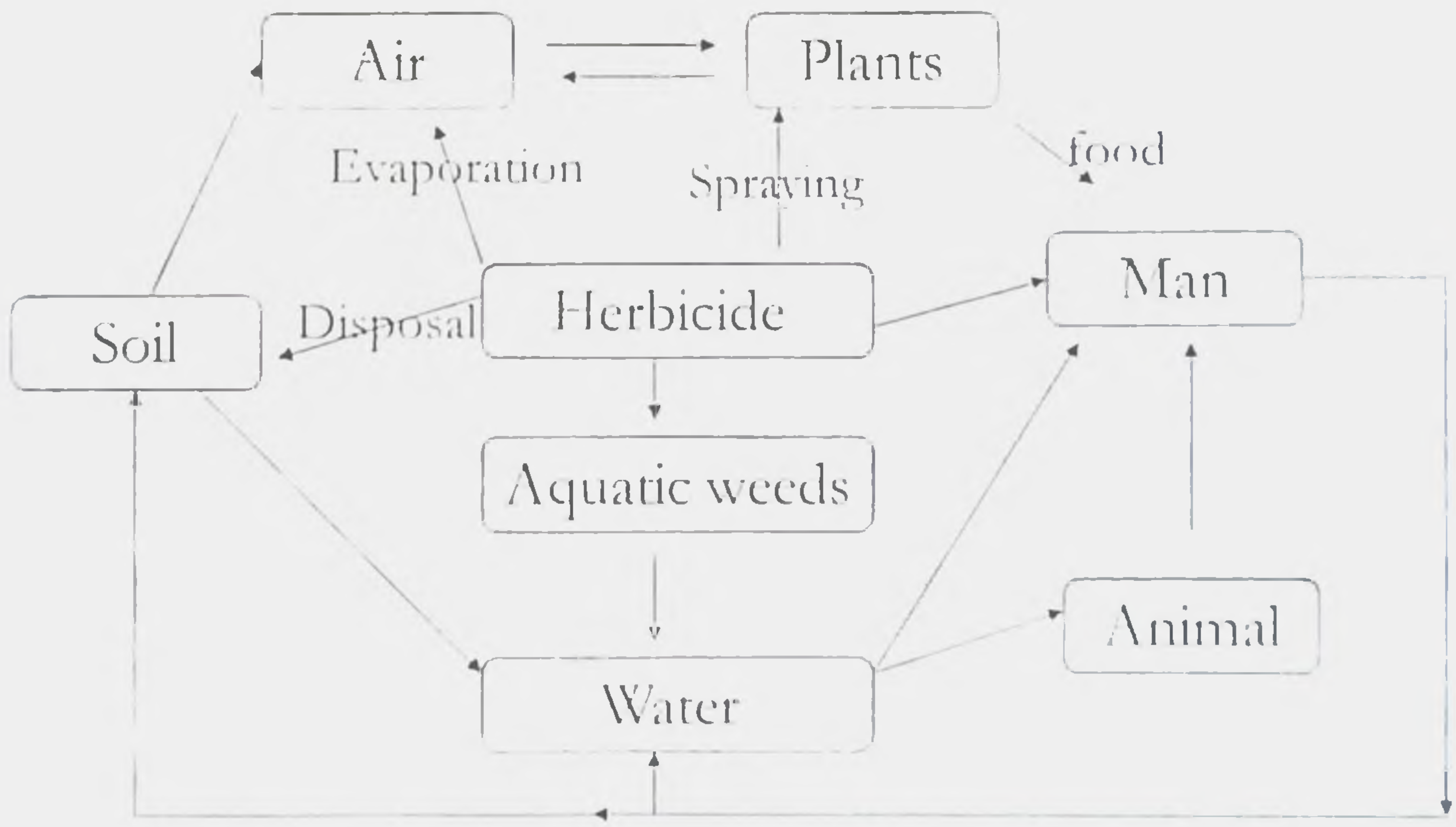
Toxicity	Oral LD_{50} (mg/kg body weight)	Dermal LD_{50} (mg/ kg body weight)
Extremely toxic	1- 50	1-200
Highly toxic (Paraquat, 2,4-D)	51- 500	201-2000
Moderately toxic (Butachlor, Diuron)	501- 5000	2001- 20000
Slightly toxic (Pretilachlor, sulfosulfuron)	>5000	>20000

Tab 2: Herbicide classification based on toxicity level (Kulshrestha, 2006)

Herbicide cycle in the environment

When an herbicide is applied in to the environment it will reach in plants, soil, air, aquatic environment and in human beings. From plants it may enter in to food chain and comes in to human beings. From soil it may reach air by volatilization or reach the soil water by leaching. From the aquatic environment it enters in to fishes and finally to human beings through food chain.

Fig.1: Herbicide cycle in the environment



4. Fate of herbicide in soil

Herbicides when comes in soil under goes many reactions like physical processes, chemical decomposition, microbial transformations, formation of soil bound residues, photochemical decomposition and adsorption.

Fig.2: fate of herbicide in soil

Volatilization

Volatile chemicals may escape in to the atmosphere through the process of volatilization. It depends on vapor pressure of the compound, its concentration and adsorption to soil and solubility in water. It is also affected by air temperature, wind velocity, soil temperature relative humidity. The esters of phenoxy acetic acids are more volatile than free acids and their salts (Rao, 1992).

Leaching

It is the downward movement into the soil as solution in the soil water. Leaching is influenced by water solubility of the herbicide as well as soil properties like soil texture, permeability and colloidal adsorption. It occurs through mass flow and diffusion.

Leaching pattern of pretilachlor in different soil types: The experiment was done in two different types of soils to find out the leaching pattern of pretilachlor. The results obtained were, fine textured soil with high organic matter content recorded lower levels of leachate compared to coarse textured soil with low organic matter and pretilachlor is not a potent herbicide to cause ground water pollution.

Dose (kg/ha)	Depth of soil (cm)	Concentration (ppm)	
		Coarse textured low O.M. soil	Fine textured high O.M. soil
Pretilachlor (0.75)	0-2	2.56	2.85
	2-4	0.19	0.11
	4-6	0.09	0.06
	6-8	0.06	0.03
	8-10	0.03	0.01
	Leachate	0.006	0.004

Tab 3. Leaching pattern of pretilachlor in different soil types (KAU, 2007)

Run off

Run off takes place when the rate of precipitation is greater than the rate of infiltration. Duration and intensity of rainfall and formulation of herbicide are the two factors affecting run off. Water soluble herbicides are susceptible to run off, if rain occurred shortly after the application. 2, 4-D was found susceptible to run off (Stearman and Wells, 1997).

Photochemical decomposition

Decomposition by light is one of the mechanisms of herbicide conversion in soil. It is induced by UV radiation. When exposed to light, organic molecules in the herbicide absorbs radiant energy and excitation of electrons takes place leading to transformations such as breaking and formation of chemical bonds, fluorescence. Rate of decomposition and nature of products depends on light source, intensity of light and structure of herbicide. Compounds like paraquat having weak bonds are subjected to decomposition (Gino, 1993).

Adsorption by soil particles

The process of adsorption results in binding of a chemical to sites on soil mineral or organic surface. Adsorption is the key factor determining the environmental fate of an herbicide in soil, its biological activity and persistence. Type of clay colloid, soil organic matter content, soil pH, soil moisture and chemical nature of herbicide are the factors affecting adsorption. Inorganic colloids with high CEC adsorb more (Rao, 1992). Adsorption occurs when a soil is having organic matter content above 2% (Kumari and Singh, 1994). Glyphosate is adsorbed at low pH (Sprankle *et al.*, 1995). Adsorption of cationic herbicide is more in soils with high organic matter content (TNAU, 1993). So clay can be used as an antidote against paraquat. The positively charged paraquat ions will bind to the negatively charged clay lattices.

Adsorption of Butachlor in different treatments:

Treatment	Total organic carbon %	Dissolved organic carbon %	Adsorption of Butachlor*
Soil alone	0.62	0.012- 0.022	3.50
Soil+Cowdung	0.93	0.055- 0.062	3.94

* In the top 5cm layer (μg/g) at 1 day after spraying (KAU, 2010)

Tab.4: Adsorption of Butachlor in different treatments

From the above research work it is clear that, adsorption increases as the organic matter content of the soil increases.

Chemical decomposition

It is not a significant pathway in herbicide decomposition. However it is significant in case of triazines, dinitro anilines and diphenyl ethers. It occurs through hydrolysis, oxidation. reduction and dealkylation reactions. The rate of decomposition is directly proportional to the concentration of the chemical.

Microbial transformations

Though microbes occupy a very small volume of soil (< 0.1 %), they are responsible for a number of transformations taking place in nature. Microbes degrade herbicides predominantly through ester or amide hydrolysis, alkylation, dealkylation, dehalogenation, oxidation, reduction, aromatic ring hydroxylation, ring cleavage and conjugation. Therefore, it is significant in case of aliphatics, amides, carbamates and phenoxy acids. Soil temperature of 20-30^{0}C, soil moisture near field capacity and moderate organic matter are optimum for this. Intracellular and extra cellular mechanisms are there. Microbes utilizes carbon atom as the energy source and releases carbon dioxide.

Mono-oxygenase enzyme produced by alcaligens converts 2, 4-D into 2, 4-dichloro phenol. Phosphenatase enzyme produced by pseudomonas which convert glyphosate in to amino methyl phosphonic acid.

Formation of soil bound residues

Binding of herbicide to insoluble organic material will result in decrease in mobility and bio availability of the residue. Bound residues are quantified by radio-labeled compounds. However, these labeling techniques do not provide any information about chemical structure. Studies using ^{14}C labeled atrazine and 2, 4-D reveals that most of the applied radioactivity is bound irreversibly to humin fraction (Xie *et al.*, 1997). The in extractable nature of humin has made it difficult to understand the nature of bound residue. It can be assumed that, bound residues are less toxic, less bioavailable and less mobile (Kastner *et al.*, 1999).

5. Persistence of herbicide

Persistence of herbicide is the residence time of chemical in soil, before being completely removed by physical, chemical or biological degradation (Scheunert *et al.*, 1993). The factors affecting the persistence of an herbicide are soil organic matter, soil microbes, soil texture, soil pH and soil moisture.

Soil organic matter

KAU (2003) studies revealed that the increased soil organic matter results increased rate of adsorption, degradation and microbial activity in soil. The organic matter improves the bioefficacy of herbicides in Rice- Rice cropping system by increasing the adsorption of herbicides (KAU, 2010).

Echinochloa population (2002- 2010) number/m^2:

Treatments	2002	2003	2006	2009	2010
T1	7	6	11	26	0
T2	20	10	11	41	34
T3	16	9	20	5	0
T4	22	9	80	90	32
T5	9	6	19	8	0

Tab.5: Echinochloa population (2002- 2010) number/m^2 (KAU, 2010)

T1: Hand weeding

T2: Butachlor + 2, 4- D (100% NPK)

T3: Butachlor + 2, 4- D (75% NPK+ 25% FYM)

T4: Pretilachlor + 2, 4- D (100% NPK)

T5: Pretilachlor + 2, 4- D (75% NPK+ 25% FYM)

The work done by KAU in the period of 2002- 2010 showed the effect of organic matter in improving the efficiency of herbicides. Farm yard manure treated plots showed less number of *Echinochloa* population compared to fertilizer treated plots.

Soil microorganisms

Microorganisms are able to degrade a wide variety of chemicals, from simple polysaccharides, amino acids, proteins, lipids *etc.* to more complex materials such as plant residues, waxes and rubbers. Many herbicides are retained in the surface layer of soils for a relatively long period and are degraded mostly by soil microbes. According to Chakraborthy and Bhattacharya (1991), *Fusarium solanum* and *F. oxysporum* effectively degraded Butachlor in 0.02M KH_2PO_4 buffer solution at pH 5.2. *Aspergillus* is the major organism responsible for degradation of 2, 4-D in acid soils (Devi, 2002). The graph below shows that the application of herbicides decreases the population of bacteria in the soil. The total population of microflora attained normal level by the time of harvest n all the treatments.

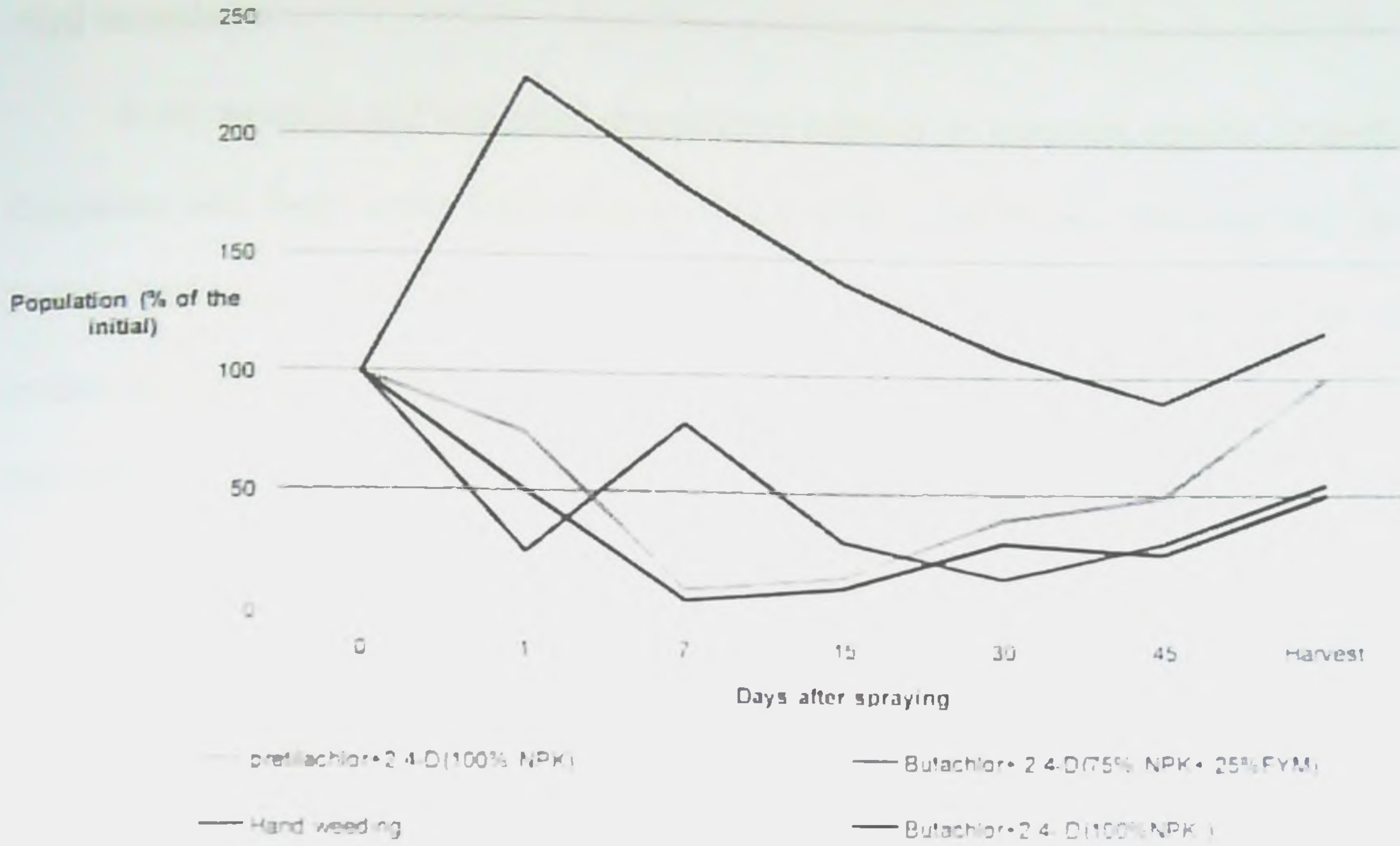


Fig. 3 Effect of herbicides on soil bacterial population

Soil texture

Clay content is one of the principal factors influencing persistence of herbicides in soil. The herbicides are deactivated easily in coarse textured soil (Miles and Moye, 1996). Adsorption and bioactivity of herbicides were correlated with clay content (Weber and Peter, 1999). Adsorption of Glyphosate related to clay content and CEC of soil (Glass, 2000).

Soil pH

Soil pH has significant effect on detoxification of herbicides by influencing their ionic and molecular characteristics, anion and cation exchange capacity of soil colloids and the inherent capacity of soil microbes to react with the herbicides. According to Grover (1999), acidification of soil enhanced the ability to retain 2, 4- D.

Soil moisture

Both chemical and microbial degradation depends on moisture content. Butachlor dissipation was faster under field capacity followed by submergence (Prakash and Devi, 2000). Half lives of Butachlor in soils under air dry, field capacity and submerged conditions ranged from 52.40- 59.57, 12.35- 20.58 and 28.48- 39.20 days respectively. The herbicide persistence of some herbicides in soil is given below in the Table:

< 3 months	3-6 months	> 6 months
Paraquat Anilofos Butachlor Fluchloralin Glyphosate Pretilachlor Sulfosulfuron 2, 4- D Propanil Dalapon	Diallate Dinitramine Isoproturon Oxyflourfen Linuron Chlorbromuron	Atrazine Bromacil Diuron Simazine Trifluralin

Tab.6: herbicide persistence (Sankaran *et al.*, 1993)

6. Herbicide residue in aquatic system

Potential sources of pollution of aquatic systems with herbicides are (i) herbicides applied for weed control in rice (ii) chemicals applied for aquatic weed control (iii) herbicides applied to plantation in hilly areas. Among the three sources, herbicidal weed control in aquatic areas has more direct impact on aquatic systems. Water solubility is the major factor determining the extent of pollution caused by an herbicide in ground water. An herbicide is considered as a potential pollutant when the solubility is greater than 30mg/ L. Phenoxy alkanoics, Sulfonyl ureas and Bipyridilliums are more water soluble than the others. Hydrolysis half life (>25 weeks), photolysis half life (> 1 week), field dissipation half life (>3 weeks) and speciation (negatively charged, fully or partially at ambient pH) are the other factors that indicate high ground water contamination of herbicides. The persistence of paraquat in water are given below

Treatments	Paraquat residue (µg/ml)			
	1DAS*	7 DAS	15 DAS	30 DAS
Paraquat 0.5 kg/ha	0.36	0.143	0.135	BDL**
Paraquat 1.0kg/ha	3.10	0.310	0.286	BDL

Tab 7. persistence of paraquat

* Days after spraying ** below detectable level (KAU, 2010)

Common aquatic algaecides and herbicides are given below

Name of the compound	Rate of application	Target plants	Toxicity
Copper sulphate pentahydrate	5.0 ppm	Water bloom Common scum Algae (Chara sp.)	2.3 to 12.0 ppm in human drinking water. 100 ppm in animal drinking water
Triazines	0.5 to 1.25 ppm	Water bloom	Unsafe for treating irrigation and drinking water bodies
Diuron	0.2- 0.4 ppm	Macro algae	Accumulate in fish tissues
Paraqaut	0.25- 1.5 ppm	Pistia, Lemna and Eichhornia	Unsafe for drinking
Glyphosate	1- 3 kg/ ha in 300 L water	Nymphaea	Non residual
Silvex (Fenoxaprop)	0.5- 4.0 ppm	Alternanthera, Nymphaea, Nelumbo	Unfit for irrigation and other uses
2, 4- D	1- 8 kg/ha or 2.0 ppm	Eichhornia, Myriophyllum	Unfit for irrigation, toxicity to fish

Tab.8: Common aquatic algaecides and herbicides (Gupta, 2001)

The study conducted at AICRP on weed control, KAU showed that there is accumulation of 2, 4- D residues in the fish up to 30 DAS and the bottom sediment depending on the quantity applied against *Salvinia*. The residues of C^{14} 2, 4- D accumulation in fish are shows in the graph below.

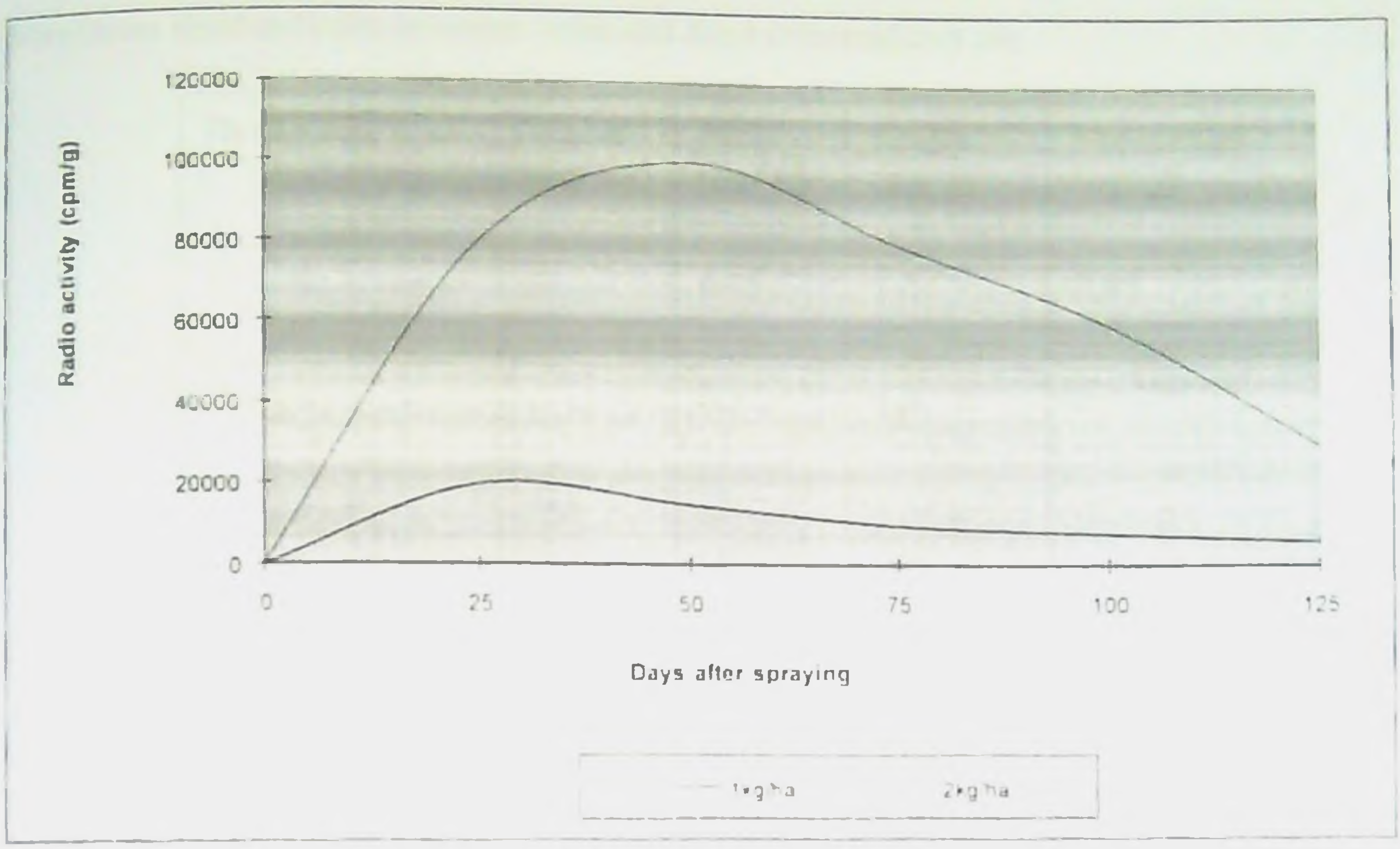


Fig.4: Residues of C^{14} 2, 4- D accumulation in fish (Devi *et al.*, 2006)

The persistence of residues of common herbicides in water, mud or sediment is given below

Herbicide	Water (days/ conc.)	Reference	Mud/ sediments (days/ conc.)	Reference
2, 4- D	365(DT [illegible])	KAU, 2004	>120	KAU, 2004
Cyhalofop butyl	$90(DT_{100})$	USEPA, 2002	$90(DT_{100})$	USEPA, 2002
Paraquat	$120(DT_{85})$	KAU, 2004	0.10- 0.56 ppm at 60 days	KAU, 2004
Glyphosate	< 0.01ppm at 6 days	Nain et al., 2000	8.5 (DT_{50})	Paveglio et al., 1996

Tab.9: The persistence of residues of common herbicides in water, mud or sediment

Maximum residue limits in water, milk and food commodities are

Herbicide	Water (µg/ L)	Milk (µg/ L)	Fruits (µg/ g)	Vegetables (µg/ g)
2, 4- D	30	0.05	5.0	0.05
Diuron	-	0.1	0.5	-
Glyphosate	700	0.1	0.05-0.2	0.01-0.1
Paraquat	-	0.01	0.05	0.05- 0.2
Pendimethalin	20	0.01	0.05	0.05
Oxyfluorfen	-	0.01	0.05	0.05
Atrazine	2	0.01	-	0.01

Tab.10 Maximum residue limits in water, milk and food commodities (Sankaran *et al.* 1993)

Herbicides showing accumulation in the aquatic flora and fauna

Herbicide	Concentration in fish or plant
2,4- D	Fish: Thilapia 2.17- 31.22µg/g
Paraquat	Fish: Clarias lazera 0.386- 1.160µg/g Plant: Chara- 2.3ppm Spirogyra- 1.3ppm

Tab.11: Herbicide accumulation in the aquatic flora and fauna (KAU, 2004)

7. Banned herbicides in Kerala

Four herbicides namely, atrazine, anilofos, thiobencarb and paraquat are banned in Kerala. The reasons for banning and their alternatives are descried below.

Atrazine: It is having high persistence in soil (>6 months) and it is a potential herbicide causing ground water pollution. This is widely used in sugarcane and sorghum which is not commonly grown in Kerala. According to Gass (1992), it causes colon cancer and gastro intestinal complaints.

Anilofos: It is a highly toxic chemical with yellow label. It is not used in Kerala because there are alternatives like Butachlor and pretilachlor. IUPAC (2005) studies showed that it causes Respiratory tract, eye and skin irritation.

Thiobencarb: It is not used in Kerala because there are alternatives like Butachlor and pretilachlor. IUPAC (2005) studies showed that it act as a potential neurotoxicant.

Paraquat: It is a highly toxic chemical with yellow label. It is commonly used through out Kerala. The two main alternatives are glyphosate and glufosinate. IUPAC (2005) studies showed that it act as a mutagen, respiratory tract, skin and eye irritant.

8. Future thrust

The herbicides causes residue problem in the soil, aquatic environment and finally to human beings either directly or through food chain. A safe alternative is needed for better future. So the future thrust should be given for bioherbicides. Bioherbicides are the formulations made from living organisms like bacteria, fungi *etc*. Example for bioherbicides used is given below.

- *Colletotrichum gloeosporioides* used to control *Aeschynemone* sp.
- *Puccina canaliculata* against *Cyperus* spp.
- *Phomopsis amaranthicola* against *Amaranthus* spp.
- *Dactylaria higginsii* against *Cyperus* spp.

9. Conclusion

- Optimum dose of herbicide: apply the herbicide only at the recommended dosage only. The higher dose applications may results in residual problems in soil and aquatic environment.
- Critical period of weed competition: It is the time span when weeds present from the beginning of crop cycle must be removed or point after which weed growth no longer affects crop yield. So herbicides should apply in this period only. For rice. it is the first 45 days. In general, for 100 days duration crops the first 35 days should be considered as critical period of competition.
- Herbicide formulation: Low volatile esters are causing less injury to the non target plants. Water soluble formulations are susceptible to leaching and thereby causing ground water contamination. Wettable powder formulations are less phytotoxic compared to emulsifiable concentrates.
- Proper use and cleaning of sprayers
- Proper disposal of containers
- Crop rotation: Growing same crop in a same area will result in using an herbicide for longer period in that area. This will lead to residue problem. So crop rotation can be advice to overcome this problem.
- Application of FYM, activated charcoal.

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12. Discussion

1. How can we estimate herbicide residue in soil?

There are biological, chemical and instrumental methods for residue analysis. The biological method includes bio assay and ELISA. The chemical method includes gas chromatography and HPLC. Instrumental method includes spectro photometry and colourimetry.

2. What are the herbicides going to be banned in the future?

2, 4- D and Diuron. 2, 4- D is a highly toxic herbicide having yellow label. It is highly soluble in water. Hence it causes aquatic environmental pollution. Diuron is a chemical having long period of persistence in soil like atrazine.

3. what is mean by LD_{50}, LC_{50} and DT_{100}

LD_{50} is the average lethal dose in milli gram/ body weight in kg required to kill 50% test population. LC_{50} is the average lethal concentration in mg/kg required to kill 50% of test population. For a highly toxic herbicide the LD_{50} value is very low. DT_{100} is called the dissipation time. That means the time required for 100 percent of initial quantity or concentration of a pesticide to dissipate from a system.

4. How are round up ready crops made?

The action of glyphosate is blocking the activity of EPSP Synthase in the Shikimic acid pathway. The EPSP Synthase is responsible for the biosynthesis of amino acid. Round up ready crops are produced by the insertion of the gene coding for a glyphosate insensitive EPSP Synthase that is obtained from a soil bacterium called *Agrobacterium* CP-4

13. Abstract

How safe are the herbicides we use in Kerala?

Abstract

Herbicides are the chemicals used to kill the weeds. Out of the total pesticide consumption in India, insecticides are used maximum followed by fungicides and herbicides. But there is a decreasing trend in the consumption of insecticides and fungicides whereas the herbicides consumption is in an increasing trend (NCIPM, 2005). The herbicide consumption of Kerala has also increased from 6% to 10% in the time period of 2007- 2010. The widely used herbicides in Kerala are paraquat, 2, 4- D, glyphosate, oxyfluorfen, clincher, diuron, pendimethalin, butachlor, pretilachlor and nominee gold. But the erratic and continuous use of herbicides can cause problems to crops, residual effects in soil, toxicity to aquatic flora and fauna and finally to the human beings.

When an herbicide is applied to the soil it undergoes different process like adsorption, chemical decomposition, microbial transformation, formation of soil bound residues and photochemical decomposition. Adsorption is the key factor determining the fate of herbicide in soil, its biological activity and persistence. When a soil is having more than 2% organic matter the adsorption occurs and it increases with increase in organic matter. Adsorption of cationic herbicides like paraquat is more in soils with high clay content (TNAU, 1993).

Persistence of herbicides is the residence time of herbicides in soil before being completely removed by physical, chemical or biological degradation. Several factors like soil organic matter, soil microbes, soil texture, soil pH and soil moisture are affecting the

persistence of herbicides in soil. Soil organic matter improves the bio efficacy of herbicides in paddy field by increasing the adsorption (KAU, 2010). When we apply herbicides, the population of bacteria decreased considerably. Atrazin and diuron are the herbicides having the maximum persistence in soil where as paraquat, 2, 4- D and glyphosate are having low persistence.

Potential sources of herbicide pollution in aquatic environment are the herbicides applied for weed control in rice, aquatic ecosystem and plantation crops in hilly areas. A herbicide is considered to be a potential pollutant when the solubility of that is greater than 30mg/L. herbicides coming under phenoxy alkanoics, sulfonyl urea are highly soluble in water. Hydrolysis half life, photolysis half life and field dissipation half life are the factors which indicate ground water contamination potential of herbicides. Herbicide residues were found in fish upto 60 days after spraying when 2, 4- D was applied to control Salvinia (Devi *et al.*, 2006).

The herbicides can enter into the human beings through food chain and cause many health problems like skin and eye irritation, colon cancer, gastro intestinal problems and neurotoxicity. The harmful effects of herbicides can be managed by applying optimum dose, correct choice of formulation, proper use and cleaning of sprayers and proper disposal of herbicide containers. Future thrust should be given to the use of bio herbicides. Many of the living microbes like fungi and bacteria are used to control the growth of weeds. So bio herbicides can be used as an eco-friendly approach to weed management.

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

PHYTOHORMONES IN SOIL

BY

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SEMINAR REPORT

Submitted in partial fulfilment for the requirement of the course

Soils 591- Masters Seminar(0+1)

MSc. Soil Science and Agricultural Chemistry

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1.INTRODUCTION

Soil is a heterogeneous body and forms the part of an ecosystem includes both biotic communities and abiotic environment mutually influencing each other to maintain the dynamics of life on earth. Rhizosphere is the region of soil which is subjected to influenced by plant roots. The term 'rhizosphere' was first introduced in 1904 by the German scientist Hiltner. Rhizosphere is characterized by greater microbiological activity than the soil away from plant roots. The intensity of such activity depends on the distance to which exudations from the root system can migrate. The term 'rhizosphere-effect' indicates the overall influence of plant roots on soil microorganisms. Greater number of bacteria, fungi and actionomycetes are present in the rhizosphere soil than in non-rhizosphere soil. Several factors such as soil type, its moisture, pH, temperature, the age and condition of plants are known to influence the rhizosphere effect. The rate of metabolic activity of the rhizosphere microorganisms are different from those of the non-rhizosphere soil. There are many interactions between plant roots and soil microorganisms and these microorganisms produce many secondary metabolites.

There are beneficial and harmful effects for soil microorganisms.

i) **The beneficial effects includes;**

1. Decomposition of organic matter
2. Increase the soil fertility
3. Production of secondary metabolites

Soil organic matter comprises residues of plant and animals at all stages of decomposition mediated by soil microorganisms. Various organic compounds which reach the soil by way of animal and plant residues are made up of complex carbohydrates, proteins, fats, oils, simple sugars, starch, lignin, cellulose, pectins and other products. The size of particles in organic matter, the nature and abundance of microorganisms involved, the extent of availability of carbon, nitrogen, phosphorus and potassium, the moisture content of soil, its temperature, pH, aeration, presence of inhibitory substances etc. are some of the major factors which influence the rate of organic matter decomposition. Soil microorganisms increases the fertility of soil by many processes including phosphorus solubilization, nitrogen fixation by biological nitrogen fixers. Microorganisms especially bacteria and fungi produce a wide range of secondary metabolites. These secondary metabolites they produced will vary according to the microorganisms and the media they grown. The metabolites includes antibiotics and plant growth regulators like indole acetic acid, gibberellins, cytokinins and ethylene.

ii) The harmful effects include;

1. Disease causing microorganisms
2. Production of phytotoxins

Some microorganisms present in the soil are plant pathogenic nature which cause diseases in plants and some produce substances which are toxic to plants like aflatoxins from *Aspergillus flavus*, helminthosporin from *Helminthosporium sativum*, lycomarasmine or fusaric acid from *Fusarium oxysporum*.

2.PHYTOHORMONES

Phytohormones or plant growth regulators are the organic substances that influence physiological processes of plants at very low concentrations. They influence the plant growth from the germination to all stages of plant growth including root growth, flowering, aging, prevention or promotion of stem elongation, leaf emergence, leaf fall and many other physiological processes. Hormones are vital to plant growth and lacking them plants would be mostly a mass of undifferentiated cells. Generally plants itself synthesize plant hormones endogenously and move from the site of production to the site of action. Plants also respond the exogenous application of plant growth regulators. Exogenous application can be given as foliar spraying, soil application, root feeding etc.

There are five major hormones in plants

a) Auxins

b) Gibberellins

c) Cytokinins

d) Ethylene

e) Abscisic acid

Also other plant growth regulators which affects the growth and development of plants includes flavonoids, brassinosteroids, jasmonates, salicylic acid, plant peptide hormones etc.

a) Auxins

Auxin first discovered by Went in 1928 and it is first isolated by Kogl and coworkers in 1934 from human urine after that only it is isolated from plant tissues by Haagen-Smith in 1946. These are the compounds that positively influence cell enlargement, cell division, root initiation and root growth inhibition and stimulation of protein synthesis. They inhibit the growth of lateral buds (apical dominance) and also promote lateral and adventitious root development. Phototropism and geotropism are main responses due to auxin. Phototropism is the response to light source and geotropism is the response to gravity.

b) Gibberellins

It is first discovered in association with the foolish or bekane disease of rice caused by *Gibberella fujikuroi* which is an imperfect stage of *Fusarium moniliformae*. The infected plants shows overgrowth or abnormal growth and this is due to some substances produced by the fungus. This substance is isolated by Yabuta and Sumuki in 1938 and named gibberellin. Gibberellins include a large number of chemicals that are produced naturally within plants. They promote cell elongation which results in increase of internodal length, cell division, breaking of dormancy and flowering. They are important in seed germination, affecting enzyme production that mobilizes food production used for growth of new cells. It also reverse the inhibition of shoot growth and dormancy induced by ABA.

c) Cytokinin

The synthetic cytokinin, kinetin was first isolated by Miller and coworkers in 1955 and naturally occurring cytokinin, zeatin first isolated by Letham after 9 years of isolation of kinetin. They promote cell division, morphogenesis and lateral bud development. They also help to delay the senescence or aging of tissues and are responsible for mediating auxin transport throughout the plant and affect intermodal length and leaf growth. They have a highly synergistic effect with auxins and the ratios of these two groups of plant hormones affect most major growth periods during plant's lifetime.

d) Ethylene

This is the only phytohormones in gaseous form and it is produced through the Yang cycle from the breakdown of methionine. Ethylene is produced at a faster rate in rapidly growing and dividing cells. It helps for cell division, morphogenesis, stomatal opening, delay of senescence and fruit ripening. It affects cell growth and cell shape, when a growing shoot hits an obstacle while underground, ethylene production greatly increases preventing cell elongation and causing the stem to swell. When stems of trees are subjected to wind, causing lateral stress, greater ethylene production occurs resulting in thicker more sturdy tree trunks and branches.

e) Abscisic acid

It is discovered by Bennet-Clark and coworkers in 1952. The name 'abscisic acid' was given because it was found in high concentrations in newly abscissed or freshly fallen leaves. It is the general growth inhibitor, that affects bud growth, seed and bud dormancy. It accumulates within seeds during fruit maturation and prevents seed germination within the fruit. It also helps in stomatal closure and opening. It responds the stress conditions and so, also called stress hormone.

3.PHYTOHORMONES IN SOIL

The current trends in agriculture which focuses on the reduction of chemical pesticides and inorganic fertilizers and the search for alternatives that sustain the agricultural inputs and environmental quality. An important means of this is through the use of microbial inoculants that have a bearing on soil health and plant growth promotion. The bacteria that have a beneficial effect on plant growth and development are referred as plant growth promoting bacteria. Such strains usually stimulate plant growth by nitrogen fixation, solubilization of nutrients, production of growth hormones and through biological control mechanisms. The major sources of phytohormones in soil are microbial production and root exudation. The microorganisms found in rhizosphere including actinomycetes, fungi and bacteria produce phytohormones as a secondary metabolite. The roots of plants exude many substances to soil and it also includes some phytohormones.

4.MICROBIAL PRODUCTION

A diverse group of soil microorganisms are capable of producing physiologically active substances that may have pronounced effects on plant growth and development. Microbial production of phytohormones in soil occurs through precursors. Microbial isolates from the rhizosphere of various crops have a great potential to synthesize and release secondary metabolites because of the rich supply of substrates. Barea *et al*. (1976) found that 86% of the bacterial isolates from the rhizosphere of various plants produced auxins in addition to other plant growth regulators. Rademacher (1992) tested 28 species belonging to the fungal genera *Sphaceloma* and *Elsinoe* for GA production and reported that 8 species belonging to *Sphaceloma* were capable of producing GA like substances. The microbial production of phytohormones depends on the species of organism and the strains of same species, growth stage of microorganism and culture conditions, the nutrients obtained for growth of microorganisms.

Table 1. Production of plant growth promoting substances and their activities by fungus *Discosia* sp.

Indole derivatives	Activity (µg/ml)
Indole-acetaldehyde (IAAld)	2.1±0.30
Indole acetic acid (IAA)	0.3±0.01
Indole acetamide (IAM)	0.7±0.05
Indole pyruvic acid (IPA)	7.0±0.60

(Rahi *et al*., 2009)

5.ROOT EXUDATION

The root system of higher plants is associated with rhizosphere bacteria, some of which can synthesize plant growth–promoting substances. The synthesis of growth promoting substances by rhizosphere bacteria often depends on the presence of hormone precursors in the root exudates of plants. Microorganisms produce phytohormones as a secondary metabolite from precursors exuded by plant roots. It is observed that a high concentration gradient of phytohormones existing in rhizoplane than the adjacent bulk soil away from rhizosphere. This is due to the exudation of precursors by the plant roots. Different hormones are produced from different precursors.

Table 2. Homones and their precursors

Hormones	Precursors
Auxins	Tryptophan
Gibberellins	Mevalonic acid
Cytokinin	Adenine
Ethylene	Methionine
Abscisic acid	Mevalonic acid

(Arshad & Frankenberger 1995)

Table 3. The amount of tryptophan in the exudates of tomato and radish seedlings

Plant	Mass of one seed, mg	Amount of tryptophan exuded per day	
		ng/seedlings	ng/mg seeds
Tomato cultivars:			
Karmello	3.3	5.3±0.7	1.6±0.3
Aromato	3.2	2.8±0.4	0.87±0.10
Radish cultivars:			
Saksa Nova	9.1	293±35	32.2±4.8
Teplichnyi	14.1	390±42	27.7±3.9

(Kravchenko *et al.*, 2004)

6.FACTORS AFFECTING MICROBIAL SYNTHESIS

a) Substrates & carbon source

b) Nitrogen

c) Phosphorus

d) pH

e) Aeration

f) Temperature

g) Trace elements

a) Substrates and carbon source

A variety of compounds have been identified as possible substrates or stimulators for the biosynthesis of plant growth regulators. Several compounds can act as precursors and a carbon or energy source is needed for the microbial production. Among these methionine with or without glucose is the most frequently used precursor and is considered as the most favourable substrate for microbial biosynthesis of ethylene.

b) Nitrogen

The external application of nitrogen negatively affects the microbial production of plant growth regulators. An excess of ammonium (10mM NH_4Cl) led to early growth termination of bacteria caused by glucose depletion and residual NH_4Cl accumulation. The inhibitory effect of these salts were found in proportion to their concentration in the range of 0-50mM. The negative effect of N on phytohormonal biosynthesis by microbial isolates may be related to the preference of the isolate utilizing N from the added source rather than N of the precursor.

c) Phosphorus

Low levels of phosphates favours the production of growth regulators by microorganisms. A reduction in the concentration of phosphate in growth medium without reducing any other components in medium, markedly stimulated the production. This increased production was strongly inhibited by exogenous addition of orthophosphate to a low level phosphate medium. A low level of phosphate (0.001mM) was about 200-500 times as effective as a high phosphate level (100mM) in stimulating the production and stimulation was readly reversed by addition of phosphate.

d) pH

A wide pH buffer range has often been employed in phytohormonal production by microorganisms. A change of medium pH from 6-12 had a negative effect, whereas a change from 6-1 had a positive effect. Optimum pH level is needed for the microbial production of phytohormones and the optimum pH level differs for different organisms, nature of substrates and incubation conditions. A change from 6 to 12 to 1 resulted in an outburst of ethylene by an extracellular preparation from *Mucor heimalis* (Lynch, 1974).

e) Aeration

Aeration is one of the critical factors that affects microbial production of plant growth regulators. Generally aerobic conditions are considerably more favourable for production of plant growth regulators by microbial cultures and also restricted oxygen supply is more conducive for microbial production in soil. Hahm et al. (1992) studied the effect of dissolved oxygen tensions on ethylene production by *Pseudomonas syringae* pv *phaseolicola* in continuous culture and reported that a high level of dissolved oxygen ($\geq$4.5 mg L^{-1}) was required for efficient production of ethylene.

f) Temperature

Since temperature affects microbial growth, respiration and enzymatic reactions, it is very likely that phytohormonal biosynthesis by microbial isolates may be affected by temperature. A temperature of 30°C is optimum for hormonal production by bacteria, whereas maximum growth was observed at 37°C and decreased production was observed when temperature is reduced below 25°C. It is found that ethylene production by *Pseudomonas syringae* pv *phaseolicola* at 30°C was 1.5 times greater than that at 18°C. Increasing temperature from 0 °C to 25 °C increased the production and beyond this temperature the rate of production of phytohormones decreased. However, with living cells the optimum temperature was 30 °C.

Table 4. Plant growth promotion attributes of *Exiguobacterium acetylicum* influenced by temperature

Temperature of incubation (°C)	IAA production (μg/ml/day)	P solubilization (μg of P/ml/day)
4	10.4±0.04	1.5±0.01
15	14.9±0.06	21.1±1.18
30	17.1±0.02	22.6±2.16

(Selvakumar *et al.*, 2010)

g) Trace elements

Trace elements are known to influence the growth and activity of microorganisms. Cu^{2+} (20 mg L^{-1}) Mn^{2+} (200 mg L^{-1}) had negative effects on microbial production but, the production can be stimulated by the addition of Fe^{3+} (200mg L^{-1}) even greater stimulation was found with Fe^{2+} (200 mg L^{-1}).

Table 5. Effects of metals on ethylene formation by *Penicillium digitatum*

Metal (0.1 mM)	Ethylene production rate (nl/mg protein)
Control	0.26
$FeSO_4 .7H_2O$	5.21
$MgSO_4 .7H_2O$	0.17
$CuSO_4 .5H_2O$	0.15
$Al_2(SO_4)_3$	0.51
$CoSO_4 .7H_2O$	0
$NiSO_4 .6H_2O$	0
$ZnSO_4 .7H_2O$	0

(Fukada *et al.*, 1986)

Phytohormones in soil affects nodulation in many plants, solubilization of inorganic phosphates, minerals and nutrient uptake by plants. A root nodule is a unique and highly organized structure that develops as a result of the symbiotic relationship between a microsymbiont and plants (e.g., legumes). This symbiosis is essential for the supply of atmospheric nitrogen to plants fixed by the rhizobia. Auxins secreted by the microsymbiont, Rhizobium, may be a regulator in the development of nitrogen fixing nodules. The first visible phase of nodulation is the characteristic root hair curling and one of the substance causing the deformation of root hairs is IAA produced by both plant itself and the bacterium. The nodules of legumes contain substantially higher amount of Gas than the roots. Root nodules of three leguminous trees, *Erythrina indica, Sesbania grandiflora* and *Pterocarpus santalinus* had higher level of phytohormones than the roots. However the exogenous application of ethylene and GA had a negative effect on the formation and function of nodules. In the presence of ethylene, the number of infected root hairs did not change, but many infection threads were aborted, and the epidermis or outer cortex and nodule primordia did not form.

Cytokinin play a critical role in root nodule development and functioning. Higher cytokinin activity was observed in nodules than in roots, microsymbiont has an ability to release cytokinin in culture media and the formation of pseudonodules or induction of early nodule formation can be seen in response to externally applied cytokinins. Abscisic acid (ABA) also plays a regulatory role in nodule formation and it's levels in nodules are usually much greater than the contents in roots. The ABA concentrations appeared to increase at the onset of nodule senescence and there is a negative relation observed in between nitrogenase activity and ABA levels in nodules.

Table 6. Phosphate solubilization after 5 days of incubation with fungus *Discosia* sp. from tea rhizosphere due to the production of auxin like substances

Phosphate source	Phosphate solubilization over control (%)
Tricalcium phosphate	62.8
Aluminium phosphate	1.2
Iron phosphate	1.3
Mussoorie rock phosphate	0.7
Udaipur rock phosphate	2.2
North Carolina rock phosphate	40.9

(Rahi *et al.*, 2009)

7.CONCLUSION

Many soil microorganisms (e.g., *Rhizobium, Azotobacter, Azospirillum, Pseudomonas*, mycorrhizal fungi and others) that significantly affect the plant growth are also capable of producing the major phytohormones. Microbially released phytohormones are not only economical, but also provide a continuous supply, which may be better than a one time application of synthetic hormones. High concentration of hormones are inhibitory to root growth, hence a continuous release of hormones at low concentrations as a result of microbial activity in the rhizosphere may be more beneficial. Lack of suitable extraction methods limits the study of phytohormones in soil, have to give attention to the precursor-inoculum interactions and screening of suitable precursors and also for the interaction with other phytohormones.

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9.DISCUSSION

1. **What is jasmonates? Explain it's function.**

They are also the plant growth regulators identified very recently. They are produced from fatty acids and seems to promote the production of defence protiens that are used to fend off invading organisms. They are believed to also have a role in seed germination, and affect the storage of protein in seeds, and seem to affect root growth.

2. **How these indole acetic acid (IAA) estimate?**

The estimation of IAA production was carried out at three different incubation temperatures 4, 15 and 30^{0}C. Estimation of IAA was done by inoculation of 200µl of bacterial suspension (3×10^{7} cells ml^{-1}) in 10 ml Luria Bertani (LB) broth amended with L-tryptophan (100 µl ml^{-1}), and incubating it for a period of 48h. The IAA content in the culture suspension was estimated by the standard colorimetric procedure.

10.ABSTRACT

The portion of soil adjacent to the root system of plants which is influenced by the root system is called rhizosphere. It is found that the roots of higher plants exerts greater influence on some group of organisms and this is due to the root exudates of these plants. Many microbial interactions were taking place in rhizosphere and the microbes produce secondary metabolites including phytohormones. They are organic substances that influence physiological processes of plants at very low concentrations. They produced endogenously by plants and move from the site of production to the site of action. They are the coordinators of plant growth and morphogenesis. There are five major phytohormones like auxins, gibberellins, cytokinin, ethylene and abscisic acid which performs different functions in plants.

In soil, microbial production and root exudation are the main sources of plant growth regulators. Microorganisms produce phytohormones as a secondary metabolite (Rahi *et al.*, 2009). Selvakumar, *et al.* (2010) reported that *Exiguobacterium acetylicum* a cold tolerant bacterial strain from Uttarakhand expressed phosphate solubilization and Indole acetic acid (IAA) production differently at suboptimal growth temperatures. The microbial synthesis is more in the rhizosphere because of the root exudation of precursors. The phytohormonal action of the rhizosphere microflora was found to be efficient when the concentration of tryptophan in rhizosphere was sufficiently high. Aseptic tomato and radish roots were found to exude 4.05 and 340 ng tryptophan per seedling per day respectively (Kravchenko, *et al.*, 2004).

Soil factors affecting microbial synthesis includes substrate and carbon sources, nitrogen, phosphorus, pH, aeration, temperature and trace elements. Phytohormones influences nodulation, phosphorus solubilization, mineral uptake and nutrient contents in plant produce. Inoculation with effective bacterial strains increased root and shoot growth and nodulation in peas and it is found that the bacterial strain produced IAA which is accounted for overall synergestic effect on growth of peas (Egamberdieva, 2008).

Phytohormones in soil are supplementary to endogenous production and a scontinuous low level supply will be there which is more effective than single exogenous application. Moreover the studies have to be undertaken for suitable

extraction methods, inoculum-precursor interactions and screening of suitable precursors for further improvement of phytohormonal conditions in soil.

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Further reading

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DEPARTMENT OF PLANT PHYSIOLOGY

THE ENIGMA OF PLANT DEATH

BY

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SEMINAR REPORT

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PP 591- Masters Seminar(0+1)

MSc. Plant Physiology

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1. INTRODUCTION

Plant kingdom is vast and diverse. The range of longevity that exist is also vast. There are certain desert annuals which live only for few days while certain other giant trees like bristle cone pines lives upto or more than 4500 years. During the course of their lives, all multicellular organisms and their organs and tissues reach a peak in terms of their physiological function and then they decline until they die. The death of whole plant occur commonly occur upon completion of fruiting. The different life-history strategies of plants are better described by the terms monocarpy and polycarpy.

2. POLYCARPIC *VERSUS* MONOCARPIC LIFE HISTORIES

There are two extremes of life-history strategies in plants polycarpy and monocarpy. Polycarpic plants are those which have more than one reproductive phase before death, while monocarpic plants have only one reproductive phase before death. According to Woolhouse (1983),monocarpy has polyphilatically evolved from polycarpy through natural selection and hybridization. Monocarpic plants are also known as semelparous species. They devote most of their energy and resources to maximizing the number of offspring in a single cycle of reproduction, and die soon after reproducing. Semelparity may be advantageous when the prospects for long-term survival are low. Annuals and biennials are examples of monocarpic life forms. Polycarpic plants,also known as iteroparous species is advantageous for long-term survival. Most of the perennial plants belongs to this group.

3. PLANT DEATH

When we think about death in living things we automatically think about death in human beings, which typically follows a period of progressive aging. But in the case of annual plants, whole populations of annual plants will die en masse at a set time of year, within the span of a few days, before bad weather has hit. Two broad questions will arise : Why annual plants kill themselves and how they do so.

The question of why annual plants kill themselves can be split into two parts:

1. **Long run advantages**

- To ensure greater population growth
- To leave space and fertilize the soil

2. **Short run advantages**

- To generate large number of seeds for survival
- To route the nutrients from the adult plants to the seeds
- To avoid abiotic stress

For the question how plants die, the reasons of death can be ageing, biotic stress or abiotic stress

4. AGING *VS* SENESCENCE

Ageing refers to the process of attaining maturity with the passage of time. Ageing includes much wider span of physiological changes, some of which may leads to the weakening of organism while others may be quite neutral with respect to capability of the biological organism to survive. Ageing is a continuous developmental process from embryogenesis to death.

The later part of the developmental process that starts after reaching the reproductive maturity and leads to loss of organization and function is termed as senescence. The word senescence comes from the *Latin* word Senescere meaning 'to grow old'. It was first used by Minot in 1879 for animals and for plants by Child in 1915. Senescence is defined as the deteriorative processes that are the natural causes of death (Leopold, 1961). Woolhouse (1984), described Senescence as a normal energy dependent developmental process that is controlled by the plant's own genetic programmes initiated by environmental cues.

4.1. Types of senescence

There are four morphological patterns of senescence in plants, viz. ,

1. Over all senescence:
   - Senescence occurs in whole plant body
   - Plants senesces to death after flowering and fruit setting.

   Example: annuals, biennials

2. Top senescence
   - Above ground parts dies with the end of growth season
   - Under ground parts live for several years

   Example: Perennial weeds – *Cyperus rotundus*

   Bulbs – Lilly

3. Deciduous senescence

   The leaf falls in particular seasons ,while in all other season the plants remain green.

   Example : Deciduous trees – Rubber

4. Progressive senescence

   Senescence occurs in older organ and or tissues while new organs and tissues developes simultaneously

   Example: green trees

4.2. Mechanism of senescence

Senescence is the last phase of development of a whole organism, organ, cell, or organelle. It is basically a well organized degenerative process that leads to the death of the living system. There appear to be three ways plants can senesce.

A) They die simply because of aging; that is, accumulated entropy causes increased sensitivity to environmental stress, bringing on death.

B) Simple nutrient withdrawal by the seeds from the leaves eventually brings on starvation or some other nutrient deficiency, causing death . That is, the seeds take what nutrients they need by diffusion from the adjacent cells and this sets up a source sink diffusion gradient where the nutrients pass from the leaves to the seeds, with no active breakdown of the leaves.

C) A hormonal or other kind of signal is released by the developing flower or seed, or the photo-induced leaves. This causes the plant to begin degrading itself and transporting the resulting nutrients out of the cells into the developing seed.

Senescence is a two-step process. It consists of a functional senescence and a final senescence. Functional senescence refers to the decline in photosynthesis, whereas final senescence will refer to actual leaf and cell death.

4.3. Functional senescence

Functional senescence involves the invisible changes that marks the beginning of senescence. It involves the reduction in photosynthesis due to the break down of Rubisco and the export of resulting amino acids to the developing seeds. Rubisco, the most abundant protein on earth contributes up to 50 per cent of the soluble proteins and up to 30 per cent of total leaf nitrogen (Feller *et al.*, 2008).

4.4. Final senescence

A number of cell physiological changes (listed below) are known to occur in all types of plants during final senescence. The cell biological changes during final senescence are:

- Large decreases in chlorophyll.
- A large decline in proteins and DNA.
- A large increase in the activities of hydrolytic enzymes- lipases, DNases, RNases, proteases and chlorophyllases .
- A drop in the level of polyamines, Spermine and Spermidine in the cells.
- A large increase in respiration.

Mitochondria remains intact and functioning until late stages of senescence. The most important of these characteristics is the rise in hydrolytic enzyme activity. This rise causes the decline in protein, chlorophyll and DNA. Protein and DNA are two of the most important elements of cell function. Their disappearance is probably the most direct antecedent of death.

5. CHLOROPHYLL METABOLISM DURING SENESCENCE

Leaf senescence causes a loss of all types of photosynthetic pigments. However, depending on the plant system and environmental conditions, differential rates of loss of chlorophyll a, chlorophyll b, and carotenoids have been demonstrated. Leaf senescence is characterized by a massive loss of green pigments, a process referred to as degreening. The degreening process of mature leaves that occurs in nature or induced by darkness is accompanied by the disorganization of various cellular and sub cellular structures.

The biosynthetic pathway of chlorophyll has been studied in considerable detail. Chlorophyll is metabolized to non fluorescent chlorophyll catabolites (NCCs). The pathway of chlorophyll degradation comprises atleast six reactions , whereby the first four are responsible for the conversion of chlorophyll to a primary colourless catabolite primary fluorescent Chi catabolite (pFCC).

Chlorophyll is first dephytylated to chlide by the action of chlorophyllase and subsequently the central Mg atom is removed by Mg dechelatase.the product of the reaction .Pheide is the last coloured intermediary catabolite of the pathway. Its porphyrin macrocycle is oxygenolytically opened in two- step reaction with a red catabolite (RCC) as an intermediate. the product. pFCC. is a fluorescent linear tetrapyrrole. This key step in chlorophyll break down is catalysed by the joint action of Pehide-a-oxygenase (PaO)and RCC reductase and it formally occurs by the addition to Pheide a of two atoms of oxygen and four atoms of hydrogen. The structures of the final products of chlorophyll breakdown, NCC, from different plants species suggest that two further common reactions take place, namely hydroxylation and non-enzymic tautomerization of the fluorescent to non- fluorescent catabolites.

6. IMPACT OF SENESCENCE ON PLASTIDS

The lamellar structure of chloroplasts varies between phototsynthetic organisms. The electron microscopic studies reveal the following basic features of a typical higher plant chloroplast. The organelle is lens shaped and the lamellar system is encircled by a double membrane envelope. The envelope acts as selective barrier to the transport of various mtabolites into and out of chloroplasts. The lamellar system of the organelle is bascally composed of protein disks that are stacked at regular intervals to form structures known as grana. The unstacked loose lamellaer, which connect stacked grana zones, are intergranal or stroma lamellae. The entire lamellar system is suspended in a granular stroma that is mainly composed of plastid genetic materials, ribosomes and starch grains. The proteins present in the stroma are mostly the enzymes of the Calvin cycle. The other components of the stroma are plastogobuli, which is darkly strained structure consisting of lipids.

The grana and stroma lamellae are the structural units of primary photochemical reactions and contain the photosynthetic pigments in addition to lipids and proteins. The lipids of the thylakoid membrane consist of galactolipids, phospholipids, and sulpholipids.

During senescence, the organelle shows disorganization at the level of both the envelope and lamellar structures. Ultra structural degradation consists of three major events: Thylakoid break downs, formation of plastoglobuli and rupture of envelope. Lamellar break down exhibits unstacking of grana thylakoids. This is followed by the formation of loose, elongated lamellae scattered in the organelle. In the next phase these lamellae undergo further degradation with the concomitant appearance of plastoglobuli. The size of the globuli increases as senescence advances. The final membrane disruption is caused by the vacuolar proteases. Vacuoles follow an autophagic pathway leading to true cell death.

7. SENESCENCE ASSOCIATED GENES

Senescence represents the sequence of metabolic events occurring in the final stage of development and ultimately culminating in the death of the whole plant, organ, tissue or cells. It is an actively ordered process that involves the synthesis of new RNAs and protein and results in highly coordinated changes in metabolism and the programmed disassembly of cells. In recent years molecular biological approaches have been utilized to identify genes that may be involved in the initiation and regulation of senescence programme. The identification and characterization of these senescence related genes has begun to provide us with an understanding of the process of senescence.

7.1. Function of senescence associated genes in senescence

The function of the senescence associated genes falls into four categories:

1) Those involved in degradative processes including genes encoding proteases, nucleases, lipid and carbohydrate metabolizing enzymes and those involved in nutrient mobilization
2) Those that code protective or stress response proteins, many of which have previously been identified as pathogen-responsive
3) Those that code for the enzymes involved in the ethylene biosynthesis and perception.
4) Those whose identity has been determined based on homology but for which no known function in senescence is obvious.

1. **Genes involved in protein degradation**

Decrease in total proteins during senescence results from increases in proteolytic enzyme activity and decreases in protein synthesis (Brady,1988) the degradation of proteins and remobilization of amino acids to the developing tissue is the predominant metabolic process during senescence. Cysteine proteases are believed to be the main proteases involved in general protein hydrolysis, and recently a number of Cysteine proteases have been identified from senescing leaves, senescing flowers and ripening fruits (Table.1).

2. **Genes involved in the break down of nucleic acids.**

While levels of total DNA remain relatively constant, total RNA ahs been shown to decreasre in senescing tissue (Bardy, 1988). This RNA is an important source of C, N, and P, which is recycled to metabolically active tissue during cell death and when P is limiting. This is accomplished through the activity of ribonuclease. This activity has been shown to increase substantially during senescence. In *Arabidopsis*, three RNase genes were identified *RNS1, RNS2, RNS3* (Taylor and Green, 1991).

3. Genes involved in membrane disassembly

The disruption of membrane integrity is the major degradative process during senescence. A characteristic of membrane deterioration in leaves and petals is a decrease in phospholipids and an enrichment in fatty acids. Recently a gene encoding phospholipase D, the enzyme that catalyzes the first step in the membrane lipid degradation pathway, has been shown to be up regulated during dark-induced senescence of excised castor bean leaves(Ryu and Wang,1995).

4. Gene s involved in remobilization of nitrogen

Following the degradation of macro molecules, nitrogen must be exported from senescing organs to metabolically active organs. The deamination of amino acids and catabolism of nucleic acids during senescence releases ammonia, which is exported via the phloem in the form of the amino acids glutamine or asparagines. The conversion of ammonia to glutamine or asparagines is catalyzed by the enzymes glutamine synthase (GS) or asparagines synthase (AS) respectively. In plants there are two forms of GS,cytosolic (GS1) and chloroplastic (GS 2). Cytosolic GS 1 may function in the mobilization of N from proteins degraded in the cytosol of senescing organs. In support of the role of GS 1 in senescence ,GS 1 genes that are up regulated during senescence have been identified in a number of plants.

5. Genes encoding protective or defense- responsive proteins

A class of senescence associated genes appears to encode proteins with the protective or stress response function, and includes a number of genes with homology to previously identified pathogenesis-related (PR) genes. These defense related genes may serve to protect vulnerable senescing tissues from pathogen attack until the senescence programme has been completed and to prevent pathogens from spreading to healthy parts of the plant. A number of these genes may also play a role in detoxification of the byproducts of macro molecule and organelle catabolism within the cell and many functions in maintaining cell viability until the cells components have been salvaged.

6. **Genes involved in ethylene biosynthesis and perception**

The biosynthesis and perception of the plant hormone ethylene are known to modulate specific components of leaf senescence, fruit ripening and flower senescence. Two enzymes,1-aminocyclopropane -1-carboxylate (ACC) synthase and ACC oxidase, have been identified as catalyzing the rate limiting steps in ethylene biosynthesis .

Table.1. Some identified Senescence associated genes and their functions.

Name	Plant	Identity/ homology	Function
SAG 23	Arabidopsis	Cysteine protease	Protein degradation
LX RNase	Tomato	Ribonucleas	Nucleic acid break down
Rlos1	Rose	Lipoxygenase	Lipid break down
GS1	Rice	Glutamine synthetase	Remobilization of nitrogen
PR1	B.napus	Chitinase	Defense -response
DCACS1	Carnation	ACC synthase	Ethylene biosynthesis

8. ABSCISSION

Abscission is the last step in a planned senescence process within tree leaves. Senescence is an ordered series of events which allow trees to conserve resources, prepare for a dormant period, and shed inefficient tissues. Near the end of the senescence process, designed fracture or failure lines develop at the base of tissues to be shed, like leaves. These prearranged fracture lines allow leaves to tear away without exposing the tree to additional damage. Leaf abscission is part of a process which allows the tree to seal-off tissues which will soon be killed or consumed by the environment. Abscission is referred to as the natural separation of organs from the parent plant. Specific cells in the petiole form an abscission layer allowing separation of senescent organs from the plants.

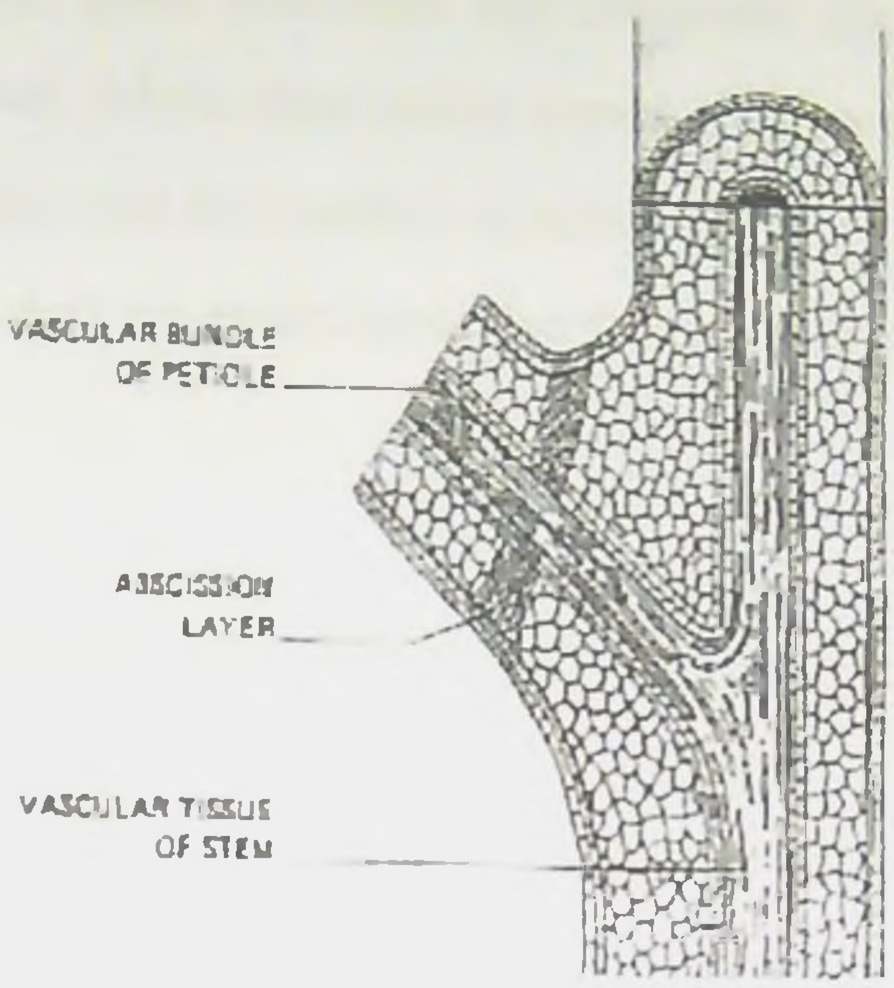

Fig.1. Abscission layer

Auxin is a primary growth regulator produced in the leaf and slowly transported toward the stem base through living cells. As long as auxin is effectively being transported across the abscission zone, abscission zone cells remain unreactive. As auxin production begins to wane in fall and auxin transport rates begin to decline due to less auxin availability, damage to living cells transporting auxin, and/or accelerating infection of living tissues by pests, cell wall changes are initiated. Cell wall changes increasingly inhibit auxin transport and accelerate ethylene production. Small amounts of ethylene hasten abscission zone development. ABA(abscisic acid), responsible (in part) for dormancy onset in the leaf, stimulates ethylene production and inhibits auxin transport.

8.1. Mechanism of abscission

Abscission Zones

Abscission zones occur at the base of leaf petioles and at the base of leaflets. Abscission zones are designed to allow leaf shedding. Leaves are shed through a number of biological actions which weaken cell walls and initiate cells tearing away from one another. Abscission zones are composed of three critical portions:

A) a cell wall degradation area;

B) a shear force generation area; and,

C) a tree protection zone.

All three abscission zone portions are required for successful leaf shedding and effective tree survival. Most abscission zones are pre-positioned to facilitate shedding. Abscission zones may not be needed or used, but they are set-up to act as an established barrier and boundary, if needed.

Wall Weakening

The abscission process begins with growth regulator signals initiating cellular changes. Abscission zone cells secrete pectinase and cellulase (wall degradation enzymes). These enzymes degrade the strength of the middle lamella and primary wall between cells. The middle lamella, the .glue. which holds cells together, begins to dissolve in the abscision zone.

At the same time, surrounding primary walls begin to swell from changes in chemical components. Calcium bridges across cell wall materials are removed. All cell wall changes are caused by enzymes and other materials deposited in the cell walls produced by surrounding living cells. The cells in the abscission zone are dense with cytoplasm and organelles. Each cell is actively respiring and using energy to produce abscission materials. These cells remain alive and active until abscission.

MoreWall Changes

As cell wall interconnections are weakened, water pressure within thin walled cells (turgor pressure in parenchyma) cause these cells to expand. As cells expand, they generate shear forces by pushing and pulling on surrounding weakened walls. Mechanically, fracture lines begin to develop between cell walls. In addition to internal forces, gravity and wind tugging on leaves help fracture lines grow. As cell walls pull apart from one another, this open wound is being closed by deposition of blocking materials and protective compounds. Astrong protective boundary zone is prepared to defend remaining tree tissues from the environment and pests. Tyloses, suberin, lignin and other protective boundary-setting materials are developed and deposited on the tree side of the abscission zone.

In The Zone

Abscission zones in trees can be between 5-40 cells wide. Within this abscission zone only 1-3 cells will disconnect from each other. Cells in the abscission zone are of the same types as found elsewhere in the tree.

Abscission zone cells tend to be smaller, more densely packed, with no intercellular spaces, less lignin, and have remained in a cell division phase longer than surrounding cells. Additional cell divisions in this zone prepares these cells for later abscission processes. Starch is stored in the abscission zone cells to assist in generating turgor pressure and enzymes for wall degradation. In most abscission zones there is a single fault line which develops and is accentuated by additional wall degradations. Cells adjacent to fault line cells will have weakened walls also, allowing any fractures to propagate along several paths for short distances. Rarely, several full fault lines occur leaving the abscission wound ragged-looking. Fault lines follow the path of the middle lamella between cells.

Passive & Active

In the abscission zone, xylem elements and epidermis cell walls are either not degraded or are slow to be weaken. These cells usually must be torn, stretched, or broken physically after connections between surrounding cells have been already fractured. Many types of gravity, wind, precipitation and animal actions can break any remaining connected tissue to allow leaf fall. The abscission process does require respiration and turgor pressure control. Breakdown of select carbohydrates, loss of small but key carbohydrate and protein wall components, increase of pectinase and cellulase enzymes, and removal of calcium bridges lead to wall weakening. As cells walls weaken, parenchyma cells osmotically expand, generating tremendous shear pressure on surrounding cell wall connections. Water is needed to generate shear force.

9. THE CONCEPT OF PROGRAMMED CELL DEATH

Programmed cell death (PCD) is the active process of cell death which occurs during development and in response to environmental cues. In plants, PCD is essential for development and survival-for example, xylem vessels are dead at maturity, the cells that are elements of the water, and nutrient conducting system live to make strong walls. Plants also employ PCD in response to pathogens. Programmed cell eath (PCD) is a physiological cell death process involved in the selective elimination f unwanted cells (Ellis et al., 1991). The cells of multicellular organisms are iembers of highly organized community. Controlling the rate of cell division and of ell death strictly regulates the number of cells in this community. If cells are no more eeded, they die by activating intracellular death program, for this reason this process amed as programmed cell death (PCD).

Three major types of programmed cell death, based mainly on morphological hanges, are recognised so far: apoptosis, autophagy and nonlysosomal cell death van Doorn and Woltering, 2005).

.1. Apoptosis

Apoptosis is characterised by a specific set of cellular morphological features uch as plasma membrane blebbing, disintegration of cytoskeletal elements, ondensation of the nucleus and the cytoplasm, internucleosomal cleavage of DNA nd membrane confined, DNA containing vesicles (apoptotic bodies). A istinguishing feature of apoptosis is that fragments of the dying cell are engulfed and igested by the lysosomes of neighbouring (living) cells (e.g. phagocytes). This latter rocess has, so far, not been observed in any plant system, which indicates that true poptosis does not occur in plants.

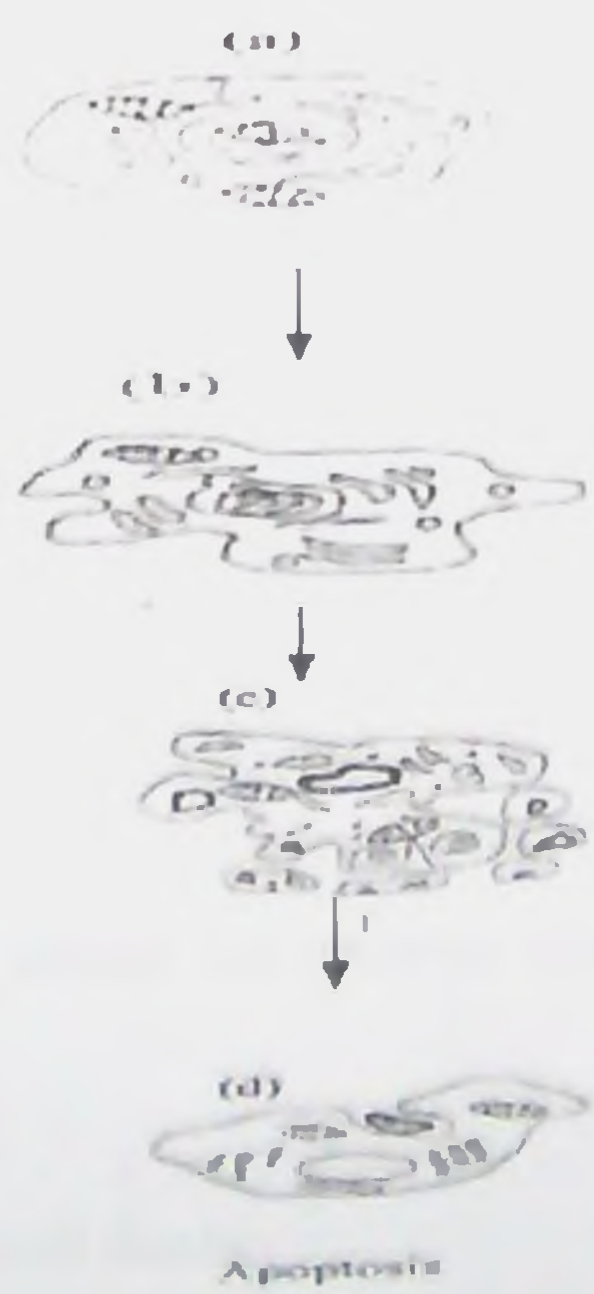

Fig.2. Schematic diagram of apoptosis

9.2. Autophagy

Autophagy (self-eating) is a major degradation and recycling system in eukaryotic cells. It is featured by degradation of cellular components by formation of autophagolysosome (Yoshimori, 2004). Autophagy is associated with cell survival as well as cell death and it may be a strategy to remobilise part of the cell contents prior to cell death. Autophagy was found to play a role in plant immune response, especially in preventing of death and pathogen spread in cells adjacent to HR lesion (Greenberg, 2005). Developmental PCD (which is associated with the normal developmental processes) is involved in degeneration of specific cells and most of the examples of developmental PCD in plants conform to the definition of autophagic PCD.

9.2.1 PCD in the Somatic embryos of Norway spruce –an autophagic PCD

The key morphogenetic event in plant embryogenesis is formation of the apical-basal pattern via establishment of the proliferating embryo proper or embryonal mass (apical) and the terminally differentiated suspensor (basal). While the embryonal mass gives rise to the plant, the suspensor functions during a brief period as a conduit of growth factors to the developing embryo and is subsequently eliminated by PCD. The terminal differentiation of the embryo-suspensor is the earliest manifestation of PCD in plant life. In spruce, the suspensor is composed of several layers of terminally differentiated cells, originating from asymmetric cell divisions in the embryonal mass. Suspensor cells do not divide but instead become committed to PCD as soon as they are produced. While the cells in the upper layer of the suspensor (i.e. adjacent to the embryonal mass) are in the commitment phase of PCD, the cells in the lower layers exhibit a gradient of successive stages of autophagic dismantling towards the basal end of the suspensor where hollow walled cell corpses are located. Thus, successive cell-death processes can be observed simultaneously in a single embryo. Moreover the position of the cell within the embryo can be used as a marker of the stage of cell death.

9.3. Nonlysosomal cell death

The third morphological type of PCD is called non-lysosomal (or necrosis-like) PCD. It does not involve a role of the lysosome of the dying cell itself nor of other cells. It is associated with swelling of organelles and formation of "empty spaces" in the cytoplasm. Although not much detailed information is available on cell morphology during the plant HR, mostly this seems to conform to this nonlysosomal type of PCD (van Doorn and Woltering, 2005). Involve synthesis of new proteins and/or activation of specific metabolic pathways. Rapid PCD process are activated to inhibit the spread of invading pathogen in the hypersensitivity reaction (HR).

10. NECROSIS

When cells die as a result of injury, typically swell and burst and they spill their content all over the neighboring cells(Unsal *et al.*, 2005).Occurs in response to pathogen infection. It is a destructive process and lead to inflammation.

Table 2 : Pathological features of apoptosis and necrosis.

	Apoptosis	Necrosis
Pattern of death	Single cells	Group of neighbouring cells
Cell size	Shrinkage	
	Fragmentation	Swelling
	Preserved continuity	
Plasma membrane	Blebbed	Smoothing
	Phosphatidylserine on surface	Early lysis
	Increased membrane permeability	
Mitochondria	Contents released into cytoplasm	Swelling, Disordered structure
	Cytochrome c, Apaf1	
	Structure relatively preserved	
	Contracted	Swelling
Organelle Shape	"Apoptotic bodies"	Disruption
	Chromatin:	
Nuclei	Clumps and Fragmented	Membrane disruption
	Fragmented	
	Internucleosomal cleavage	
DNA Degradation	Free 3' ends	Diffuse and Random
	Laddering on electrophoresis	
	DNA appears in cytoplasm	
Cell Degradation	Phagocytosis	Inflammation
	No inflammation	Macrophage invasion

11. CONCLUSION

Senescence and programmed cell death plays a very important role in the life cycle of leaving organisms. Senescence is a natural degradative process that leads to deathof the plants. But it is not a complete devastation process. It involves the reutilization of nutrients by the developing plant part for the maintenance of next spaces" in the cytoplasm. Although not much detailed information is available on cell morphology during the plant HR, mostly this seems to conform to this nonlysosomal type of PCD (van Doorn and Woltering, 2005). Involve synthesis of new proteins and/or activation of specific metabolic pathways. Rapid PCD process are activated to inhibit the spread of invading pathogen in the hypersensitivity reaction (HR).

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11. CONCLUSION

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12. DISCUSSION

1) **Why annuals die after a short period while perennials leave long?**

   Perennials have the capacity to retain the shoot apical meristems after each of its growth season but the annuals do not have the capacity to do so.

2) **What is the role of genes encoding protective proteins?**

   During the senescence the plant parts become weak and more susceptible to pest and diseases. Since senescence also involves the effective mobilization of nutrients these proteins are needed to protect the plant.

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14. ABSTRACT

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Department of Plant Physiology
PP 591 Masters Seminar

Name of the student: Naeema Naushad Ali
Admission no : 2010-11-129

Venue: Seminar Hall
Date: 1.4.2011
Time:11.30 am

THE ENIGMA OF PLANT DEATH

ABSTRACT

One of the most puzzling events in a living system is its death. Plants and their parts develop continuously from germination to death. Among angiosperms, life span is highly variable. It ranges from desert annuals which live for only one week to red wood tress and bristle cone pines which live for about 3000- 4500 years.

The different life strategies of plants can be described by the terms monocarpy or semilparity and polycarpy or iteroparity (Amasino, 2009). Polycarpic species reproduce repeatedly and live long (eg. perennials) while monocarpic species reproduce once and die (eg. annuals). This suicidal death of plants can be explained as a way of increasing the number of progeny surviving to reproductive age and a way of increasing the rate of evolution.

Ageing is one of the most important factor that leads to death. The complete loss of organization and function during the latter part of ageing is termed as senescence. Leopold (1961) defined senescence as the deteriorative processes that are the natural cause of death. Morphologically plant senescence can be classified as over all senescence, top senescence, deciduous senescence and progressive senescence.

Senescence is a two step process consisting of functional senescence and final senescence. During functional senescence, rubisco constituting 50 per cent of the soluble leaf protein and 30 per cent of leaf nitrogen (Feller *et al.*, 2008) is degraded by hydrolytic enzymes and utilized by the developing plant parts *viz.*, reproductive organs. In the second step, i.e. final senescence, there is a general cellular degradation of the whole plant. This involves degradation of chloroplast and other organelles.

Programmed cell death (PCD) is the active process of cell death which occurs during development and in response to environmental cues. If cells are no more [illegible] intracellular death programme, for this reason this

process is named as programmed cell death (PCD) (Palavan-Unsal *et al.*, 2005). PCD include apoptosis, autophagy and non-lysosomal cell death. Apoptosis is not observed in plants while autophagy operates in the developmental processes and plant immune responses that prevent the spread of diseases. Non-lysosomal cell death is involved in the death of cells due to pathogen attack.

Death is the inevitable end of the process of senescence. Plant death is the process of recycling of nutrients and materials among generations. Plants live for the great purpose of sustaining the universe and they die for the same.

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DEPARTMENT OF HOME SCIENCE

RESISTANT STARCH IN FOODS: NUTRITIONAL IMPLICATIONS

By
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2010-24-101
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Seminar Report submitted in partial fulfillment of the requirement for the course

Hmsc.691- Doctoral seminar

College of Horticulture
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RESISTANT STARCH IN FOODS: NUTRITIONAL IMPLICATIONS

INTRODUCTION

Starch, the major dietary source of carbohydrates, is the most abundant storage polysaccharide in plants, and occurs as granules in the chloroplast of green leaves and the amyloplast of seeds, pulses, and tubers. Starch provides an economical means of storing carbohydrate in an insoluble and tightly packed manner.

Food starches may be either glycemic or resistant. Glycemic starches are those that are degraded to glucose by enzymes in the digestive tract. Resistant starch refers to the portion of starch and starch products that resist digestion as they pass through the gastrointestinal tract. Resistant starches show potential health benefits and show promising physiological benefits in humans. The greater awareness on the part of consumers, of the relationship between a nutritious diet and health and well-being has been one of the reasons for the increase in popularity of novel foods with good nutritional properties.

CLASSIFICATION OF STARCH

Chemically, starches are polysaccharides, *i.e.* they are composed of a number of monosaccharides or sugar (glucose) molecules linked together with α-(1–4) and/or α-(1–6) linkages. Two main structural types of starch exist: amylose and amylopectin. Amylose is a linear α-(1–4) molecule and typically constitutes 15–20 per cent of starch. It has a molecular mass of 105 to 106 g/mol. The chains can easily form single or double helices. Amylopectin (107 to 109 g/mol) which is a larger branched molecule with α-(1-4) and α- (1-6) linkages and is a major component of starch. Its structure is often described by a cluster model.

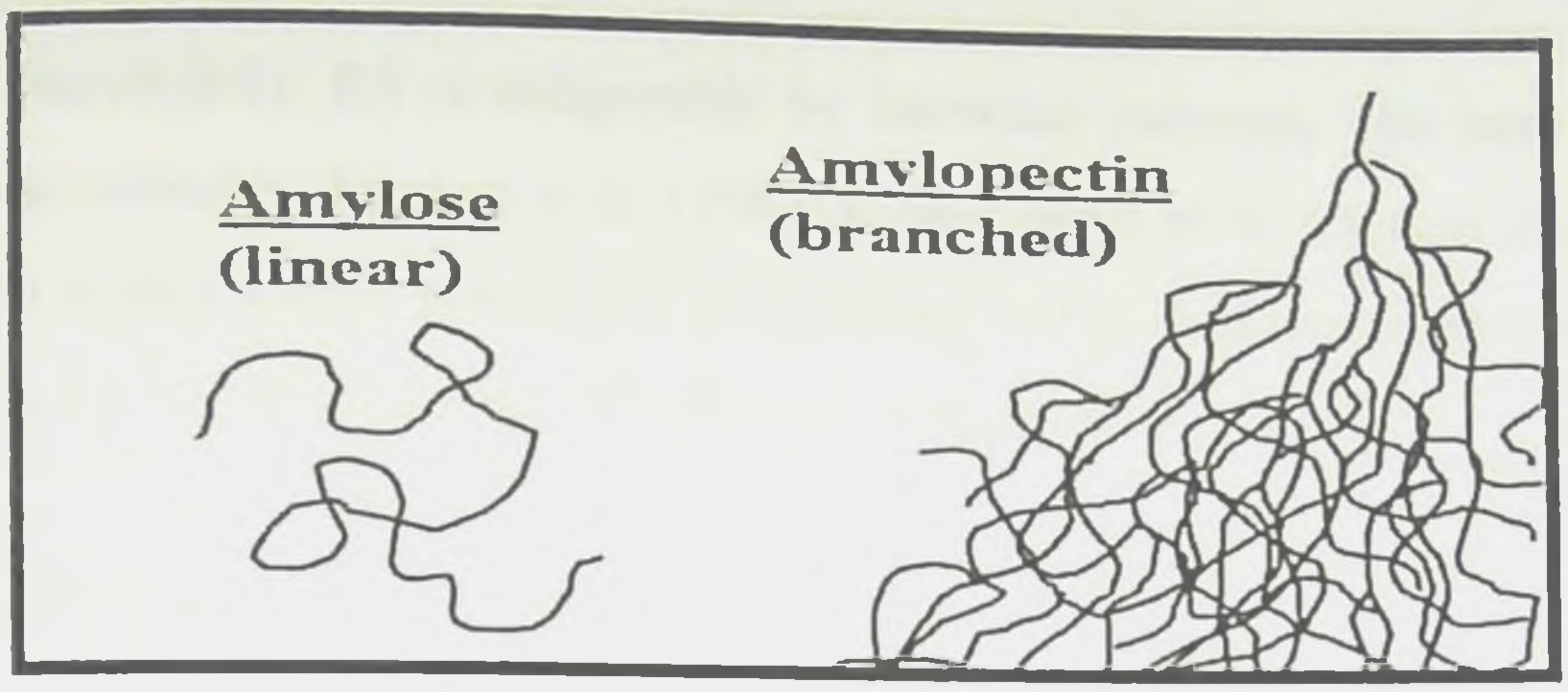


Figure No.1 Structural components of starch

On the basis of X-ray diffraction experiments, starch granules are said to have a semicrystalline character, which indicates a high degree of orientation of the glucan molecules. About 70 per cent of the mass of starch granule is regarded as amorphous and about 30 per cent as crystalline. The amorphous regions contain the main amount of amylose but also a considerable part of the amylopectin. The crystalline region consists primarily of the amylopectin.

TYPES OF STARCH IN FOODS

Classification based on the extent of digestibility of the starch as follows.

a. Digestible starches: These include the starches digestible by body enzymes, namely the rapidly digestible starches (RDS) and the slowly digestible starches (SDS). RDS consists mainly of amorphous and dispersed starch and is found in high amounts in starchy foods cooked by moist heat, such as bread and potatoes. It is measured chemically as the starch, which is converted to the constituent glucose molecules in 20 minutes of enzyme digestion. Like RDS, SDS is expected to be completely digested in the small intestine, but for 1 reason or another, it is digested more slowly. It is measured chemically as starch converted to glucose after a further 100 minutes of enzyme digestion.

b. Resistant starch(RS): RS is indigestible by intestinal enzymes. The term "resistant starch" was first coined by Englyst *et al.* (1982) to describe a small fraction of starch that was resistant to hydrolysis by exhaustive α - amylase and pullulanase treatment *in vitro*. RS is the starch not hydrolyzed after 120 minutes of incubation.

WHAT IS RESISTANT STARCH?

In 1982, while developing an *in vitro* assay for non-starch polysaccharides, Englyst and co-workers found that some starch remained after enzymic hydrolysis. Follow-up studies with healthy ileostomy subjects confirmed the presence of similar starches, which resisted digestion in the stomach and small intestine. Further analysis revealed that these starches could be fermented in the large intestine *in vivo*. The term 'resistant starch' (RS) was coined and used to describe these starches (Englyst *et al.*, 1982). RS that reaches the large intestine can act as a substrate for microbial fermentation, the end-products being hydrogen, carbon dioxide, methane and short chain fatty acids (SCFA).

"Resistant starch has been defined as the fraction of starch, which resists digestion in the small intestine of healthy individuals and is available for fermentation in the large intestine" (Englyst *et al.*, 1992).

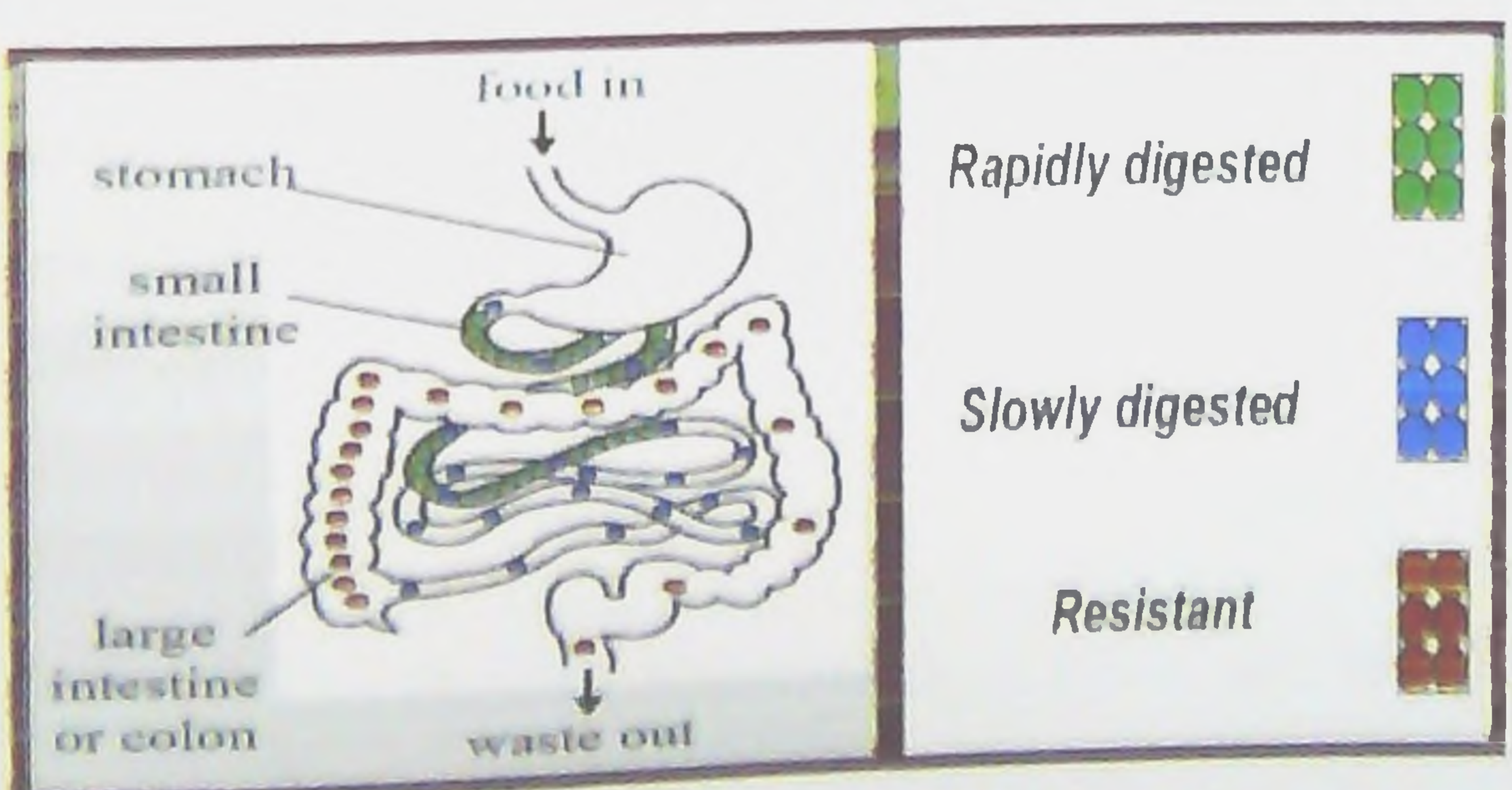


Figure-2 Mode of digestion of RS

CLASSIFICATION OF RESISTANT STARCH

Resistant starch is subdivided into 4 fractions: RS_1, RS_2, RS_3, and RS_4.

RS_1 represents starch that is resistant because it is physically inaccessible to digestion by entrapment in a non digestible matrix. Examples: whole and partially milled grains and seeds.

RS_2 represents starch that is in a certain granular form and resistant to enzyme digestion. In raw starch granules, starch is tightly packed in a radial pattern and is relatively dehydrated. This compact structure limits the accessibility of digestive enzymes, various amylases, and accounts for the resistant nature of RS_2 such as, ungelatinised starch. Examples: raw potatoes, green bananas, some pulses and high amylase corn. RS_1 and RS_2 represent residues of starch forms, which are digested very slowly and incompletely in the small intestine.

RS_3 represents the most resistant starch fraction and is mainly retrograded amylose formed during cooling of gelatinised starch. Most moist-heated foods therefore contain some RS_3. RS_3 is entirely resistant to digestion by pancreatic amylases. Examples: Cooked and cooled starch products.

RS_4 is the RS where novel chemical bonds other than α-(1-4) or α-(1-6) are formed. Modified starches obtained by various types of chemical treatments are included in this category.

STRUCTURE OF RESISTANT STARCH

Figure 3-6 show the structure of different types of RS

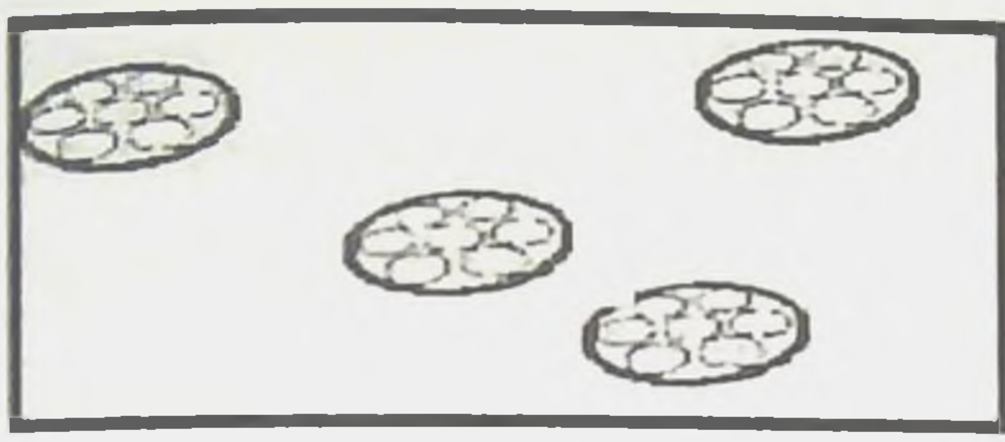


Figure-3 RS1

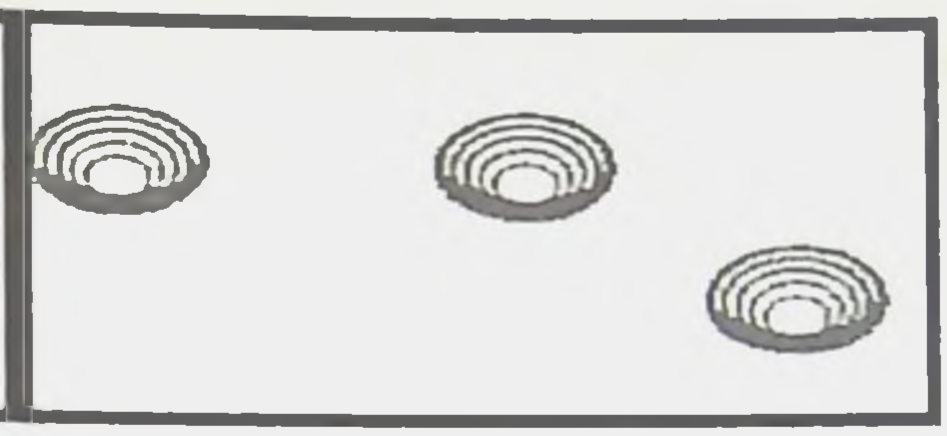


Figure-4 RS_2

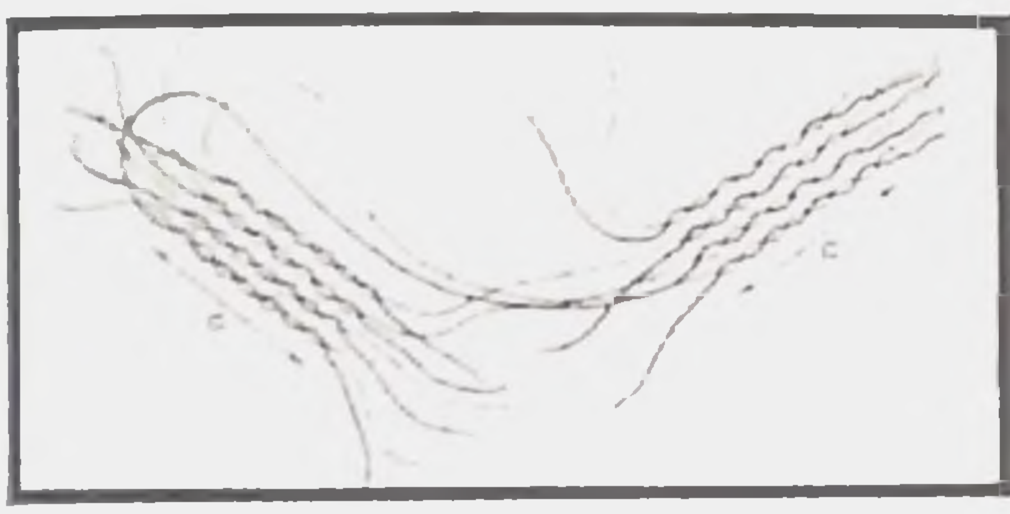


Figure-5 RS3

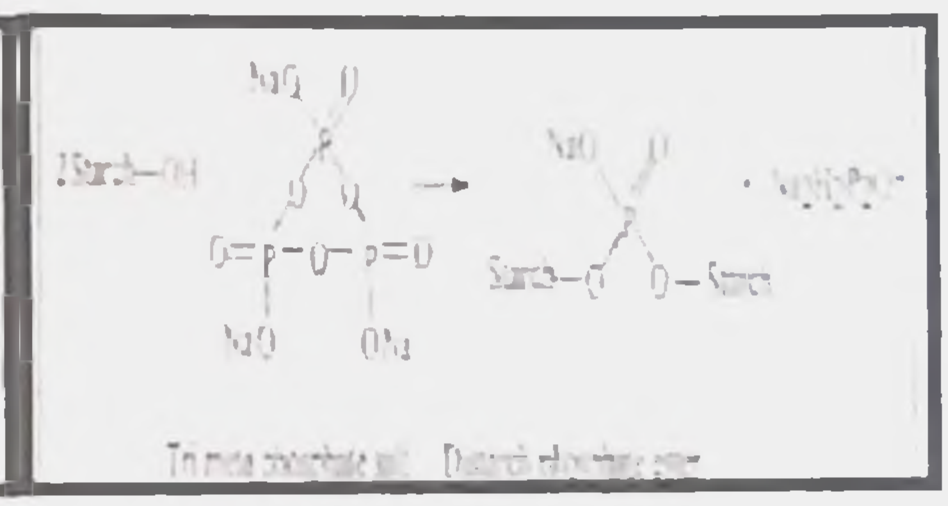


Figure-6 RS_4

FOOD SOURCES OF RESISTANT STARCH

Legumes, lentils, navy beans, green gram, raw banana, raw potatoes, whole grains, cooked and cooled rice, rice flakes, corn flakes etc. are the major of food sources of resistant starch.

RECOMMENDED DIETARY ALLOWANCES (RDA) OF RESISTANT STARCH

Approximately 20 g/d is recommended to obtain the beneficial health benefits of RS (Sajilata *et al.*, 2006). However, worldwide, dietary intakes of RS are believed to vary considerably. Dietary intakes in India and China were estimated at 10 and 18g/d (Platel and Shurpalekar, 1994; Muir *et al.*, 1998).

DETERMINATION OF RESISTANT STARCH

a. *In vitro* methods

The main step of any method to measure the content of RS in foods is to remove all of the digestible starch from the product using thermostable –amylases (Goni *et al.*, 1996). Figure- 7 shows protocol for the determination of RS in foods.

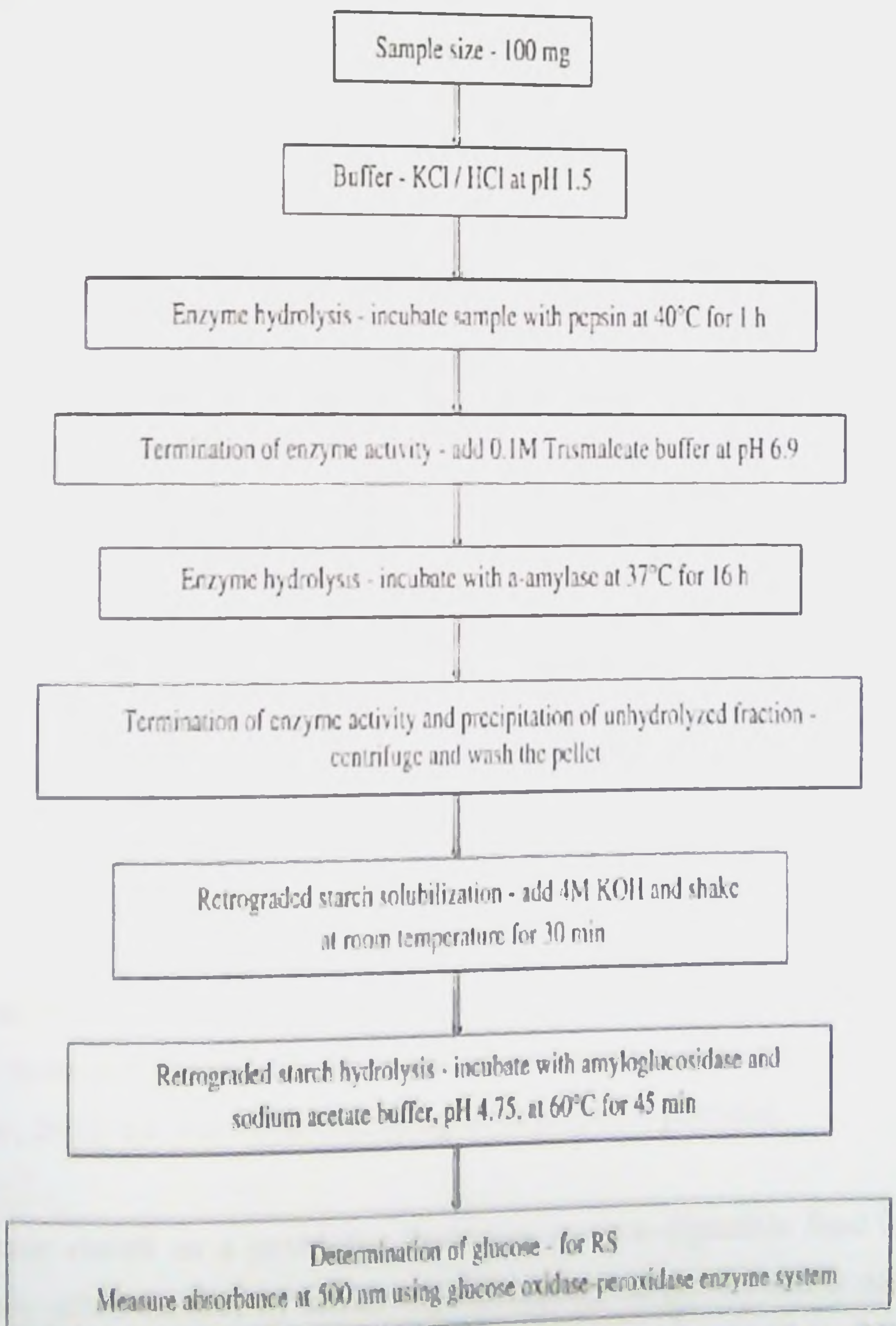


Figure- 7 Goni *et al.* (1996) protocol for the determination of RS in foods

b. In vivo methods

The classic way to substantiate starch digestion is by measuring the glycemic index. This implies measuring the area under the curve (AUC) of the serum glucose concentration over the first 2 h after administering a starch and dividing this by the serum glucose response after consumption of an equal amount of glucose.

RESISTANT STARCH AND DIETARY FIBRE

Difference between RS and dietary fibre is given in Table-1.

Table- 1 RS and dietary fibre

Resistant starch	Dietary fibre
Constituent of starch	Non starch polysaccharide
Properties of soluble fibre	Consists of soluble and insoluble fibre
Fermentation in large intestine –produce SCFA (Butyric acid)	Fermentation in large intestine –produce SCFA (Butyric acid, acetic acid and propionic acid)
Helps in absorption of minerals	Hinder absorption of minerals
Blends well with other foods	Does not blend well with other foods
Satiety value	Bulk producing

BENEFICIAL PHYSIOLOGICAL EFFECTS OF RESISTANT STARCH

RS has received much attention for both its potential health benefits and functional properties (Sajilata *et al.*, 2006). RS acts largely through its large bowel bacterial fermentation products which are, in adults, short-chain fatty acids (SCFA) (Topping *et al.*, 2003) but interest is increasing in its prebiotic potential.

a. Resistant starch as a prebiotic: Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or more bacteria (probiotics) in the gastrointestinal tract and thereby exert a health-promoting effect. RS acts as a substrate for the growth of probiotic microorganisms and therefore is called a "prebiotic". RS has also been suggested for use in probiotic compositions to promote the growth of such beneficial microorganisms as bifido-bacterium (Brown *et al.*, 1996).

(a) (b) (c)

(a) Human intestine (b) Porcine intestine

(c) Showing adherence bifidobacteria

Figure-8 High amylose starch granule through intestine

b. Prevention of colonic cancer: Starch unabsorbed in the small intestine is fermented by the microflora of the large intestine. The fermentation of natural resistant starch reduces intestinal pH and the production of potentially harmful secondary bile acids, ammonia and phenols.

Fermentation of resistant starch increases short-chain fatty acids in the colon. RS ferment in the large bowel and produce high levels of butyric acid. As butyrate is one of the main energy substrates for large intestinal epithelial cells and inhibits the malignant transformation of such cells *in vitro*; this makes easily fermentable RS fractions especially interesting in preventing colonic cancer. Figure-9 shows the action of butyrate. The butyrate can have an inhibitory effect on the growth and proliferation of tumor cells *in vitro* (Sharma *et al.*, 2008).

Population studies in the cecum of rats fed RS preparations have shown that increase in fecal bulking and lower fecal pH, as well as greater production of SCFA, are associated with the decreased incidence of colon cancer (Tharanathan and Mahadevamma, 2003).Rs helps in colorectal cancer mitigation (Zhang *et al.*, 2007).

A study was conducted in which 20 volunteers with a family history of colorectal cancer. The study included 3 diets: control, Wheat bran fibre (WB) (12 g fibre/d), and Wheat bran fibre plus resistant starch (WBRS) (12 g WB fibre plus 22 g RS/d), each continued for 3 week. During 5 consecutive days of each dietary period, the subjects collected their total faecal output for analysis. The WBRS diet resulted in greater faecal output, lower faecal pH, higher faecal concentration and daily excretion of acetate, higher faecal concentration and daily excretion of butyrate, a higher faecal ratio of butyrate to total short-chain fatty acids, and lower concentrations of total phenols and ammonia (Muir *et al.*, 2004).

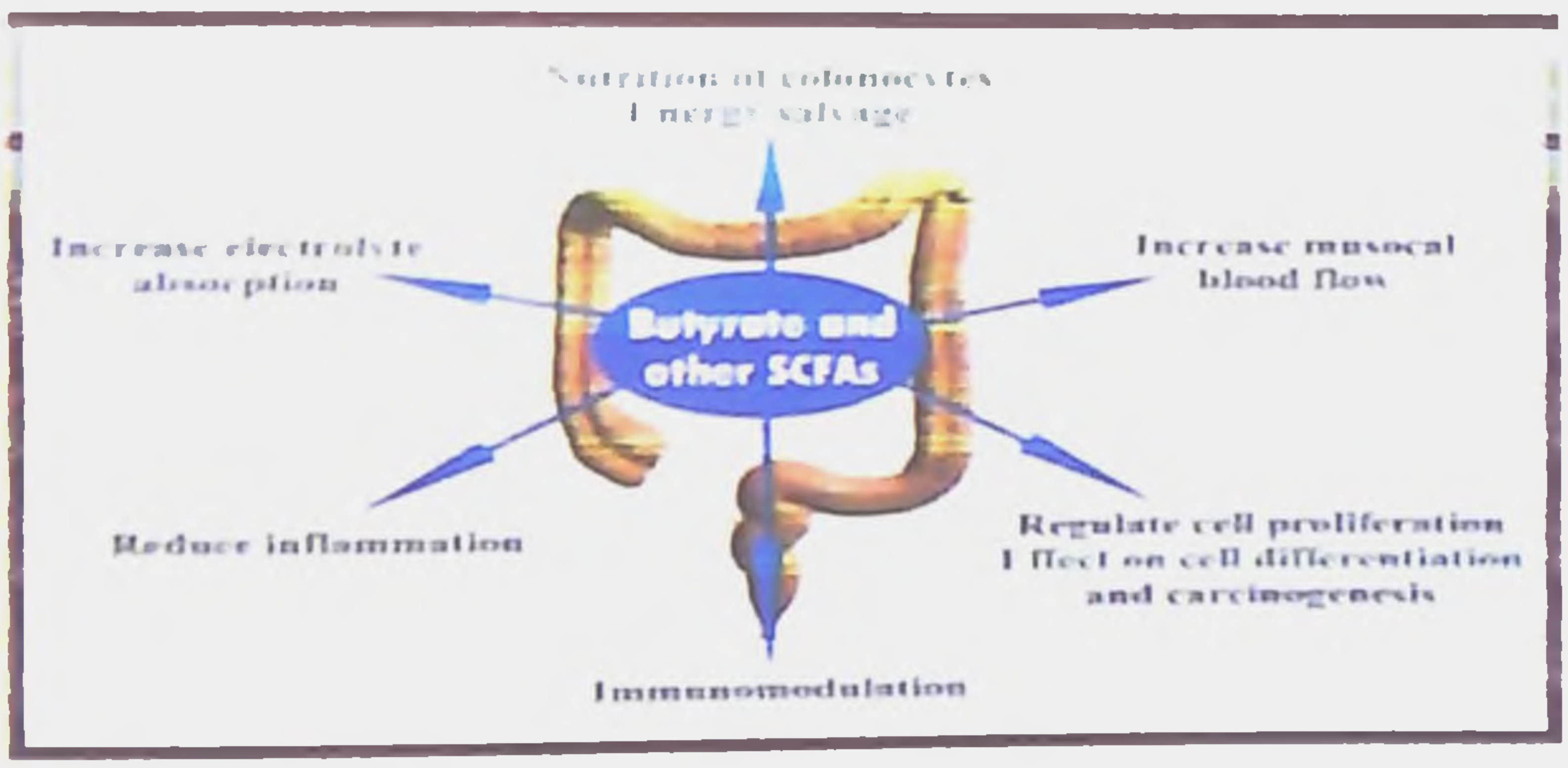


Figure-9 Action of butyrate

c. Hypoglycemic effect: Consumption of resistant starch by humans has been shown to result in decreased glycemic response in healthy individuals, decreased glycemic response in diabetics, increased insulin sensitivity in healthy individuals, individuals with Type II diabetes (Zhang, *et al.*, 2007) as well as insulin resistant individuals (Johnston, *et al.*, 2010)

Forty randomly selected newly detected type 2 diabetic patients were screened and they were placed in 2 homogenous groups of 20 patients each. To one group (group I), 150g retrograded rice containing 8-10 per cent RS was tested and the other group

(group 2) acts as control. The patient's in group 2 took usual and normal food including same variety of rice (150 g of the rice per day). The study continued for three months and effects in the blood parameters were observed after taking blood samples of all the volunteers at monthly intervals. It was found that fasting blood sugar (FBS) values of group1 subjects were reduced from 158mg/dl to 140 mg/dl, whereas in group 2 subjects FBS values ranges between 152 mg/dl to 154 mg/dl (Mitra *et al.*, 2007).

Taggart (2006) reported that replacing flour with high amylase resistant starch educed the postprandial plasma glucose response by 45 per cent (Figure -10).

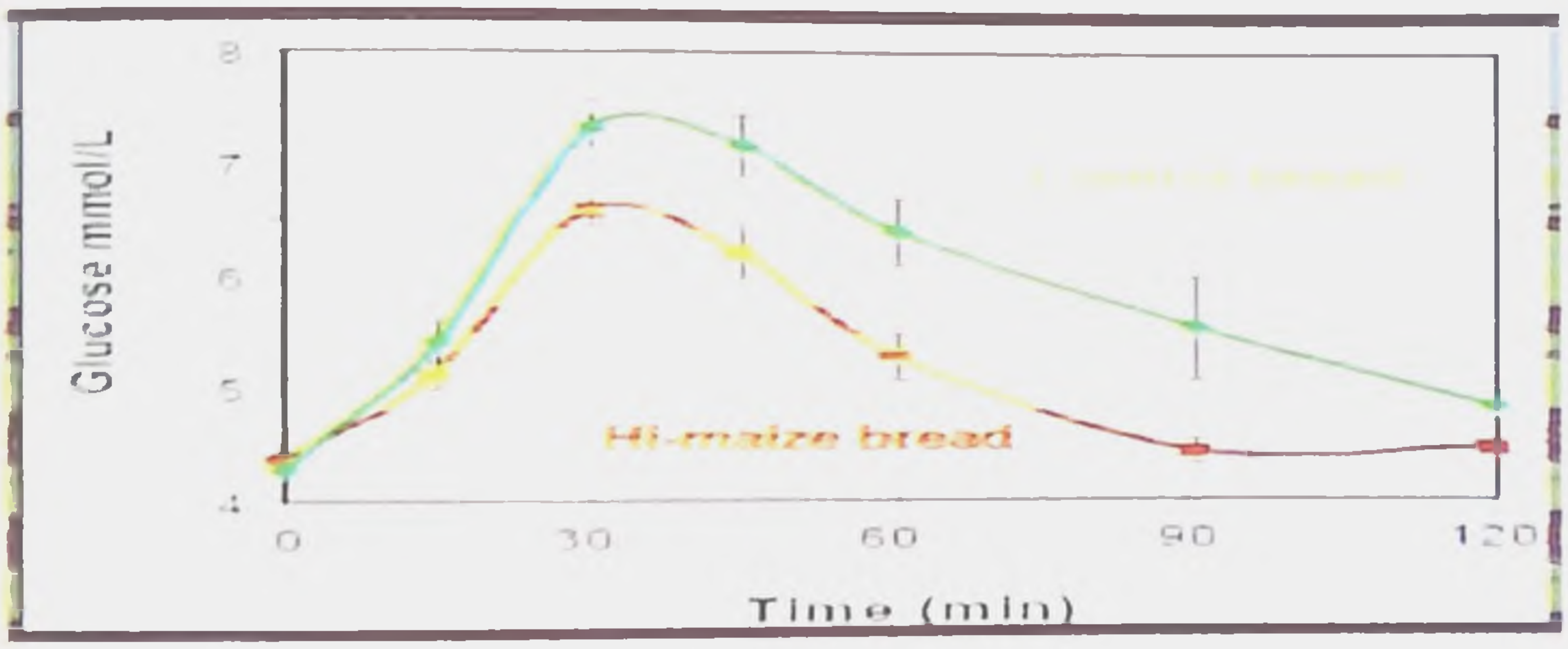


Figure -10 Resistant starch lowers glucose response

d. Hypocholesterolemic effects: Resistant starch appears to particularly affect lipid metabolism. Resistant starch increases the formation of SCFA and its absorption. SCFA suppresses cholesterol synthesis by an increase in bile acid secretion.

Hypocholesterolemic effects of RS have been widely demonstrated. In rats, RS diets (25% raw potato) markedly raised the cecal size and the cecal pool of short-chain fatty acids (SCFA), as well as SCFA absorption and lowered plasma cholesterol and triglyceride levels (Sajilata *et al.*, 2006).

e. Weight reduction: A number of authors have examined the potential of RS to modify fat oxidation and various studies have examined its potential as satiety agent and also an ingredient by weight management. It is proposed that eating a diet rich in RS may increase the mobilization and use of fat stores as a direct result of a reduction in insulin secretion. Replacement of 5.4 per cent of total dietary carbohydrates with RS in a meal of 12 subjects significantly increased postprandial lipid oxidation, suggesting reduction in fat accumulation in the long term (Higgins *et al.*, 2004).

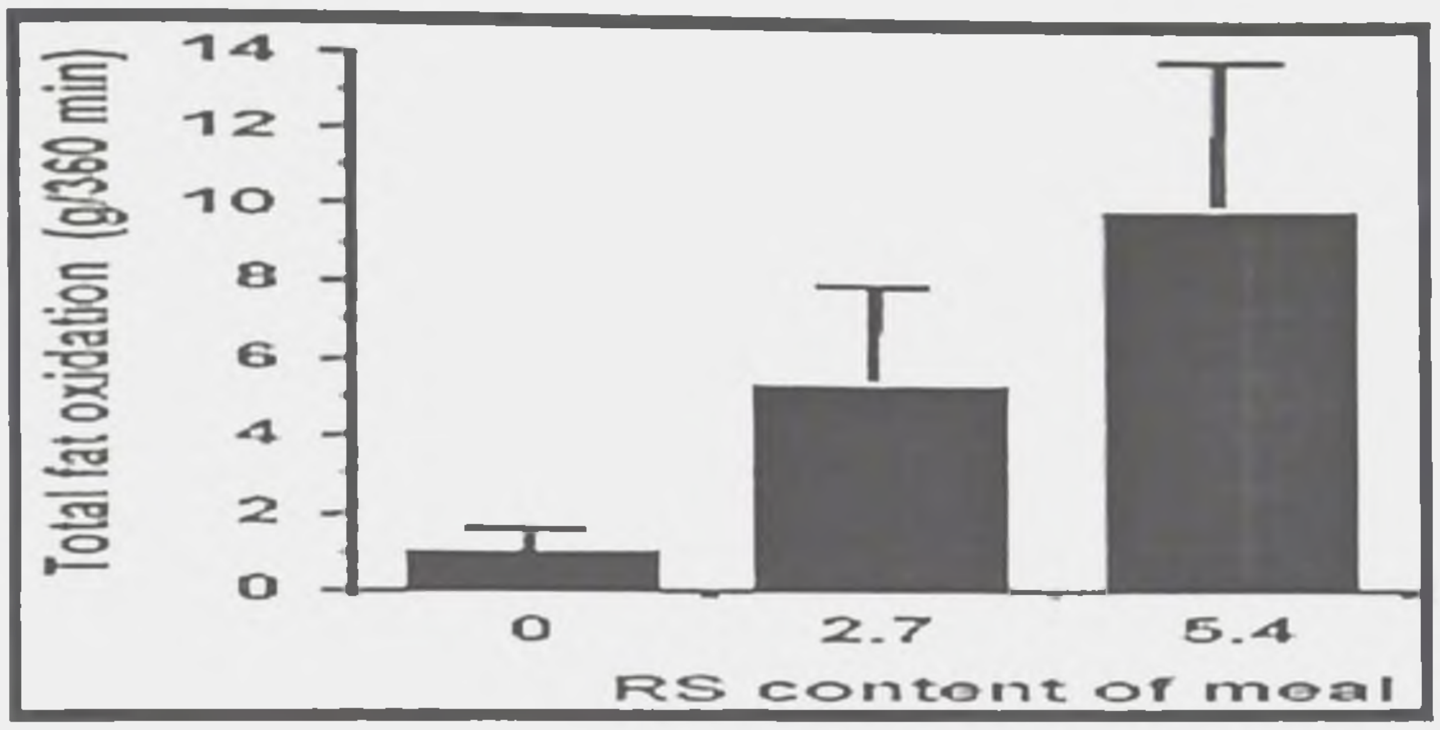


Figure -11 Total fat oxidation in response to RS content of meal

f. Absorption of minerals: Resistant starch enhances the ileal absorption of a number of minerals in rats and humans. Sajilata *et al.* (2006) reported an increased absorption of calcium, magnesium, zinc, iron and copper in rats fed RS rich diets. In humans, these effects appear to be limited to calcium. RS could have a positive effect on intestinal calcium and iron absorption. A study to compare the apparent intestinal absorption of calcium, phosphorus, iron, and zinc in the presence of either resistant or digestible starch showed that a meal containing 16.4 per cent RS resulted in a greater apparent absorption of calcium and iron compared with completely digestible starch (Morais *et al.*, 1996).

FACTORS INFLUENCING THE FORMATION OF RS

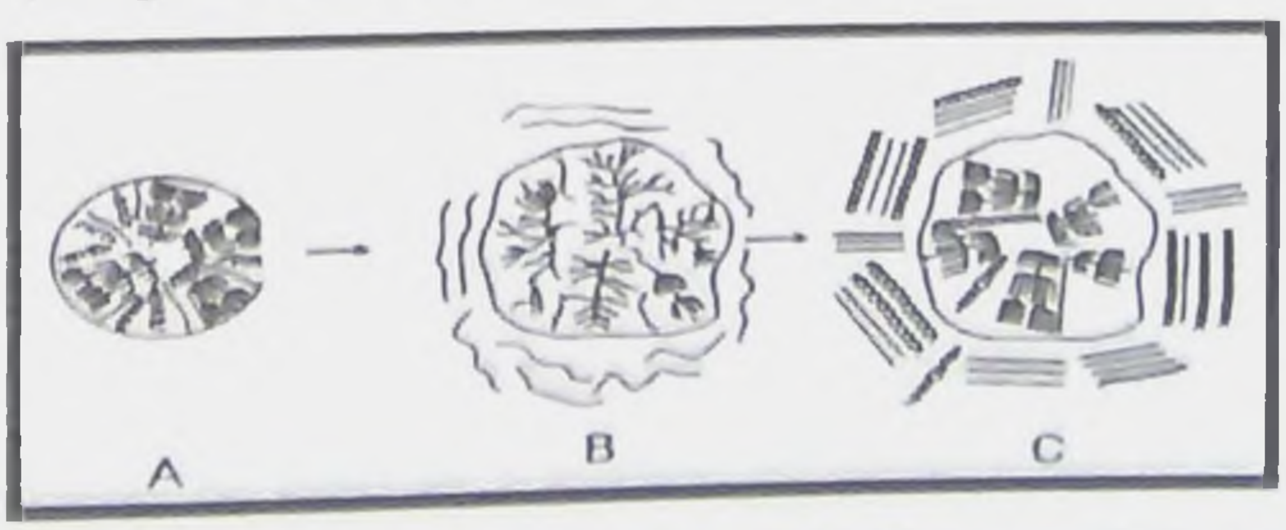
1. Amylose content

A higher content of amylose lowers the digestibility of starch due to positive correlation between amylose content and formation of RS (Sievert and Pomeranz, 1989). The importance of the amylose: amylopectin ratio in the postprandial glycemic and insulinaemic responses to corn was studied in commonly consumed corn products. The meals containing high amylose (70%) corn flour had an RS of 20 g/100 g DM than that containing ordinary corn flour (25% amylose) that had RS of 3 g /100 g DM (Granfeldt *et al.*, 1995).

2. Thermal processing (Heat and Moisture)

Optimum heat and moisture in processing helps RS formation. Processing techniques may affect both the gelatinisation and retrogradation processes, influencing RS formation. This fact is of great importance for the food industry since it offers the possibility of increasing the RS content of processed foods and foodstuffs. Baking, pasta production, extrusion cooking, autoclaving, and so forth are known to influence the yield of RS in foods. Cooking under conditions of high moisture and temperature can significantly lower the RS content by disrupting crystalline structure (Sajilata *et al.*, 2006).

When heated to about 50°C, in the presence of water, the amylose in the granule swells; the crystalline structure of the amylopectin disintegrates and the granule ruptures. The polysaccharide chains take up a random configuration, causing swelling of the starch and thickening of the surrounding matrix such as, gelatinisation—a process that renders the starch easily digestible. On cooling/drying, recrystallisation (retrogradation) occurs (Figure-12 and 13). This takes place very fast for the amylose moiety as the linear structure facilitates cross linkages by means of hydrogen bonds. The branched nature of amylopectin inhibits its re-crystallisation to some extent and it takes place over several days. Retrograded amylose in peas, maize, wheat, and potatoes was found to be highly resistant to amylolysis (Ring *et al.*, 1988).



A: Native starch B: Gelatinised starch C: Retrograded starch

Figure-12 Retrogradation of amylose

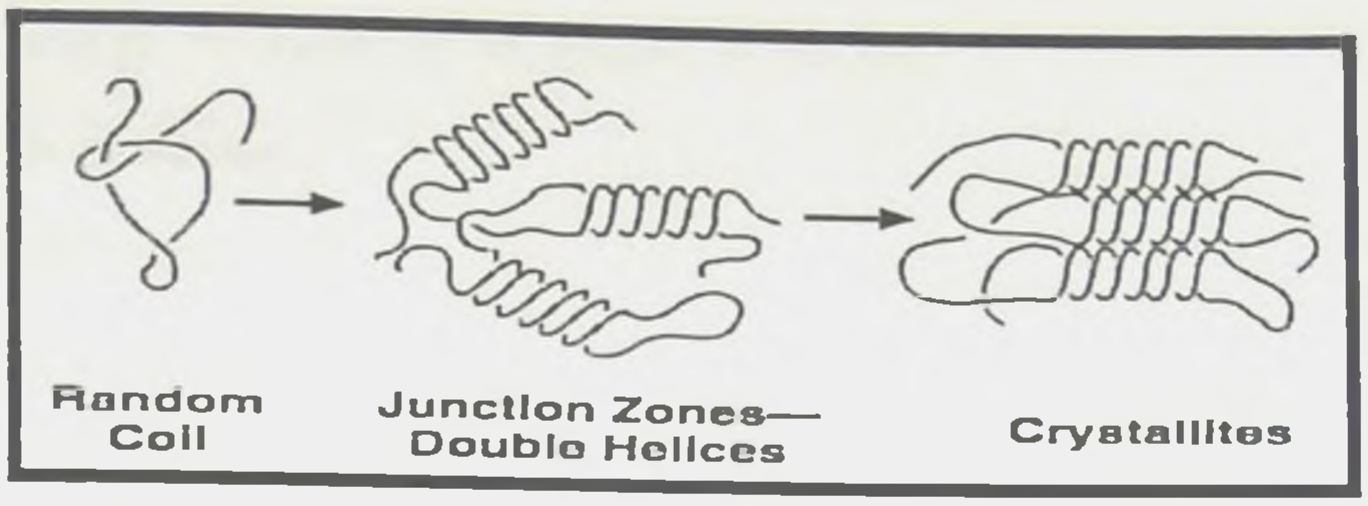


Figure-13 Schematic of amylose retrogradation

The rate and extent to which a starch may retrograde after gelatinisation essentially depends on the amount of amylose present. Repeated autoclaving of wheat starch may generate up to 10 per cent RS. The level obtained appeared to be strongly related to the amylose content, and the retrogradation of amylose was identified as the main mechanism for the formation of RS that can be generated in larger amounts by repeated autoclaving (Bjorck *et al.*,1990). During storage, the dispersed polymers of gelatinised starch are said to undergo retrogradation to semicrystalline forms that resist digestion by pancreatic α-amylase. It forms a major portion of RS in wheat bread and corn flakes whereas only 25 per cent of the RS in cooked, cooled potatoes can be accounted for as retrograded amylose (Englyst and Cummings, 1985). The digestibility of legume starch is much lower than that of cereal starch, which is attributable to higher content of amylose in the former. The digestibility of high amylose cereal starch is reported to be significantly lower (Tharanathan and Mahadevamma, 2003).

Water content is an important factor that affects formation of RS. Repeated heat/moisture treatment is associated with a decrease in the hydrolysis limit of pancreatic α-amylase and increased formation of RS. Maximum RS yield was obtained at a starch: water ratio of 1: 3.5 (w/w) (Sievert and Pomeranz, 1989). Heat treatment at 18 per cent moisture gave increased levels of the degree of crystallinity of normal and waxy starches and thus reduced enzyme susceptibility. However, at 27 per cent moisture, starch degradation to some extent made areas of starch more accessible to enzyme attack. Thus, proper heat treatment could be used as a method of preparation of RS (Franco *et al.*, 1995).

Different types of Thermal Processing Methods Includes:

A. **Steam cooking**

B. **Autoclaving**

C. **Parboiling**

D. **Baking**

E. **Extrusion cooking**

F. **Microwave cooking**

A. Steam cooking

Steam cooking helps in the production of RS. Starches isolated from several steam-heated legumes were rich in indigestible RS (19% to 31%), which was not observed in raw beans .Similarly, RS measured directly in conventionally and high-pressure steamed beans were 3 to 5 times higher than in the raw pulses, suggesting retrogradation to be mainly responsible for the reduction in digestibility. Prolonged steaming as well as short dry pressure heating decreased the enzymically assessed total starch content of whole beans by 2 per cent to 3 per cent, indicating that these treatments may induce formation of other types of indigestible starch (Tovar and Melito, 1996).

B. Autoclaving

Autoclaving results in increase in RS. Autoclaved wheat starch has 9% RS compared with less than 1 per cent in uncooked wheat starch (Siljestrom and Asp, 1985). Autoclaved wheat starch contained 6.2 per cent RS; this increased to 7.8 per cent after 3 further reboiling/cooling cycles (Bjorck *et al.*, 1987). The thermoanalytical data suggested that amylose-lipid complexes were not involved in the formation of RS. Yields in excess of 20 per cent RS can be obtained from autoclaved amylomaize starch containing 70 per cent amylose. They can be raised to levels of 40 per cent by increasing the number of autoclaving-cooling cycles up to 20 (Eerlingen and Delcour, 1995).

Heat-moisture treatment (autoclaving at 121 °C) with subsequent cooling was used to produce amylase-resistant starch (RS) from purified high-amylose starch samples. The formation of RS in barley starch was strongly affected by the number of autoclaving-cooling cycles; increasing the number of cycles from 1 to 20 raised the RS yield from 6 per cent to 26 per cent (Szczodrak and Pomeranz, 1991).

C. Parboiling

Parboiling increases RS production. Studies on 5 rice varieties, differing in amylose content, the *in vitro* and *in vivo* RS levels were low and positively correlated with amylose content. Higher RS starch levels were found in cooked and parboiled-cooked rice than in raw rice; waxy rice had very low values. Higher contents of RS have been reported in parboiled rice than raw white rice, which also increased by cooling or freezing (Marsono and Topping, 1999).

D. Baking

Baking increases RS content. A low-temperature, long-time baked product contained significantly higher amounts of RS than bread baked under ordinary conditions (Liljeberg *et al.*, 1996). Addition of lactic acid increased RS recovery further whereas malt had no impact on RS yield. The highest level of RS was noted in long-time baked bread based on high- amylose barley flour. RS isolated from wheat-based foods such as chapatti and phulka was structurally characterized as a linear 1, 4- linked -D-glucan essentially derived from retrograded amylose fraction, which was dependent on the severity of the processing treatments as well as the levels of gluten and damaged starch in the wheat flour (Tharanathan and Tharanathan, 2001).

E. Extrusion cooking

Effect of extrusion cooking, at different temperatures (90, 100, 120, 140, or 160 °C), moisture contents (20%, 25%, 30%, 35%, or 40%) and screw speeds (60, 80, or 100 rpm), was investigated on the formation of RS of type 3 (RS_3) in hull-less barley flours from CDC-Candle (waxy) and Phoenix (regular). The RS_3 content of the native flours, in general, decreased by extrusion cooking, but not significantly. Storage of extruded flour samples at 4 °C for 24 h before oven drying slightly increased RS_3 content (Faraj *et al.*, 2004). Extrusion followed by cooling, to induce crystallization, increases the levels of RS (Haralampu, 2000).

F. Microwave cooking

Microwave irradiation improves the digestibility of tuber starches, which could be accompanied by physicochemical and structure changes. Microwave cooking of legumes such as chickpeas and common beans produced a redistribution of the insoluble non-starch polysaccharides to soluble fraction, although the total non-starch polysaccharides were not affected. This was evaluated by assessing the physicochemical, nutritional, and micro structural modifications in starch and non-starch polysaccharides. The RS level decreased from 32.5 per cent of total starch in raw chickpeas and beans, respectively, to about 10 per cent in cooked samples with a concomitant increase in the level of rapidly digestible starch from 35.6 per cent and 27.5 per cent to about 80 per cent (Marconi *et al.*, 2000).

3. Interaction of starch with other components

Interactions of starch with different components present in the food system are known to influence the formation of RS as follows.

a. Protein: Starch-protein interaction has been believed to reduce RS contents as observed in case of potato starch and added albumin when autoclaved and subsequently cooled at 20°C (Escarpa *et al.*, 1997).

b. Enzyme inhibitors: Polyphenols, phytic acid and lectins present mainly in leguminous seeds, have been reported to inhibit *in vitro* starch hydrolysis and to lower the glycemic index (Thompson and Yoon, 1984). Tannic acid significantly inhibits both amylases and intestinal maltase activity (Bjorck and Nyman, 1987).

c. Sugars: The addition of soluble sugars such as glucose, maltose, sucrose, and ribose has been found to reduce the level of crystallization and subsequently reduce the yields of RS (Kohyama and Nishinari, 1991). The mechanism of retrogradation inhibition was considered as the interaction between sugar molecules and the starch molecular chains, which change the matrix of gelatinised starch (the sugars act as anti-plasticisers and increase the glass transition temperature).

d. Lipids : From studies on isolated barley starch autoclaved with sodium stearoyl lactylate (SSL), distilled monoglycerides, diacetyl tartaric acid esters of mono-diglycerides (DATEM), and ethoxylated monoglycerides (bakery additives), it is postulated that amylose crystallisation that is involved in the formation of RS is competitively affected by its complexation with lipids (Szczodrak and Pomeranz, 1992).

Amylose-lipid complexes can also be formed during food processing (autoclaving and cooling). Lecithin, palmitic acid, oleic acid and soya bean oil affect retrogradation to a lower extent than monoglycerides.

4. Miscellaneous treatments

a. Milling: Leguminous seeds, in which cell structures are preserved after cooking and bean flour with intact cells; have lower physical accessibility of starch to amylase action, and thereby contribute to higher RS contents. In some foods, physically inaccessible starch is likely to be an important fraction of the total starch that is resistant to digestion *in vivo*.

b. Germination: Germination is shown to decrease the RS content in bengal gram, field beans, cow pea, and green gram (Kavita *et al.*, 1998).

c. Fermentation : Fermentation reduces RS content. RS formation has also been shown to decrease in the fermented products, idlis and dhoklas (Kavita *et al.*, 1998).

5. Storage conditions

Generally, RS increases on storage, especially low-temperature storage. Cold storage seems to support an increase in RS content. Rice stored at -20 °C retrograded more than rice stored in the refrigerator (Mitsuda, 1993).

Increase in RS was reported for gelatinised samples of corn, wheat, ragi, rice, sago, and potato flours on low-temperature storage. RS content was observed to increase in the samples stored at refrigeration temperature for longer duration (Yadav *et al.*, 2010). The longer the duration of storage of gelatinized wheat flour, the greater was the formation of RS (Kavita *et al.*, 1998).

FUNCTIONALITY OF RS

Resistant starch has desirable physicochemical properties such as swelling, viscosity increase, gel formation, and water-binding capacity; making it useful in a variety of foods (Fausto *et al.*, 1997). It has a small particle size, white appearance, and bland flavour and also provides good handling in processing and crispness, expansion, and improved texture in the final product. RS also has a low water-holding capacity. These properties make it possible to use most resistant starches to replace flour on a 1-for-1 basis without significantly affecting dough handling or rheology.

The functional properties and advantages of commercial sources of RS_2 and RS_3 have been summarized as follows. They are natural sources, bland in flavor, white in color, with fine particle size (which causes less interference with texture). They have high gelatinization temperature, good extrusion and film-forming qualities, and lower water-holding properties than traditional fiber products. They allow the formation of low-bulk high-fiber products with improved texture, appearance, and mouth feel (such as better organoleptic qualities) compared with traditional high-fiber products. They increase coating crispness of products and the bowl life of breakfast cereals. They are functional food ingredients lowering the calorific value of foods and useful in products for celiac, as bulk laxatives and in products for oral rehydration therapy (Sharma *et al.*, 2008). Some of these properties of RS have been successfully used in a range of baked and extruded products.

APPLICATION OF RS IN FOOD INDUSTRY

The industrial applications of RS are mainly in the preparation of moisture-free food products. Bakery products such as bread, muffins, and breakfast cereals can be prepared by using RS. The amount of RS used to replace flour depends on the particular starch being used, the application, the desired fibre level, and in some cases, the desired structure-function claims. From a quality standpoint, some applications are more sensitive to flour replacement than others. For example, bread and rolls, which generally have a bland flavor, are low-fat and require a minimum amount of gluten for structure; the maximum flour replacement is typically 10 per cent to 20 per cent without noticeably changing the texture (Sajilata *et al.*, 2006).

1. RS in bread-making: The physical properties of RS, particularly its low water-holding capacity, allow it to be a functional ingredient that provides good handling in processing and crispness, expansion, and improved texture in the final product. Bread is commonly fortified with dietary fibre. However, dark color, reduced loaf volume, poor mouthfeel, and masking of flavor are all negative attributes that are often associated with high-fiber breads (Baghurst *et al.*, 1996).

2. RS as a texture modifier in baked goods: RS were incorporated in a variety of baked goods, many of which include batter systems, such as in cakes, cake-like muffins, or brownies. In general, application tests showed that RS acts as texture modifier, imparting a favorable tenderness to the crumb. A panel rated 40 per cent RS loaf cakes as best for flavour, grittiness moisture perception, and tenderness 24 h after baking (Fuentes *et al.*, 2010).

3. RS as a crisping agent: Among other functional properties, RS can be used as an ingredient that improves crispness in foods where high heat is applied to a product's surface during processing. French toast and waffles, especially frozen reheated types, represent foods in which surface crispness is desired. Based on an evaluation by a trained sensory panel of toasted waffles for initial crispness, crispness after 3 min, moistness and overall texture, RS waffle showed greater crispness than control or traditional fibre (Fuentes *et al.*, 2010).

4. RS as a functional ingredient in other foods: Along with textural enhancement, RS can improve expansion in extruded cereals and snacks. Dried pasta products containing up to 15 per cent RS can be made with little or no effect on dough rheology during extrusion. Although the resultant pasta was lighter in color, a firm texture was obtained in the same cooking time as a control that had no added fibre. RS may also be used in thickened, opaque health beverages in which insoluble fibre is desired. Insoluble fibres generally require suspension and add opacity to beverages. Compared with insoluble fibres, RS imparts a less gritty mouthfeel and masks flavors less.

COMMERCIAL SOURCES OF RS

The first commercial RS was introduced as Hi-maize in Australia in 1993 by Starch Australasia. This product is a natural granular form of starch produced from a corn hybrid containing more than 80 per cent amylose. Hi-maize analyses as 42 per cent RS and has gained widespread use in Australia in breads and other baked goods. List of commercial sources of RS is given in Table-2.

There are a number of advantages to using commercially manufactured RS in food products. Unlike natural sources of RS (that is, legumes, potatoes, bananas), commercially manufactured RS are not affected by processing and storage conditions. For example, the amount of RS_2 in green bananas decreases with increasing ripeness; however, a commercial form of RS_2, Hi-maize, does not experience these difficulties.

Among the newest developments in resistant starches is an RS_2 that remains resistant after mild food processing (Novelose 240). Most importantly, the commercial RS has a much lower water-holding capacity than do various traditional fibers. Because it absorbs less water, adjustments in product formulations and processing are substantially minimised.

Table-2 Commercial sources of RS

Product name	Per cent of RS	Source	Agency and Country
Hi- maize	42	Hybrid corn	Starch Australia, Australia
CrystaLean	41	ae-VII hybrid of corn	Opta Food Ingredients, U.S.A
Novelose 240	47	ae-VII hybrid of corn	Natl. Starch and Chemical Co., U.S.A
Novelose 260	60	ae-VII hybrid of corn	Natl. Starch and Chemical Co., U.S.A
C*ActiStar	58	Tapioca starch	Cerestar Food and Pharma Specialities, U.S.A
Fibersym™ HA	70	High amylose corn	MGP Ingredients, Inc., U.S.A and Cargill, U.S.A

RS is well-suited for low-moisture food systems where they can be used at very high levels compared to traditional starches. The majority of the commercially available RS rely on intact granules or compact crystalline regions with high melting temperatures to resist digestion. Therefore, these products generally will not swell or contribute viscosity during most processing. Essentially insoluble, RS would not replace viscosifying starch in liquid applications.

Compared with conventional fibers, it has many advantageous features. It is white and has a bland flavour and a fine particle size between 10 and 15 µm. It also has a reduced caloric content and may be used as a bulking agent to complement reduced sugar or reduced-fat formulations.

CONCLUSIONS

Resistant starch, the portion of starch and starch products that resist digestion, appears to confer several health benefits. Being nondigestible, RS can be used in reduced-fat and sugar formulations. Foods containing high levels of RS yield fewer calories and lower glycemic loads-important formulation considerations for diabetics as well as the weight-conscious. RS is classified as fibre component with partial or complete fermentation in the colon, producing various beneficial effects on health. It is likely that RS mediates some or all of its effects through the action of SCFA.RS also offer an exciting new potential as a food ingredient. Its fine particles and bland taste make possible the formulation of a number of food products with better consumer acceptability and greater palatability than those made with traditional fibres. RS shows improved crispness and expansion in certain products and better mouthfeel, color, and flavor over products produced with some traditional, insoluble fibers. It is ideal for use in RTE cereals, snacks, pasta/ noodles, baked goods, and fried foods, conferring additional nutraceutical benefits. Technically, it is possible to increase the RS content in foods by modifying the processing conditions such as pH, heating temperature and time, number of heating and cooling cycles, freezing, and drying. A number of commercially available RS preparations would make it possible for a wide range of applications with nutraceutical implications. RS has received much attention for both its potential health benefits and functional properties.

Future research priorities include a more in-depth exploration of the effects of RS on colonic function and inflammatory bowel disease. There is also a need for properly designed, controlled studies to determine the exact effects of RS on human lipid and glucose metabolism, particularly over longer time periods and, in individuals with impaired glucose responses. The potential of RS as an agent in weight loss and maintenance regimens will undoubtedly be explored as part of attempts to curb the global increasing incidence of obesity. However, there is a real need to determine the molecular mechanisms of action of RS. Resistant starch may be the future "Weight Buster" and "Health Mascot" (Potty, 2011).

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DISCUSSION

1. What is meant by modified starch and give an example for modified starch?

Ans: Modified starches are prepared by physically, enzymatically, or chemically treating native starch, thereby changing the properties of the starch. Starches may be modified to increase their stability against excessive heat, acid, shear, time, cooling, or freezing; to change their texture; to decrease or increase their viscosity; to lengthen or shorten gelatinisation time; or to increase their visco-stability. Modified starches are used in practically all starch applications, such as in food products as a thickening agent, stabilizer or emulsifier; in pharmaceuticals as a disintegrant; or in paper as a binder.Examples:alkaline-modified starch (E1402)with sodium hydroxide or potasium hydroxide and bleached starch (E1403)with hydrogen peroxide.

2. What is the difference between prebiotics and probiotics?

Ans: Probiotics are dietary supplements containing potentially beneficial bacteria or yeasts. According to FAO/WHO probiotics are "live microorganisms which when administered in adequate amounts confer a health benefit on the host". Prebiotics are non-digestible food ingredients that stimulate the growth and/or activity of beneficial bacteria in the digestive system in ways claimed to be beneficial to health.

3. What is meant by bland flavour?

Ans: Bland flavour is one which lacks taste or flavour, not irritating and not stimulating and having soft and soothing qualities.

4. Germination decreases RS. So as a nutrition student which kind of food you suggest to take, germinated or non-germinated?

Ans: Germinated foods are easily digested with maximum nutrient availability. So while considering the nutritional function, germinated foods are recommended. But when we are going for functional properties, as in conditions of diabetes, obesity etc., where there is a restriction in toatal calories, we can recommend RS in their diets. So the use of food items either for their nutritional properties or for their functional properties, depend on the condition of the body.

5. Which is more beneficial, dietary fibre or resistant starch?

Ans: Resistant starch is more beneficial than fibre. RS undergoes fermentation in the large intestine and produces butyric acid, which act as a primary energy source for the large intestine. RS has a small particle size, white appearance, bland flavor and low water-holding capacity. Hence it blends well with other foods. But this property lacks in fibre. RS helps in mineral absorption whereas fibre hinders the absorption of minerals. RS also possesses the properties of soluble fibre.

6. What is the function of *Bifido* bacterium?

Ans: Bifidobacteria exist in the large intestine are helpful for maintenance of human health. Prebiotics increase the number and/or activity of bifidobacteria. Bifidobacteria have several beneficial effects on the host, especially in terms of improving digestion (including enhancing mineral absorption) and intrinsic strength of the immune system. It promotes the growth of other beneficial microorganisms in our intestine and releases useful substances in the intestine.

7. Is there any resistant starch incorporated product in India?

Ans: No. There is no resistant starch incorporated product in India till date.

8. How resistant starch prevents colon cancer?

Ans: Fermentation of resistant starch reduces intestinal pH, production of potentially harmful secondary bile acids, ammonia and phenols and increases short-chain fatty acids in the colon, especially high levels of butyric acid. Butyrates have an inhibitory effect on the growth and proliferation of tumor cells.

9. How resistant starch helps to decrease blood glucose level?

Ans: Resistant starch helps to maintain healthy blood sugar levels by lowering the glycemic and insulin response of foods.

10. Is there any undesirable manifestations for RS?

Ans: Yes, but not in humans. There are two undesirable manifestations of RS in experimental animals. One is the cecal enlargement. But, in humans, it is said to be of little relevance because of the considerably smaller size and weight of cecum as well as its minor role in the human physiological function. Pelvic nephrocalcinosis is another phenomenon observed in experimental animals.

11. Ragi or rice, which contains more resistant starch?

Ans: Ragi contains less amount of resistant starch compared to rice, but ragi is rich in fibre.

ABSTRACT

Starch, the major dietary source of carbohydrates is the most abundant storage polysaccharide in plants. Chemically, starches are homoglycans; composed of a number of monosaccharides or sugar molecules linked together. Amylose and amylopectin are the two main structural components of starch.

The term 'resistant starch' was first coined by Englyst *et al.* (1982). Resistant starch has been defined as the fraction of starch, which resists digestion in the small intestine of healthy individuals and is available for fermentation in the large intestine (Englyst *et al.*, 1992).

Resistant starch (RS) is sub-divided into four fractions: RS_1, RS_2, RS_3, and RS_4 (Fuentes *et al.*, 2010). RS_1 is physically inaccessible to digestion by entrapment in a non-digestible matrix. RS_2 is ungelatinised starch or native starch. RS_3 represents retrograded starch. RS_4 includes selected chemically-modified starches.

Several factors like amylose content, processing which involves heat-moisture treatments, interaction of starch with different components in the food and storage conditions, influence the formation of RS. Technically, it is possible to increase the RS content in starchy foods by modifying the processing conditions such as heating temperature and time, moisture content, repeated heating and cooling cycles and freezing and drying of gelatinised starch.

A number of physiological effects have been ascribed to RS, which have been proved to be beneficial for health. RS acts largely through its large bowel bacterial fermentation products which are short chain fatty acids (SCFA). RS intake seems to decrease postprandial glycemic and insulinemic responses, improve whole body insulin sensitivity, lower plasma cholesterol and triglyceride concentrations, increase satiety, and reduce fat storage (Higgins, 2004).

Approximately 20g/day of RS is recommended to obtain the beneficial health effects of RS (Sajilata *et al.*, 2006). RS can be determined by *in vitro* and *in vivo* methods.

Resistant starch has desirable physico-chemical properties, making it suitable for incorporating in a variety of foods. A number of commercially available RS preparations would make it possible, for a wide range of applications with nutraceutical implications. RS has received much attention for both its potential health benefits and functional properties.

BIOCATALYSTS IN FOOD PROCESSING

By
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2010-24-101
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Seminar Report submitted in partial fulfillment of the requirement for the course

FN.692- Doctoral seminar

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BIOCATALYSTS IN FOOD PROCESSING

INTRODUCTION

Catalysts are substances that modify and increase the rate of a chemical reaction without being consumed in the process (Manay and Shadaksharaswamy, 2007). Based on the source, catalysts can be divided into two: chemical catalysts and biological catalysts. Enzymes are the biological catalysts. Pelczer *et al.* (1996) defined enzymes as the biocatalysts, which break down the macromolecule to simpler forms, without undergoing any change by themselves. Enzymes are protein molecules that catalyse or accelerate reactions without undergoing a net change themselves (Matz, 1996).

HISTORICAL BACKGROUND

The term 'enzyme' was introduced by German physiologist Wilhelm Kuhne in 1877. The term enzyme comes from the Greek word *zymosis* meaning 'in leaven' or yeast. In 1897 Eduard Buchner identified the ability of yeast extracts that lacked any living cells to ferment sugar. He named the enzyme that brought about the fermentation of sucrose "zymase".

ENZYME ACTION

Enzymes are made up of long chains of amino acids. The chains are folded to form the active site. Active site is highly specific. During a reaction the substrate can bind to the active site of enzyme to form enzyme – substrate complex. The reaction proceeds at the binding site to produce the products. When the reaction is complete the products are released and the enzyme can be used again.

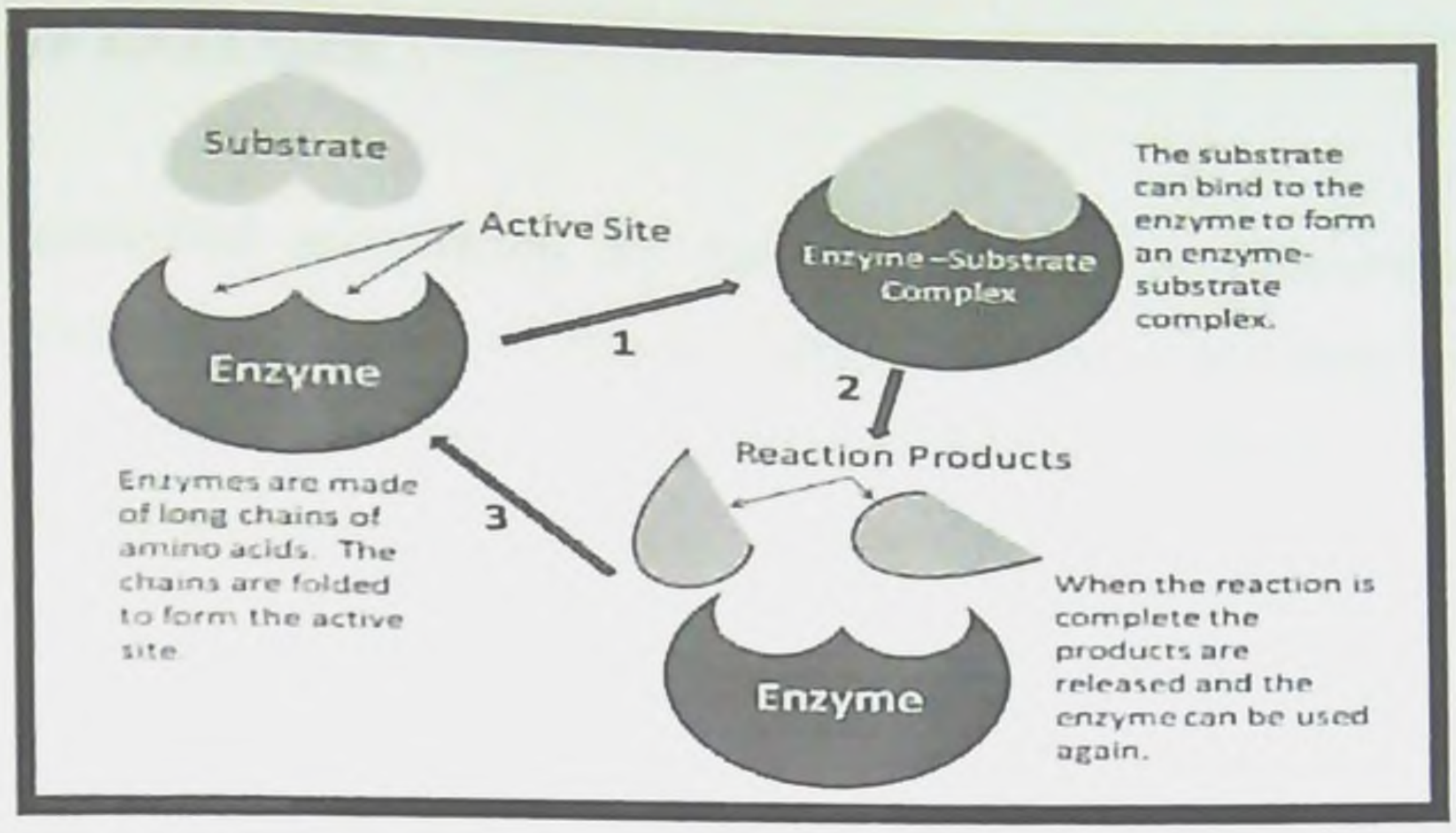

Figure-No.1 Enzyme action

MECHANISM OF ENZYME CATALYSIS

Stabilisation of the transition state of the substrate reduces the activation energy of the overall reaction; this is the most important feature of enzyme catalysis. The binding sites of enzymes bind more strongly to the substrate molecules in the transition state than to those in the ground or stable state. In addition, when a substrate molecule in ground state binds to the binding site, it is forced into a configuration closer to that of transition state; this lowers the energy needed for reaching the transition state.

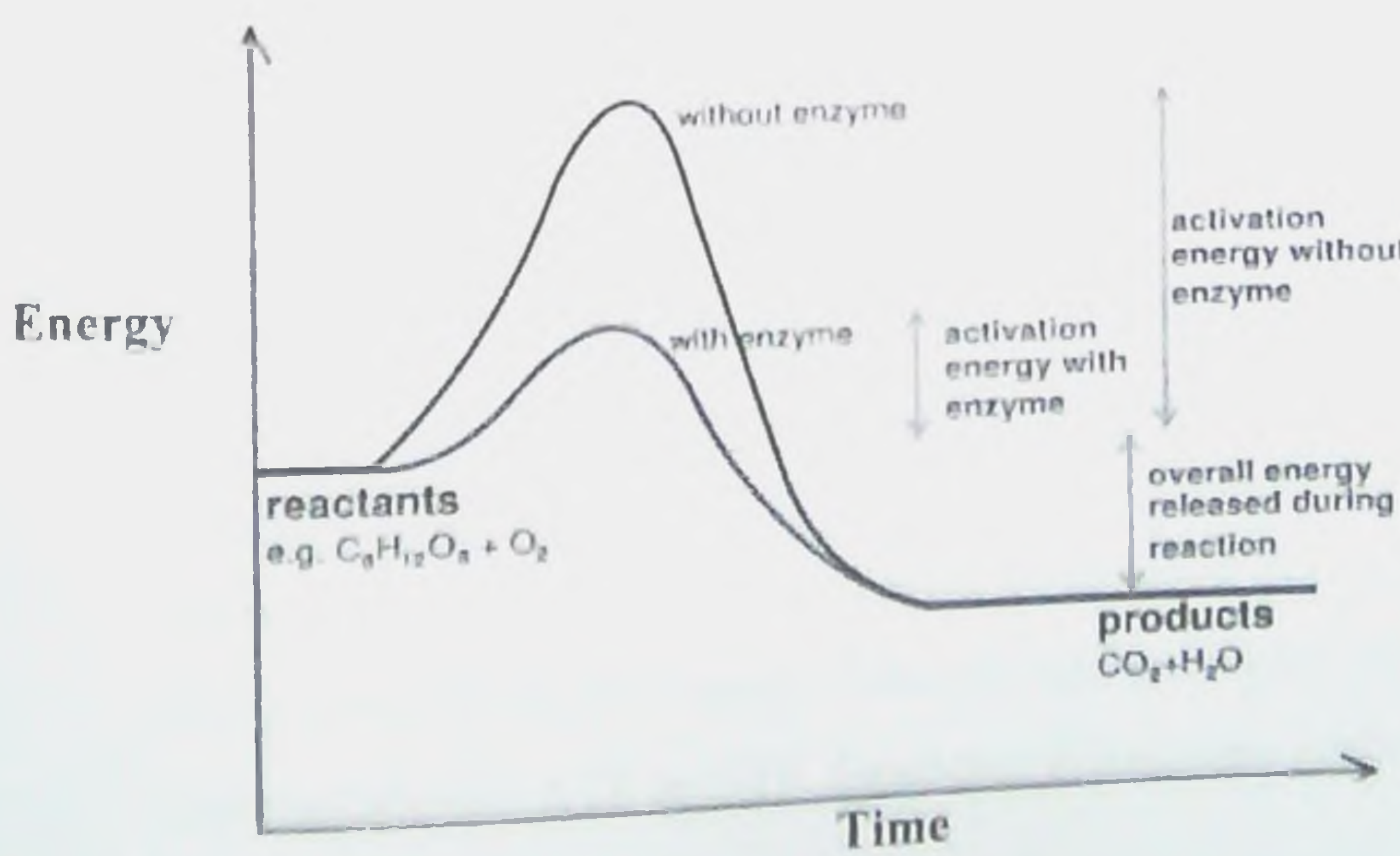

Figure No. 2

Reaction co-ordinate diagrams for an enzyme catalysed and uncatalysed reaction

CLASSIFICATION OF ENZYMES

Enzymes are classified and named by the Commission on Biochemical Nomenclature of the International Union of Biochemistry. The various enzymes have been classified in the following six classes; on the basis of general type of reaction they catalysed (Manay and Shadaksharaswamy, 2007).

a) **Oxidoreductases**: These are involved in redox reactions, *i.e.*, transfer of hydrogen or oxygen atoms between molecules. This class includes: dehydrogenases, oxidases, oxygenases, and peroxidaes. Example: glucose oxidase.

b) **Transferases**: Catayse the transfer of an atom or group of atoms between two molecules. The transferred groups are different from those transferred by the other classes of enzymes like oxidoreductases, etc. Example: aspartate aminotransferase.

c) **Hydrolases**: These are those enzymes, which catalyse hydrolytic reactions; this class includes esterases, glycosidases, proteases and lipases. Example: Chymosin.

d) **Lysases**: Are involved in elimination reactions resulting in the removal of a group of atoms from the substrate molecule. This class includes aldolases, decarboxylases, dehydratases and some pectinases. Example: histidine ammonia lyase.

e) **Isomerases**: Catalyse the formation of isomers of molecules; they include epimerases, racemases and intramolecular transferases. Example: xylose isomerase.

f) **Ligases**: These catalyse the formation of covalent bonds between two molecules utilising the energy obtained from hydrolysis of a nucleoside triphosphate like ATP or GTP. Example: glutathione synthase

ENZYMES Vs CHEMICAL CATALYSTS

Enzymes are similar to chemical catalysts in the following respects: (i) they lower the activation energy of reaction, (ii) they do not participate in the reaction, and return to their original form at the end of reaction, and (iii) they only increase the reaction rate. But (i) enzymes increase the rate of reaction at a phenomenal scale. They are (ii) highly specific in that they can distinguish between similar parts of the substrate molecule (regiospecificity), and between optical isomers of the substrate (steriospecificity). In addition, enzymes (iii) are subject to a variety of regulations, and (iv) their reaction rates show substrate saturation, which is not the case with chemical catalysts. Enzymes are attractive because (v) they operate under mild conditions of temperature, pressure and pH, which saves energy, and (vi) undesirable by- products are not produced by enzymes. Hence enzymes are the unique natural processing aids in the food and beverage industry.

Table -1 Enzymes Vs Chemical Catalysts

Enzymes	Chemical catalysts
Enzymes are proteins	Metal and non metal inorganic molecules
Natural non toxic substances	May /can be toxic
Highly specific	Non specific
Works at mild temperature, pH and pressure	Often high temperature and pressure required
Active at low concentration	Require high concentration
Rate of reaction enhanced by a factor of $10^3 - 10^6$	Rate of reaction enhancement only a fraction of that by enzymes
Reactions they catalyse can be easily controlled	Reactions they catalyse cannot be easily controlled
No unwanted side reactions	Side reactions may occur
Positive impact on environment	Negative impact on environment

SOURCES OF ENZYMES IN FOOD PROCESSING

Modern enzyme technology involves the use of exogenous enzymes obtained from various plant, animal or microbial sources (IUFoST, 2010). Plant enzymes are derived from a variety of plant sources and are most effective when addressing a broad pH range. Papain, a protein degrading enzyme from papaya, is used in meat tenderization, brewing and other protein modification applications. Animal enzymes, such as pancreatic enzymes, trypsin and rennet have a limited pH range and are specific in action. Chymosin, a widely used enzyme of animal origin, is a very selective clotting protease extracted from the fourth stomach of unweaned calves. Fungal and bacteria enzymes work in a broad pH range and are extracted from microorganisms after fermentation. Most commercial enzyme preparations come from bacterial or fungal fermentation. Microbial sources of enzymes are cost effective as the time required for large scale production is less. The desired enzyme has to be recovered in fairly large quantities with minimum contamination of other enzymes, spores, proteins etc. Lists of some industrially important enzymes are given in Table -2-6.

Table -2

Animal enzymes in food processing

Enzyme	Source
Lipase	Bovine pancreas
Trypsin	Bovine pancreas
Rennin	Stomach of unweaned calves
Catalase	Beef liver

Table -3

Plant enzymes in food processing

Enzyme	Source
Alpha amylase	Malted barley
Beta amylase	Malted barley
Beta glucanase	Malted barley
Ficin	Fig latex
Lipoxygenase	Soyabeans
Bromelin	Pineapple
Pectinase	Lemon peel
Papain	Papaya latex

Table -4

Bacterial enzymes in food processing

Enzyme	Source
Alpha amylase	*Bacillus*
Beta amylase	*Bacillus*
Glucose isomerase	*Bacillus*
Pullulanase	*Klebsiella*

Table -5

Fungal enzymes in food processing

Enzyme	Source
Alpha amylase	*Aspergillus*
Glucoamylase	*Aspergillus*
Pectinase	*Aspergillus*
Lactase	*Aspergillus*
Stachyase	*Aspergillus*
Protease	*Aspergillus*
Rennin	*Mucor miehei*

Table -6

Yeast enzymes in food processing

Enzyme	Source
Invertase	*Saccharomyces*
Raffinase	*Saccharomyces*
Lactase (Beta galactosidase)	*Kluyveromyces*

(Singh, 2007)

ROLE OF ENZYMES IN FOOD PROCESSING

Processed foods provide convenience, improved shelf - life, increased palatability and offer variety in the diet. Several processing techniques- physical and chemical - are used for obtaining the finished product. Chemical methods are harsh and affect the quality of the product adversely. Enzymes offer an alternative to chemical catalysts as they work under mild conditions of pH and temperature.

Enzymes are proteins, which catalyse and reduce the energy threshold requirements for chemical reactions. They function at the molecular level on substrates such as carbohydrates, proteins and fats. Hydrolysis by enzymes is largely responsible for many of the changes required by the food industries. After modification of the substrate, the enzyme remains unchanged. Enzymes are the unique natural processing aids in the food and beverage industry.

Enzymes present in the raw material can, along with processing, affect the functional and nutritional properties of the final product. Enzymes are commonly employed for texture modification, increasing yields, recovering high value ingredients, beverage clarification, as bakery aids, for meat tenderisation, milk coagulation and protein hydrolysate preparation (James and Simpson, 1996). Some commonly used enzymes in food processing are the carbohydrases, proteases, lipases and some oxidising enzymes (Manay and Shadaksharaswamy, 2007).

A) CARBOHYDRASES

Amongst carbohydrases, alpha and beta amylases which bring about hydrolytic cleavage of starch, invertase which hydrolyses sucrose into glucose and fructose, pectinases which hydrolyse pectic substances, cellulases which bring about the hydrolysis of cellulose and glucose isomerase which isomerises glucose to fructose are some of the enzymes used in food industries.

a) Amylases in baking: The use of special enzyme preparations is extensively important in baking, improving the loaf volume by increasing the available fermentable sugar. Flour normally contains two amylase alpha and beta amylases both together known as diastases. The substrate of the enzyme is starch. Complete hydrolysis of starch molecule can be carried out by the joint activity of the two enzymes.

The first stage in the baking process immediately following milling is the fermentation period, during which the alpha amylase catalyses the dextrinisation of the damaged starch granules. The dextrins are further hydrolysed by beta amylase and converted to maltose which provides the fermentable sugar for the yeast cells. The damaged starch granules produced by milling are the only ones accessible to the enzyme attack and therefore become the limiting factor in the fermentation period.

The enzymatic process discussed previously continues throughout the next stage, the baking process. The high oven temperatures during this period gelatinise the undamaged starch granule providing a more than adequate substrate for further enzymic attack. If during this baking period, the dextrinogenic activity of alpha amylase was uncontrolled, an over liquefaction of starch could result, producing a softening of the bread structure with the possible formation of a sticky crumb. This can be minimised by using the fungal (*Aspergillus*) alpha amylase preparations. Since this enzyme is heat sensitive, its activity will be destroyed as the oven temperature rises. The main advantage of fungal alpha amylase is to provide fermentable sugar for yeast fermentation to produce bread with a softer crumb, deeper crust colour, greater volume (due to carbon dioxide production) and improved grain and texture.

b) Amylase in confectionery: The thermo stability of bacterial (*Bacillus*) amylolytic enzymes, make them unsuitable for the baking industry, they make an ideal preparation for starch liquefaction. These enzymes will not attack raw starch but will degrade starch gels, thus their capacity to hydrolyse starch at these high gelling temperatures becomes an important feature. They are further applied in the liquefaction of heavy starch pastes formed as a result of excessive heat treatment of concentrated starchy products in the manufacture of glucose or glucose syrups. Example: chocolate syrup.

c) Amylases in brewing industry: The thermo stability of bacterial (*Bacillus*) amylolytic enzymes even at high temperatures is of considerable importance in the brewing industry where microbial amylases are added to supplement low diastatic malt. Amylases help in the conversion of starch to maltose for fermentation.

d) Invertase in confectionery: Invertase is responsible for the hydrolysis of sucrose. This hydrolytic process is called the inversion of sucrose, since there is an accompanying change in the optical rotation from positive (dextro) to negative (levo). The products of hydrolysis – invert sugar consists of equimolar amounts of glucose and fructose, have a much sweeter taste than the original sucrose. It is this property of sweetness characteristics of invert sugar that makes it invaluable in the confectionery industry. Invertase is available commercially from a number of sources including baker's and brewer's yeast as well as molds. It is commercially applied in the production of cream and liquid centers through its ability to liquefy cream or fondant containing material. Invertase has a further commercial application in the production of invert sugar syrup as well as artificial honey.

e) Glucose isomerase in confectionery: Glucose isomerase converts glucose to fructose. Cornsyrup treated with this enzyme gives high- fructose syrup, which is 50 per cent more sweet than sucrose. High fructose syrup is used in the manufacture of aerated drinks.

f) Pectinase in juice and wine industry: One of the major cause of haze formation in fruit juices and wines is attributed to the presence of cloud forming pectic substances particularly pectin. These substances are located in the cell walls and are liberated when the fruit is pulped. The colloidal properties associated with pectin in fruit juices hinder them from their sedimentation. In the presence of suitable enzyme preparation – pectinase- the pectin molecules are hydrolysed, the product formed will loose their colloidal properties associated with pectin. This loss in colloidal property facilitates a rapid sedimentation of the cloud – forming particles which can now be readily centrifuged, filtered off or decanted.

There are cases where cloud stability is desirable in fruit juices or tomato puree manufacture. In these processes it is important to preheat the juices to destroy any pectinase which may be present, thus ensuring a retained cloudiness.

Saritha (2011) found that a combination of banana fruit pulp, 0.3 per cent pectinase, *saccharomyces cerevisiae* and sugar gave maximum yield (82%) and clarity (87%) for the prepared banana wine.

Pectinase for fruit juice clarification under cold conditions is produced using cheap raw pectin rich substrates like orange peel, apple peel, grape must, guava pulp and mango peel, which are wastes from fruit processing industry (Padma *et al.*, 2011).

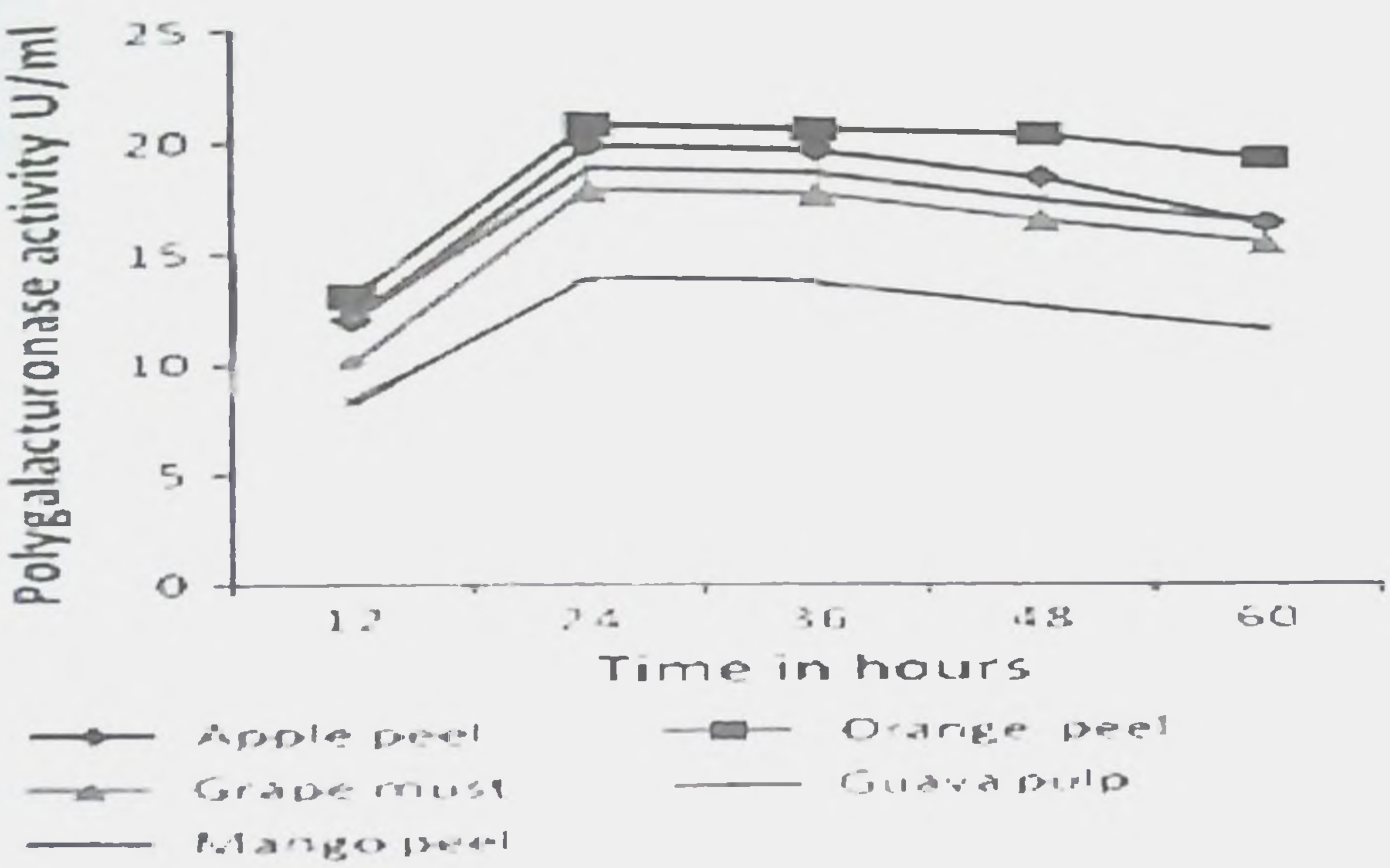

Figure No. 3

Pectinase production from pectin rich substrates like fruit wastes

Fruit waste utilisation for pectinase production through solid state fermentation was studied and maximum pectinase production was found from grape waste using *Aspergillus foetidus I 15* (Venkatesh, 2003).

g) Pectinases in coffee manufacture: Small quantities of pectic enzymes are used in coffee manufacture to accelerate the digestion of the mucilage.

h) Cellulases: Cellulase is used in the clarification of citrus and other juices where haze is due to a cellulose cloud formation. It also solubilises cellulose in more fibrous foods thereby improving their palaltability. So it is used to tenderise vegetables prior to cooking and also to extract flavour compounds from spices.

Vanillin is extracted from vanilla green pods using cellulose and pectinase (Teren *et al.*, 2001).

h) Hemicellulases: These enzymes are used in coffee manufacture to degrade the gums which normally cause the liquid coffee concentrate to gel during the production of the instant product.

j) Lactase: Lactase hydrolyses lactose in dairy products to glucose and galactose. It is used to prevent lactose crystallisation in ice cream. It is also used to prepare lactose hydrolysed products for lactose intolerant patients.

k) Stachyase: Hydrolyses stachyose. Hence it helps to decrease flatulence in leguminous products.

l) Naranginase: Hydrolyses the bitter component 'naringin' in grape fruit juice. Thus narnginase debitter grape fruit juices.

m) Limoninase: Hydrolyses the bitter component 'limonin' in orange juice.

B) PROTEASES

Proteases are enzymes that cleave a protein molecule by the hydrolysis of peptide bonds. They find important uses in many food industries, such as baking, meat tenderisation, cheese manufacture and beer manufacture.

i) Baking industry: Proteases are utilised in the baking industry since the main ingredients of flour are starch and protein. In the baking industry, to obtain a product of required volume, texture, flavor and better storage properties, it is necessary that both starch and the protein gluten of wheat flour undergo some degradative changes.

and also to extract flavour compounds from spices.

Vanillin is extracted from vanilla green pods using cellulose and pectinase (Teren *et al.*, 2001).

h) Hemicellulases: These enzymes are used in coffee manufacture to degrade the gums which normally cause the liquid coffee concentrate to gel during the production of the instant product.

j) Lactase: Lactase hydrolyses lactose in dairy products to glucose and galactose. It is used to prevent lactose crystallisation in ice cream. It is also used to prepare lactose hydrolysed products for lactose intolerant patients.

k) Stachyase: Hydrolyses stachyose. Hence it helps to decrease flatulence in leguminous products.

l) Naranginase: Hydrolyses the bitter component 'naringin' in grape fruit juice. Thus narnginase debitter grape fruit juices.

m) Limoninase: Hydrolyses the bitter component 'limonin' in orange juice.

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In general wheat contains a very low protease activity. So that flour milled from normal wheat usually reflects such a deficiency. As a result supplementation of this enzyme is required in the baking process. The source of this enzyme preparation is the same as that for the amylases *i.e.*, the fungus *Aspergillus oryzae*. The activity of the proteolytic enzyme is confined to the protein gluten, which is responsible for the visco elastic properties of the flour. It is in fact the quantity and quality of the gluten which is the critical factor on the resultant flour strength. A high protein concentration is normally associated with strong flour, resulting in dough with good tolerance to mixing. The property can be modified by improving agents such as bromates or peroxides which produce stronger flour.

The proteolytic enzyme attack brings about a decrease in the viscosity of the flour. This decrease in the viscosity results a reduction in mixing time to obtain the optimum gas retention in the dough, rends it more pliable and extensible. There is however a danger of excessive softening leading to unmanageable sticky dough if the enzyme concentration is too high. Modern industrial techniques can produce fungal enzyme supplements of required activity enabling the baking industry to control the condition of the dough to their own specific requirements. The fungal protease also plays an important role in improving the quality of the bread. Enzyme treated dough appear to have a much improved gas retention and overall, exhibit an increased volume, better symmetry and texture and improved flavour as well as better storage.

ii) Meat industry: Proteolytic enzymes are used in the tenderisation of meat. The value of enzymes in tenderising meat is not only commercial but has a nutritional role. The function of a tenderiser is to hydrolyse one or more of the muscle tissue components in particular sarcolemma which holds the muscle fibres together. If there is too great a degradation of the muscle fibres, this could lead to a mushy tissue. A number of proteolytic enzymes of plant, animal and microbial sources have proved to be efficient tenderisers. Among these are trypsin, papain, bromelin and Rhozyme P.11 respectively from bovine pancreas, papaya latex, pineapple, fig latex and *Aspergillus*.

The initial stage is to dissolve the sarcolemma followed by the disappearance of the nucleus, and degradation of the muscle fibres then occurs with complete loss of cross striations. Plant enzymes are characterised by their strong action on connective tissue (collagen) and this degradation can be enhanced by heating as carried out during cooking. Elastin the other major component of connective tissue is not altered either by cooking or aging and is present in large amounts in those tissues requiring tenderisation. Ficin, papain and bromelin all show extensive activity on elastin.

There are several ways by which tenderiser is applied. Such methods involve either sprinkling the meat cut with a powdered enzyme preparations or immersing it into a liquid preparation. Injection of a proteolytic enzyme into the vascular system of cattle prior to slaughter is also adopted.

The tenderisation effect of a new elastase from *Bacillus* sp. EL31410 and papain was investigated on beef meat and found that *Bacillus* elastase (EL31410) is a promising substitute for papain as a favourable meat tenderiser (Qihe, 2006).

iii) Brewing industry: Protease is used to remove non-biological haze in beer. Haze in beer can be either due to the proliferation of infecting microorganisms (biological haze) or as a result of chemical reaction between substances in the beer (non biological haze). Modern technology has now eliminated the biological type of haze while the latter type is still a serious problem.

The non biological haze is a result of the combination of polypeptide and tannin molecules in beer giving rise to easily observed particles. Carbohydrates and heavy metals are also involved in this reaction. Overall there appear to be two stages in beer leading to this type of haze formation.

1) The ploymerisation of the tannin molecules to form active polymers.

2) The reaction between the active polymers and polypeptide molecules.

The condensation of a tannin and polypeptide occurs in several steps. Initially there is a reversible association between tannin and polypeptide through hydrogen bonding between the hydroxyl group of the tannin and the carboxyl group of the polypeptide link. This weak linkage is then further stabilised by the formation of a strong covalent bond. Proteolytic enzymes are used successfully in preventing this type of haze; since the protein molecule is considerably larger than the tannin component, it is their size which determines the final aggregate size. Consequently by reducing the polypeptide size with suitable enzyme preparations, the time for the aggregate to reach optical size will be increased.

iv) Cheese manufacture: Rennin, a major proteolytic enzyme obtained from the stomach of calf, plays an important role in the production of cheese. The primary stage in the process involves the curdling of milk by rennin, obtained commercially from the stomach of a calf.

Other proteases can also curdle milk but of all of them, rennin and pepsin produce the largest amount of curd over the same period of time. The ferment curd obtained using rennin had an enzyme activity ten fold greater than that of any other protease.

v) Production of protein hydrolysates: Protease, have been used to hydrolyse soybean or ground nut protein isolates, casein, fish, meat etc. to produce protein hydrolysates. Papain and fungal protease are used on a commercial scale.

Protein hydrolysates were prepared from bovine lung, bovine rumen and from partially defatted tissue by treatment at 50°C with pepsin at pH 3·0 (Webster *et al*., 2003).

C) LIPASES

Lipases are enzymes that hydrolyse ester linkages in glycerides.

i) Cheese manufacture: This group of enzymes plays a major role in cheese manufacture and their hydrolytic activity is determined by the micro flora of cheese. At various phases during the ripening of the product a different microorganism will predominant by its enzymic activity.

There are two main type of cheese, hard and soft. In the hard cheese the ripening is brought about by bacterial action in the cheese itself. For example in cheddar cheese, the organism involved is *L. cirovorum*. In contrast to this the soft varieties involve yeasts, slime molds or bacteria on the surface of the cheese, limiting the final product to a small size to ensure penetration of the surface microorganisms which will result in uniform flavour throughout the cheese.

During cheese ripening there is extensive lipolysis of the butterfat and work has been carried out to supplement lipolytic activity of the microorganisms with enzymes.

The use of pregastric esterases has been successfully utilised in cheese ripening. These enzymes have been extracted from the exercised glands of cattle, lamb and goats. They liberate free fatty acids from cream.

ii) Break down emulsions: Lipases helps to break down emulsions

iii) Whipping properties of egg albumin: Lipases helps to improve whipping properties of egg albumin

The negative effects of egg yolk contamination in egg whites on the functional properties like foam volume, foam capacity, and foaming power can be reversed by treatment with *Mucor miehei* lipase (Macherey *et al.*, 2011).

D) OXIDOREDUCTASES

Some important oxidoreductases are glucose oxidase, catalase, peroxidase and lipoxygenases.

i) Glucose oxidase: Glucose oxidase is an enzyme which oxidises glucose to gluconic acid in presence of oxygen and in the process hydrogen peroxide is formed.

Glucose oxidase is commercially used to remove traces of glucose and oxygen in a variety of food products, such as beer, cheese, carbonated beverages, dried eggs, wines, etc., to prevent deterioration during storage by oxidation or browning.

ii) Catalase: Catalase destroys hydrogen peroxide used for food sterilization. It is also used to remove hydrogen peroxide from glucose oxidase reaction.

iii) Peroxidase: Peroxidases are enzymes which oxidise hydrogen peroxide or organic peroxides in the presence of an oxidisable substance. This enzyme is quite heat stable. About 50 per cent of enzyme activity remains even after the enzyme is heated at 85^0C for over 30 minutes.Because of this property the activity of this enzyme is used to detect effectiveness of blanching. The loss of peroxidase activity in a blanched food product is taken to indicate the inactivation of the deteriorative enzymes.

iv) Lipoxygenases: Lipoxygenases are used in some countries, particularly, United States and Canada in the production of bread. The enzyme brings about bleaching by oxidation of the natural pigments of the flour to produce a very white crumb.

MISCELLANEOUS APPLICATION OF ENZYMES IN FOOD PROCESSING

Enzymes have been used in the processing of several other food products. These are briefly described below.

i) Diacetyl reductase: Diacetyl is formed in varying amounts in beer during fermentation. It imparts the flavour of butter to beer. The enzyme diacetyl reductase obtained from *Aerobacter aerogenes* has been added to beer to reduce diacetyl to 2, 3 butylene glycol which has no flavour (Swaminathan, 1987).

ii) Tannase: Tannase helps in solubilising tea solids. Brewed tea becomes turbid due to the precipitation of proteins by tannins. The enzyme tannase obtained from *A.niger* has been used to hydrolyse tannins and prevent the precipitation of proteins.

iii) Myrosinase: Myrosinase helps to detoxify thioglucoside in mustard and rape seeds. By the action of the enzyme myrosinase, on the toxic glycoside present in rape and mustard seeds, allyl isothiocyanate is released. This is recovered as a volatile material by steam distillation.

iv) Lysozyme: This enzyme has been used in humanising cow's milk. Human milk contains lysozyme while cow's milk does not contain this enzyme. Lysozyme is being added to cow's milk to make it more suitable for human infants. Lysozyme has also been used as a preservative for milk, cheese, etc.

v) Phytases: The mineral content of legumes is generally high, but the bioavailability is poor due to the presence of phytate, which inhibits iron and zinc absorption. The antinutritional effect of phytate is due to its chelating nature. Phytases reduces or eliminates the chelating ability of phytate. Chinese Academy of Agricultural Sciences (CAAS) developed a corn with high levels of phytase (IUFoST, 2010).

vi) Asparaginase: Many plant derived food ingredients such as rice, wheat, corn, barley, soy, potato and oats are primarily carbohydrate rich with sufficient amounts of aspargine in the protein content. The reaction between reducing sugars and amino acids is responsible for the colour and flavour in many of the baked, fried and toasted foods. Acrylamide, a by- product of the cooking process, is formed by the reaction of asparagine, an amino acid and a carbonyl group of reducing sugars (glucose) at high temperatures of cooking. The discovery of acrylamide in food is of great concern because it is a potential human carcinogen. Asparaginase catalyses the conversion of aspargine to aspartic acid and ammonia. Treatment of potato chips with a solution of asparaginase decreased the content of acrylamide by 60 per cent (Pedreschi *et al*., 2008).Aspartic acid, the product does not react form acrylamide. The browning, taste and nutritional properties remain unaffected.

IMMOBILISATION OF ENZYMES

The term 'immobilised' means unable to move or stationary. Enzyme immobilisation can be defined as the attachment of enzymes to different types of supports resulting in reduction or loss of mobility of the enzyme (Khan and Alzohairy, 2010). The materials used for immobilisation of enzymes, called carrier matrices, are usually organic inert polymers or inorganic materials. The various methods used for immobilisation of enzymes may be grouped into the following four types: (a) adsorption, (b) covalent bonding, (c) entrapment, and (d) membrane confinement.

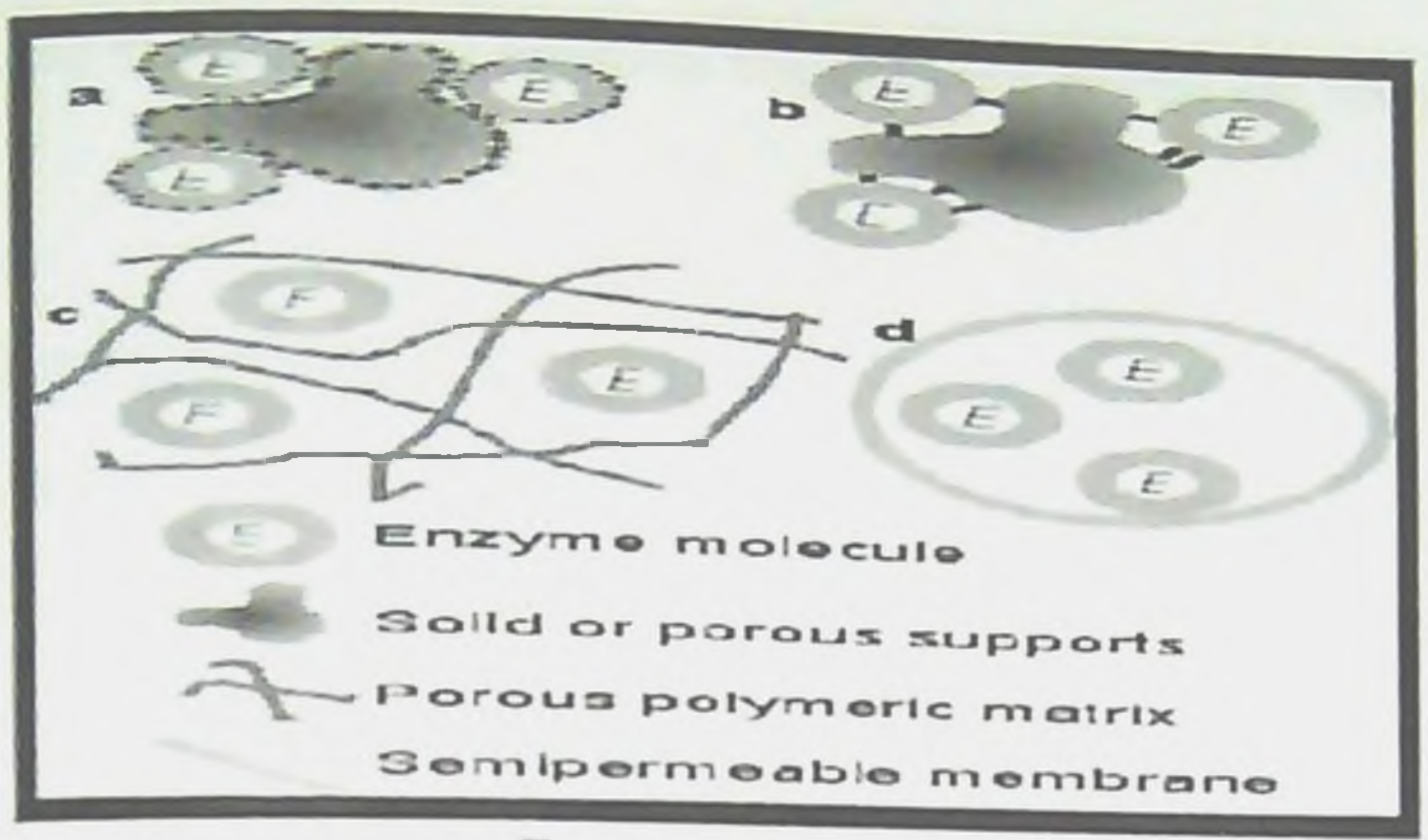

Figure- No. 4

Methods of immobilization

a) Adsorption: In case of adsorption, the enzyme molecules adhere to the surface of carrier matrix due to a combination of hydrophobic effects and the formation of several salt links per enzyme molecule. Some of the commonly used matrices are ion exchange matrices, porous carbon, clays, hydrous metal oxides, glasses, and polymeric aromatic resins.

Invertase was adsorbed onto micro-porous acid-activated montmorillonite clay (K-10) by two procedures, namely adsorption and covalent binding (Sanjay and Sugunan, 2006).

b) Covalent binding: In this system the enzyme molecules are attached to the carrier matrix by the formation of covalent bonds. As a result, the strength of binding is very strong. The most commonly employed matrices are agarose, celluloses and polyacrylamides.

c) Entrapment: In this approach, enzyme molecules are held or entrapped within suitable gels or fibres and there may or may not be covalent bond formation between the enzyme molecules and the matrix.

d) Membrane confinement: Enzyme molecules, usually in an aqueous solution, may be confined within a semipermeable membrane which ideally, allows a free movement in either direction to the substrates and products but does not permit the enzyme molecules to escape.

ADVANTAGES OF IMMOBILISATION

1. Enzymes are costly items. Immobilisation permits their repeated use.
2. The product is readily freed from the enzyme.
3. Continuous production systems can be used, which is not possible with free enzymes.

The production of galacto-oligosaccharides (GOS) from lactose by *A. oryzae* beta-galactosidase immobilised on cotton cloth was studied. The thermal stability of the enzyme increased approximately 25-fold upon immobilization on cotton cloth (Albayrak and Yang, 2002).

COMMERCIAL ENZYMES

List of some of the commercial enzymes available in the market is given below:

Table -7

Commercial enzymes

Product Name	Industrial application
BakeWell FA	Fungal amylase enzyme for dough improvement in bread-making
BakeWell FP	Fungal protease for dough dough improvement in bread-making
Ultrabrew APG	Mixture of Amylase, Protease and Beta Glucanase for filteration
Ultrabrew FA	Fungal Alpha Amylase for fermentation

CONCLUSION

Enzymes occur in all living organisms and catalyse biochemical reactions necessary to support life. Enzymes have many applications in modern food processing. Their property benefits both the food industry and the consumer. Enzymes are able to selectively improve flavour, texture, nutritional value and digestibility of foods, because of their efficiency and specificity. The role of enzymes in efficient use of raw materials, improved product recovery and quality management may lead to better applications of enzymes in the coming decades.

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DISCUSSION

1. How are enzyme preparations made?

Ans: Commercial sources of enzymes are obtained from three primary sources, *i.e.*, animal tissue, plants and microbes. These naturally occurring enzymes are quite often not readily available in sufficient quantities for food applications or industrial use. However, by isolating microbial strains that produce the desired enzyme and optimising the conditions for growth, commercial quantities can be obtained. This technique is called fermentation. Once fermentation is completed, the microorganisms are destroyed; the enzymes are isolated, and further processed for commercial use.

2. What is IUFoST?

Ans: International Union of Food Science and Technology

3. What is the purpose of immobilisation?

Ans: Enzymes are generally rather difficult to isolate in pure form. However, after purification, they spontaneously denature. Finally to be used, they need to be mixed with the substrate, after which it may be very difficult to get the enzyme back. Enzyme immobilization is a technique to solve this problem.

4. Are enzymes living organisms?

Ans: No. Although enzymes are formed in living cells, they are not living materials.

ABSTRACT

Catalysts are substances that modify and increase the rate of a chemical reaction without being consumed in the process. Based on the source, catalysts can be divided into two: chemical catalysts and biological catalysts. Enzymes are the biological catalysts. Pelczer *et al.* (1996) defined enzymes as the biocatalysts, which break down the macromolecule to simpler forms, without undergoing any change by themselves. In 1877, German physiologist Wilhelm Kuhne first used the term enzyme. The name comes from the Greek word *zymosis* meaning 'in leaven' or yeast.

An enzyme molecule has a highly specific binding site or active site to which its substrate binds to produce enzyme-substrate complex. The reaction proceeds at the binding site to produce the products, which remain associated with the enzyme. The product is then liberated and the enzyme molecule is freed in an active state to initiate another round of catalysis. The most important feature of enzyme catalysis is stabilisation of the transition state of the substrates and the reduction of the activation energy of the overall reaction. Enzymes are categorised into six main groups on the basis of the general type of reaction they catalyse.

Enzymes are the unique natural processing aids in the food and beverage industry. There are a number of advantages of using enzymes in food processing. Enzymes are natural nontoxic substances that catalyse a given reaction without causing unwanted side reactions. They are active under mild conditions of temperature and pH, active at low concentrations and the reactions they catalyse can be easily controlled.

Enzymes used in food processing are obtained from three primary sources, i.e., animal tissue, plants and microbes. Enzymes are commonly employed for texture modification, increasing yields, recovering high value ingredients, beverage clarification, as bakery aids, for meat tenderisation, milk coagulation and protein hydrolysate preparation (James and Simpson, 1996).

Some commonly used enzymes in food processing are the carbohydrases, proteases, lipases and some oxidizing enzymes. Amongst carbohydrases, alpha and beta – amylases, invertase, cellulase, glucose isomerase and pectinases, are some of the enzymes used in food processing industry. Pectinases for fruit juice clarification under cold conditions is produced using cheap raw pectin rich substrates like orange peel, apple peel and mango peel which are wastes from fruit processing industry (Padma *et al.*, 2011). Proteases are enzymes that cleave a protein molecule by the hydrolysis of peptide bonds. They find important uses in many industries such as baking, meat tenderisation, cheese and beer manufacture. Lipases are enzymes that hydrolyse ester linkages in fats liberating free fatty acids. Lipases are mainly involved in the manufacture of cheese.

Ordinarily, added enzymes are inactivated after they serve the desired purpose, so it cannot be used again. Enzyme immobilisation is a technique to solve this problem. Enzyme immobilisation can be defined as the attachment of enzymes to different types of supports resulting in reduction or loss of mobility of the enzyme (Khan and Alzohairy, 2010).

Enzymes are able to selectively improve flavour, texture, nutritional value and digestibility of foods, because of their efficiency and specificity. The role of enzymes in efficient use of raw materials, improved product recovery and quality may lead to better applications of enzymes in the coming decades.

DIABETES MELLITUS - A GLOBAL THREAT AND ITS DIETARY MANAGEMENT

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DIABETES MELLITUS - A GLOBAL THREAT AND ITS DIETARY MANAGEMENT

1. INTRODUCTION

Diabetes mellitus is a silent chronic disorder characterized by elevated blood sugar levels either due to defective insulin secretion or action or both. It is associated with altered metabolism of carbohydrates, fats and proteins. *Diabetes* is the Greek word for 'siphon' (since people with uncontrolled diabetes tend to urinate copiously) and *mellitus* is Latin word for 'honey' or 'sweet'.

2. WHAT IS DIABETES?

Diabetes or 'madhumeham' is a disease related to sweetness. Man requires energy for all of the daily activities. This energy is mainly derived from carbohydrates. When we eat carbohydrates through our diet, our blood sugar increases. If it rises beyond 180 mg/dl, sugar is excreted in the urine. Normally, insulin, a hormone produced by the beta cells of the pancreas helps to utilise sugar for the production of energy by the body. It helps in glucose uptake by the cells, prevents a rise in blood sugar and maintains its level within certain standard limits. In diabetes, either the pancreas cannot produce enough insulin or what is produced is not enough in controlling the blood sugar. This affects the metabolism of several nutrients.

3. DEFINITION

The term diabetes mellitus describes a metabolic disorder of multiple aetiology characterized by chronic hyperglycaemia with disturbances of carbohydrate, protein and fat metabolism resulting from defects in insulin secretion, action, or both. The effects of diabetes mellitus include long-term damage, dysfunction and failure of various organs (WHO, 2010).

Diabetes is a disease in which the body does not produce or properly use insulin to convert sugar, starches and other food into energy needed for daily life (ADA, 2010). Diabetes mellitus is a chronic metabolic disorder that prevents the body to utilise glucose completely or partially. It is characterised by raised blood glucose concentration and alterations in the carbohydrate, protein and fat metabolism (Sreelakshmi, 2000).

4. PREVALENCE

World Health Organisation predicts that developing countries will bear the burnt of this epidemic in the 21st century. Currently, more than 70 per cent of people in the world with diabetes live in low and middle-income countries. An estimated 285 million people, corresponding to 6.4 per cent of the world's adult population, lived with diabetes in 2010. The number is expected to grow to 438 million by 2030, corresponding to 7.8 per cent of the adult population.

In the United States, there are some 21 million diabetics, of whom roughly 15 million are diagnosed and the remainder are undiagnosed (Katz, 2008).

With an estimated 50.8 million people living with diabetes, India has the world's largest diabetes population, followed by China with 43.2 million. The largest age group currently affected by diabetes is between 40-59 years (IDF, 2010). In Kerala, 14.9 percent men and13.2 percent women live with diabetes. Approximately 16 million men and 14 million women suffered from Type 2 diabetes.

Though, the highest increase in prevalence will be in China, the greatest increase in numbers will be seen in India. The number of diabetics will rise from 19 million in 1995 to 57 million in 2025, heading the list of countries with the greatest numbers of diabetics. ndia is thus designated to become the "diabetes capital of the world". The global increase n diabetes occurred because of population ageing and growth, and of increasing trends owards obesity, unhealthy diets and sedentary lifestyles (Das and Rai, 2008).

The prevalence of diabetes in India is steadily increasing in the urban areas from 2.1 er cent reported in early 1970 to 12.4 per cent in 2001.There is also evidence to suggest ıat prevalence of diabetes even in rural areas is slowly increasing from 1.3 per cent in 979 to 2.5 per cent in 2001. Based on the available data, there are about 25 million ersons with diabetes, of which only 3.6 million receive pharmacological treatments (Rau d Shivashankara, 2008).

Diabetes is one of the major causes of premature death worldwide. Every 10 seconds a rson dies from diabetes-related causes, mainly from cardiovascular disease. Diabetes is a ent epidemic that claims as many lives each year as HIV/AIDS. In India, 62,506 people urban and 46,627 people in rural area died due to complications associated with ibetes mellitus (WHO, 2004).

5. TYPES (CLASSIFICATION)

The classification encompasses both *clinical stages* and *aetiological types* of diabetes mellitus and other categories of hyperglycaemia. The clinical staging reflects that diabetes, regardless of its aetiology, progresses through several clinical stages during its natural history. Moreover, individual subjects may move from stage to stage in either direction. Persons who have, or who are developing, diabetes mellitus can be categorized by stage according to the clinical characteristics, even in the absence of information concerning the underlying aetiology. The classification by aetiological type results from improved understanding of the causes of diabetes mellitus.

The first widely accepted classification of diabetes mellitus was published by WHO in 1980 and, in modified form, in 1985 (WHO, 1985). According to this, there are mainly 5 types.

1. Insulin dependent Diabetes Mellitus (IDDM)
   - Ketosis prone
   - Ketosis resistant
   - With pancreatic calculi
2. Non-insulin dependent Diabetes Mellitus (NIDDM)
3. Gestational Diabetes Mellitus (GDM)
4. Malnutrition related Diabetes Mellitus (MRDM)
5. Impaired glucose tolerance (IGT)

5.1. TYPE1 OR INSULIN DEPENDENT DIABETES MELLITUS (IDDM)

Type 1 diabetes is often called juvenile onset diabetes. Type 1 diabetes can occur at any age, but it usually starts in people younger than 30. It develops most often in children and young adults. Symptoms are usually severe and occur rapidly. The child is usually under weight. Ketoacidosis is common. The pancreas produces little or no insulin. A person who has type 1 diabetes must take insulin daily to live.

Without adequate insulin, glucose builds up in the bloodstream instead of going into the cells. The body is unable to use this glucose for energy despite high levels in the bloodstream, leading to increased hunger. In addition, the high level of glucose in the blood causes the diabetic patient to urinate more, which in turn causes excessive thirst. This type can be further classified into three types.

5.1.1 Ketosis-prone

These are especially seen in the west. The onset is sudden and the children are prone to lapse into coma

5.1.2 Ketosis-resistant

These are especially seen in the tropics. It is originally developed in Jamaica and labeled 'J' type; they are also seen in India.

5.1.3 With pancreatic calculi

This is most common in South India with intermittent abdominal pain. Stones are observed in the pancreatic duct.

RISK FACTORS

1. Autoimmune attack

Type 1 diabetes is an autoimmune disease. An autoimmune disease results when the body's system for fighting infection, the immune system, turns against a part of the body. In diabetes, the immune system attacks and destroys the insulin-producing beta cells in the pancreas. Scientists do not know exactly what causes the body's immune system to attack the beta cells, but they believe that autoimmune, genetic, and environmental factors, possibly viruses, are involved.

2. Family history

Heredity is a small factor in predicting type1 diabetes. People with an immediate family member who has type 1 diabetes are fifteen times more likely than the general population to develop the disease.

Table 1. Risk of diabetes based on heredity

Family history	Risk of diabetes (%)
One parent diabetic	5
Father diabetic	6
Mother diabetic	3
One twin diabetic	30 to 70
Close relative diabetic	10

3. Environmental triggers

The exact theory behind environmental factor is not known. Environmental toxins, virus or medication may be the physiological straw for children predisposed to the disease. Clinical studies implicated that fourteen different viruses develop the disease namely, adenovirus, coxsackie B virus, mumps virus, enterviruses, rubella virus etc.

Symptoms of IDDM

- Polydypsia (increased thirst)
- Polyuria (increased urination)
- Polyphagia (increased appetite)
- Weight loss
- Nausea
- Vomiting
- Abdominal pain
- Fatigue
- Blurred vision

- Dry, itchy skin
- Headaches
- High blood pressure
- Delayed wound healing

5.2.TYPE II OR INSULIN DEPENDENT DIABETES MELLITUS (NIDDM)

Type 2 diabetes, often called adult or non-insulin-dependent diabetes .Type 2 diabetes is a chronic, life-long disease that results when the body's insulin does not work effectively. The insulin is either too little or excess. So rarely develop Ketoacidosis. Insulin is necessary for glucose to move from the blood to the inside of the cells. As insulin is present, the patients can control blood sugar by oral hypoglycemic drugs, diet and exercise.

Type 2 diabetes usually occurs gradually. Most people with type 2 diabetes are overweight at the time of diagnosis. However, the disease can also develop in lean people, especially if elderly. The onset appears after 40 years of age.

Unless glucose gets into cells, the body cannot use it for energy. Excess glucose remains in the blood, and is then removed by the kidneys. A main component of type 2 diabetes is "insulin resistance". This means that the insulin produced by the pancreas cannot connect with fat and muscle cells to let glucose inside and produce energy. This causes hyperglycemia (high blood glucose).

RISK FACTORS

The biggest indicator of type 2 diabetes is the diagnosed presence of prediabetes. But since the vast majority of people with prediabetes remain undiagnosed, assessing the presence of the other common risk factors for type 2 diabetes is important.

1. **Age**

According to American Diabetes Association, over half of all cases of type 2 occur in people over age 55, and close to seven million people aged 65 and older suffer from the disease. Individuals over age 45 should be tested for diabetes and retested every month if the initial test is normal.

2. Heredity

Heredity plays a major role in the development of type 2 diabetes. If there is a first degree relative with type2 diabetes, the chance of developing the disease is doubled.

Table 2. Risk of diabetes based on family history

Family history	Risk of diabetes (%)
Both parent diabetic	99
One parent diabetic	50
Close relative diabetic	25
Twin diabetic	90

3. Obesity

People who eat too much food and lead a sedentary life become overweight and obese. Obesity reduces the sensitivity of tissues to the action of insulin in the utilisation of glucose.

Why weight is a risk factor?

Too much fat makes it difficult for the body to use its own insulin to process blood glucose and bring it down to normal circulating levels. There are three reasons.

- Overweight people have fewer available insulin receptors

When compared to muscle cells, fat cells have fewer insulin receptors, the place where the insulin binds with the cell and 'unlocks' it to process glucose into energy.

- More fat requires more insulin

The pancreas starts producing larger and larger quantities of insulin in order to 'feed' body mass, and consequently insulin resistance occurs. Excess sugar must be stored as fat, and excess fat promotes further insulin resistance.

- Fat cells release free fatty acids

Fat cells and tissue, particularly abdominal fat, release free fatty acids, which interfere with glucose metabolism.

Leptin, a hormone in fat cells that helps to metabolize fatty acids, has provided an important clue to the relationship between obesity and type 2 diabetes. Leptin also plays a part in sending satiety or 'all full'signal to the brain to stop eating when body fat increases, and an 'empty' signal when body fat is insufficient. It appears that a type of leptin resistance may lead to a situation where fatty acids are deposited instead of metabolized, leading to eventual insulin resistance.

4. Smoking

Smoking constricts blood vessels, raising blood pressure and increasing the risk of coronary artery disease. It also stimulates the release of catecholamines, which have been shown to promote insulin resistance.

5. Stress

During stress the body releases adrenaline, noradrenaline and cortisol hormones that raise blood glucose levels to provide a quick source of energy for coping with stress. In acute cases of stress blood glucose levels may rise quite profoundly and in extreme cases diabetic ketosis and coma also may result particularly in those with a genetic predisposition.

6. History of gestational diabetes

Pregnant women who have a risk of diabetes develop related complications and after delivery can also continue with the diabetic conditions.

SYMPTOMS

- Polydypsia (increased thirst)
- Polyuria (increased urination)
- Polyphagia (increased appetite)
- Sudden weight loss
- Tiredness

- Blurred vision
- Headache
- High blood pressure
- Delayed wound healing
- Sexual problems
- Numbness or tingling in hands and feet
- Vaginal infections

Table 3. Difference between IDDM and NIDDM

IDDM	NIDDM
Inflammatory reaction in islets (insulitis)	No insulitis
Destruction of beta cells	No destruction of beta cells
Presence of islet cell antibodies	No islet cell antibodies
No genetic bias	Strongly genetic bias

5.3 GESTATIONAL DIABETES

Gestational diabetes mellitus (GDM) resembles type 2 diabetes in several respects, involving a combination of relatively inadequate insulin secretion and responsiveness. It occurs in about 2–5 per cent of all pregnancies and may improve or disappear after delivery. Gestational diabetes is fully treatable but requires careful medical supervision throughout pregnancy. About 20–50 per cent of affected women develop type 2 diabetes later in life.

Even though it may be transient, untreated gestational diabetes can damage the health of the foetus or mother. Risks to the baby include macrosomia (high birth weight), congenital cardiac and central nervous system anomalies, and skeletal muscle malformations. Increased foetal insulin may inhibit foetal surfactant production and cause respiratory distress syndrome. Hyperbilirubinemia may result from red blood cell destruction. In severe cases, perinatal death may occur, most commonly as a result of poor placental perfusion due to vascular impairment. Labor induction may be indicated with decreased placental function. A cesarean section may be performed if there is marked foetal distress or an increased risk of injury associated with macrosomia, such as shoulder dystocia.

Symptoms

- Increased thirst
- Increased urination
- Weight loss inspite of increased appetite
- Fatigue
- Nausea and vomiting
- Frequent infections including those of the bladder, vagina, and skin
- Blurred vision

5.4 MALNUTRITION RELATED DIABETES MELLITUS (MRDM)

This type of diabetes has been categorized as a separate entity. It is often seen commonly in developing countries, India being one of them. It occurs in the young mostly between the ages of 15-30 years. People look thin, lean and malnourished. The reason for this type of diabetes is that the pancreas does not produce enough insulin (necrotic tissues on the pancreas) and hence these individuals require insulin. Very often hormonal disorders may occur. It has also been seen that when insulin is discontinued, the complications are lesser than type1 diabetes.

5.5. IMPAIRED GLUCOSE TOLERANCE (IGT)

Glucose tolerance is assessed by taking the fasting blood sugar value. An oral glucose load of 75 grams glucose is administered and blood sugar value checked again after 1 ½ -2 hrs. The value of sugar obtained is checked against the normal fasting value. If values are above normal, then the condition is described as impaired glucose tolerance. In this type, the individuals are free from the symptoms of diabetes. But they could develop diabetes at a later stage if they are unable to control the diet and avoid obesity. Regular exercise also helps in maintaining the blood sugar levels.

6. METABOLISM IN DIABETES

When insulin is not produced or is ineffective, the formation of glycogen is decreased, and the utilisation of glucose in the peripheral tissues is reduced. This is achieved by hyperglycemia and gluconeogenesis. When the blood glucose level exceeds the renal threshold glycosuria develops. The loss of glucose in the urine results in an increased elimination of sodium and water. As a result rapid dehydration and thirst occurs. With deficiency of insulin, carbohydrate is not fully utilised for energy and for this purpose fat is used and lipolysis is greatly increased. The fatty acids released from adipose tissue are oxidised by the liver to form 'ketone bodies'. The appearance of one of these ketones, acetone in the urine produces ketoacidosis. Acetone is excreted by the lungs and gives the acetone smell in the breath of diabetics. The ketones (organic acids) combined with base so that the alkaline reserve is depleted, and the accompanying dehydration leads to circulatory failure, renal failure and coma. The rapid release of fatty acids into the blood circulation results in hypercholesterolaemia and development of atherosclerosis. Tissue protein is also broken down in an effect to secure energy causing weight loss and nitrogen excretion in the urine. Also, blood supply to the brain is affected due to defect in glucose metabolism and as a result stupor (a deep sleep like state) and lethargy (reduction in alertness) occurs.

7. DIAGNOSIS

A diagnosis of diabetes is a scary thing, but having a health team that is knowledgeable and communicative can make the ride a little less bumpy. Diabetes is diagnosed through a lab test that measures the level of glucose in the blood. In the absence of overt symptoms or a hyperglycemic crisis, two tests taken on different days are recommended to confirm the diagnosis. There are different types of diagnostic blood and urine tests conducted to detect diabetes mellitus.

7.1. FASTING BLOOD SUGAR TEST (FBS)

This test measures plasma glucose levels at the fasting stage. No food or drink is given from 8 to 12 hours prior to test. Fasting stimulates the release of the hormone glucagon, which in turn raises plasma glucose levels by triggering the breakdown of glycogen (stored glucose) in the liver. In people without diabetes, the body will produce and process insulin to counteract this rise in glucose levels. With diabetes, this does not happen and the tested glucose levels will remain high. Blood is taken by a finger prick or from the vein.

Finger-prick Blood Sugar Screening: It is a quick process and requires only a drop of blood by a prick on the fingertip

- Blood sample is placed on a plastic strip.
- The strip is then inserted into a small machine that reads accurate blood sugar level

From vein: Blood is drawn from the vein and tested for blood glucose level.

According to ADA (2010) clinical practice guidelines, a fasting reading of 126 mg/dl or higher indicates diabetes, and a second test on a different day should be performed to confirm the diagnosis. If test results are less than 126 mg/dl, but symptoms of diabetes are present a follow-up oral glucose tolerance test should be performed.

7.2. ORAL GLUCOSE TOLERANCE TEST (OGTT)

The OGTT is a test that measures blood glucose at hourly intervals over a three-hour period. This test is always conducted early in the morning on an empty stomach

- The eight to twelve hour interval between last meal and the first blood sample gives us the fasting glucose level in the blood.
- After that 75g of glucose for adults and 1.75 g/kg of body weight glucose for children is orally administered.
- Blood samples are then taken on hourly basis for next three hours and the glucose level is measured.

When glucose is given to the subjects, it causes glucose levels to rise in the first hour, and then fall back to normal within three hours as the body produces more insulin to normalize glucose levels. So the test is done at hourly intervals. People who have worse glucose tolerance may have high blood sugar level after meals. Their fasting level may however lie within the normal range. Such people are not diabetic but are likely to develop it.

7.3. RANDOM BLOOD SUGAR TEST (RBS)

The random blood sugar test, also called a casual plasma glucose test, can be given at any time of the day, regardless of whether the patient has eaten or not. This test forms a part of a regular physical examination and helps to assess the state of health. Small blood sample is drawn from the vein for analysis.

Table 4. Criteria for diagnosis

Test	Normal levels (mg/dl)	Impaired glucose tolerance (mg/dl)	Diabetes (mg/dl)
FBS	<110	≥110 and <126	≥126
OGTT	140]	≥140 and <200	≥200
RBS			≥200 in presence of symptoms

(ADA, 2010)

Table 5. Guidelines for diagnosing gestational diabetes

Test	Range (mg/dl)
FBS	≤ 95
1 hour OGTT	≤ 1140
2 hour OGTT	≤ 120

(ADA, 2010

7.4. GLYCATED HAEMOGLOBIN TEST (HbA-1C TEST)

After diabetes is confirmed another test called glycated haemoglobin test is done to measure average blood sugar level for around three months. Unlike other blood tests, this test measures blood sugar only at a point of time. The principles of this test are:

- Some sugar attaches to the haemoglobin of the red cells when they are exposed to high glucose levels.

- They remain attached to the haemoglobin over entire cell life (around three months). This is called glycated haemoglobin.
- Blood is drawn from a vein in the arm to determine glycated haemoglobin level. The higher the percentage of glycated haemoglobin, the higher the blood glucose levels over the past 3 months.
- People without diabetes have an HbA-1C of around 5 per cent. American Diabetic Association suggests ≤ 6.5 per cent for diabetics to minimize the risk of long-term complications.
- FDA approved a single-use test kit, which uses blood from a finger prick, and displays results in eight minutes.

7.5. URINE TESTS

Urine testing is an essential part of complete physical examination routine. They help in diagnosing state of the body and provide valuable information. However, urine test are rarely used to diagnose diabetes. They are less accurate and are difficult to understand. The level of sugar in the blood required to produce sugar in the urine changes from person to person. A person can have blood sugar without having sugar in the urine. Apart from glucose, other reducing sugars such as lactose (in lactating women) which are unrelated to diabetes, can give rise to false positive results. Therefore, values of blood glucose are more reliable than urinary sugar. Commercially, diagnostic strips (uristix test) and Benedict's test are conducted to detect the presence of sugar in the urine. It is better to carry the test in the morning in the second urine sample.

7.5.1. Uristix test

This test requires small quantity of urine and conducted in a few minutes. Here chemically coated plastic strips or paper is dipped in the urine and removed immediately. Dark blue color indicates high sugar level in the urine. This test is less accurate and the level of sugar in the blood required to produce sugar in the urine changes from person to person.

7.5.2. Benedict's test

This is a very simple and effective method of ascertaining the presence or the amount of glucose in the urine and can be done by the diabetic himself.

Procedure:

- Take 5 ml (one teaspoon) of Benedict's solution in the test-tube.
- Hold the test-tube with the holder, heat it over a spirit lamp till the Benedict's solution boils without overflowing
- Add 8 to 10 drops of urine into the boiling Benedict's solution
- Again boil the mixture and let it cool down.
- While cooling, the mixture changes colour.
- The colour of the mixture serves as a guide to the amount of sugar in the urine.

Table 6. Interpretation of Benedict's test

Colour	Report	sugar in urine (g/100 ml)	sugar in blood (mg /dl)
Green discolouration	0 to trace	-	< 200
Green precipitate	+	0.25	200-250
Greenish-yellow precipitate	+ +	0.5	250-300
Yellowish-orange precipitate	+ + +	1.0	300-350
Brick-red precipitate	+ + + +	> 2.0	> 350

(Raghuram *et al.*, 2003)

The positive sign in the report shows the severity of the disease. It is clear that these tests need not only be used for identification of new cases but also for the management of old / chronic patients. Regular assessment of vital parameters such as renal, blood and liver function tests along with blood glucose and glycated haemoglobin can prevent or delay the onset of several complications which arise due to sustained elevated blood glucose levels.

8. COMPLICATIONS

The complications may be acute or chronic in nature and need to be handled as of utmost urgency.

8.1 Acute complications

Acute complications are when something happens suddenly. The body does not have time to adjust to the changes and a person suddenly feels very sick with multiple symptoms. Acute complications of diabetes are severe and can lead to coma. They are directly related to blood glucose levels and include the following.

a. Hypoglycemia
b. Ketoacidosis
c. Infection
d. Somogyi effect
e. Hyperglycemic Hyperosmolar Nonketotic Coma

8.1.1 Hypoglycaemia

Hypoglycaemia is a lowered blood glucose level. It may be caused by exogenous, endogenous, or functional causes. In general, hypoglycaemia occurs when blood glucose levels are below 35 mg/dl in the newborn for the first 48 hours of life, and 45-60 mg/dl in children and adults. Hypoglycaemia in diabetes is sometimes called insulin shock or insulin reaction.

If the hypoglycaemic individual is conscious, ingestion of fast-acting carbohydrate is preferred. If the individual is unconscious, intravenous glucose or subcutaneous glucagon administration will reverse the hypoglycaemia. After the crisis, the individual should be observed for a subsequent relapse, and an additional, long-lasting source of carbohydrates should be provided. Prevention of episodes of hypoglycaemia through alternate therapeutic regimens and proper education should be the goal.

Symptoms

- Sweating
- Shakiness
- Nervousness
- Dizziness
- Weakness
- Irritability
- Hunger

8.1.2 Ketoacidosis

Ketoacidosis, a serious complication of diabetes mellitus, is a common cause for hospital admissions, and mortality rates. Diabetic acidosis develops when there is an absolute or relative deficiency of insulin, and an increase in insulin counter-regulatory hormones: catecholamines, cortisol, glucagon, and growth hormone. Under these conditions, hepatic glucose production increases, peripheral glucose usage decreases, fat mobilization increases, and ketogenesis is stimulated. These changes cause hyperglycemia, osmotic diuresis, volume depletion, and acidosis. Diabetic coma can develop in 12-24 hours.

Without enough insulin, the cells of the body will be unable to use the glucose in the blood for energy. Secondly, glucose cannot be converted to glycogen in the liver for future use. So to make energy available, the fat sources will be used for getting energy as a result of which ketoacids in the blood and urine will increase. Severe Ketoacidosis is a life threatening condition. The treatment of diabetic ketoacidosis involves continual administration of low-dose insulin to decrease glucose levels. Fluids are administered to replace lost fluid volume, and electrolytes particularly sodium, potassium and phosphorous.

Symptoms

- Polyuria
- Polydypsia
- Polyphagia
- Drowsiness
- Unexplained weight loss
- Slow healing of cuts and wounds
- Dry itching skin
- Vaginal itching
- Abdominal pain
- Rapid shallow breathing with acetone smell

8.1.3 Infection

A variety of factors may predispose the diabetic patient to an increased incidence, or increased severity of infections. These factors include adverse effects of dehydration, malnutrition, vascular insufficiency, and neuropathy. In addition, in hyperglycaemic individuals, polymorphonuclear leukocyte function is impaired and delayed hypersensitivity is reduced. With the exception of mucormycosis and malignant external otitis, most infections in the diabetic patients are similar to those observed in non-diabetics. Rhinocerebral mucormycosis occurs almost exclusively in acidotic diabetic patients. The pathophysiology of mucormycosis infection is not completely understood, but it has been hypothesized that during acidosis iron metabolism is impaired leading to compromised cell-mediated immunity.

8.1.4. Somogyi effect

The Somogyi effect is a unique combination of hypoglycaemia during the night with rebound hyperglycaemia in the morning. The problem is more common in individuals with Type I diabetes mellitus, particularly in children, and should be investigated whenever fluctuations in blood sugar levels are serious. The Somogyi effect occurs when hypoglycaemia stimulates glucose counter-regulation, including epinephrine, growth hormone, cortisol, and glucagon release. These hormones serve to increase blood glucose by gluconeogenesis and glycogenolysis. They mobilize fatty acids and proteins while inhibiting peripheral glucose use.

In addition to fluctuating glucose levels, subtle symptoms of hypoglycaemia occur. The individual often complains of nightmares and early morning headaches. Both symptoms probably reflect a hypoglycaemic state. Ketonuria may occur if the mobilization of energy sources overshoots the body's need for glucose and exogenous insulin is depleted. Treatment consists of decreasing insulin dosage or changing the time of administration.

8.1.5 Hyperglycemic Hyperosmolar Nonketotic Coma

Hyperglycemic hyperosmolar nonketotic coma (HHNKC) is characterized by severe hyperglycemia (glucose level typically greater than 600 to 800 mg/dl), dehydration, and altered mental status in the absence of ketosis. In HHNKC, hyperglycemia causes glycosuria. Osmotic diuresis results in volume contraction and a reduction in both the glomerular filtration rate and glucose excretion.

HHNKC occurs most often among persons over 60 years of age. When persons who are chronically ill, debilitated, or institutionalized have mild renal insufficiency and lack normal thirst mechanisms or access to water, they are at risk of developing HHNKC. Acute illnesses (stroke, myocardial infarction, or pneumonia), drugs (diuretics or glucocorticoids), surgery, and, occasionally, large glucose loads (through enteral or parenteral nutrition or peritoneal dialysis) may precipitate HHNKC. The mortality rate for HHNKC has been reported to be as high.

The patient with HHNKC has severe hyperglycemia and azotemia without ketoacidosis. Both diffuse and focal central nervous system deficits may occur. These may include hallucinations, aphasia, nystagmus, hemianopsia, hemiplegia, hemisensory deficits, and focal or grand mal seizures. Coma may also occur. Therapy is primarily directed at replacement of fluid and electrolytes while supportive care is given. Insulin therapy is designed to slowly return the blood glucose level to a near normal range, within 24 to 48 hours. When therapy is successful, the patient may be significantly sensitive to further insulin. Ultimately, the patient may achieve metabolic control through diet and/or oral agents.

8.2. Chronic complications

Chronic complications are when something happens gradually over time. When this happens the body has time to make adjustments and a person may only have mild symptoms or possibly none at all.

Chronic complications of diabetes involve changes in blood vessels, tissues and organs. Consistently high blood glucose levels can cause a hardening and thickening of the blood vessels which can lead to many other diseases.

8.2.1. Atherosclerosis

Cardiovascular disease is the leading cause of morbidity and mortality among persons with diabetes. In the United States in 1986, approximately 80,000 deaths from cardiovascular disease were associated with diabetes.

The annual risk for death from cardiovascular disease is two to three times greater for persons with diabetes than for persons without diabetes. Among persons without diabetes, women have a lower rate of cardiovascular disease than men do; among persons with diabetes, women are not preferentially spared.

In persons with diabetes, smoking is a powerful risk factor for cardiovascular disease, and the prevalence of smoking appears to be higher in young people (less than 21 years old) with diabetes than in young people without diabetes.

Hypertension, also a strong risk factor for cardiovascular disease, occurs two to three times more often in persons with diabetes than in persons without diabetes. The risk for cardiovascular disease increases early with increases in blood pressure.

Abnormalities in the concentration of lipids and lipoproteins in plasma have been reported to occur in almost 30% of persons with diabetes. The risk for cardiovascular disease is directly proportional to the concentration of low-density lipoprotein (LDL) cholesterol and inversely proportional to the concentration of high-density lipoprotein (HDL) cholesterol. Although hypertriglyceridemia is common among persons with non-insulin- dependent diabetes mellitus, whether the triglyceride level independently predicts cardiovascular disease is uncertain.

The precise relationship between hyperglycaemia and atherosclerosis is also unknown. Among persons with diabetes, several concomitant conditions may affect the aetiology of atherosclerosis: obesity, inactivity, hyperinsulinemia, abnormalities in platelet function, high cholesterol in the blood and defects in blood coagulation and flow. Drugs and changes in the diet can reduce the cholesterol in the blood.

Among persons with diabetes, part of the increased likelihood of cardiovascular disease appears to be a consequence of the increased frequency of risk factors. Yet diabetes itself is an independent risk factor for cardiovascular disease. All diabetics should check their cholesterol in serum once in 2 years.

Table 7. Desired blood lipids

Desirable cholesterol levels	mg/dl
Total cholesterol	< 200
HDL cholesterol	> 40
LDL cholesterol	< 150
VLDL cholesterol	< 40

(Sreelakshmi, 2000)

8.2.2. Retinopathy

The process by which diabetes results in retinopathy and macular oedema is not fully understood. It is known that diabetes causes the retinal capillaries to become functionally less competent. Long duration diabetes with uncontrolled sugar may affect the small blood vessels of the eyes (microangiopathy). This can result in rapid deterioration of the eyesight (retinopathy). Diabetic retinopathy is often asymptomatic in its most treatable stages. Swelling of the macula, part of the retina, is called macular oedema, and is a possible complication that can cause blurred vision. Often, symptoms of retinopathy are not noticed until they reached an advanced or proliferative stage. Since diabetic retinopathy cannot be prevented, routine early evaluation, timely laser surgery, and careful follow-up are critical. Unfortunately, only about half of persons with diabetes receive adequate eye care. Early detection of diabetic retinopathy is critical.

Blindness occurs 25 times more frequently in diabetic patients than in control subjects and is seen most often after the disease has been present for at least 15 years, in the setting of advanced retinopathy. In type 2 diabetes, though the incidence of blindness is lower, higher disease prevalence results in an even larger number of patients affected with severe visual loss (Williams, 2003).

1.2.3. Nephropathy

Diabetic nephropathy represents a distinct clinical syndrome characterized by albuminuria, hypertension, and progressive renal insufficiency. Diabetic nephropathy can lead to end-stage renal disease (ESRD), a serious condition in which a patient's survival depends on either dialysis or kidney transplantation.

Among persons who have had insulin-dependent diabetes mellitus (IDDM) for 20 years, the incidence of ESRD approaches 40%. Among whites, the incidence of ESRD is lower among those with non- insulin-dependent diabetes mellitus (NIDDM) than among those with IDDM. In certain populations including blacks, Hispanics, and Native Americans-persons with NIDDM have a higher incidence of ESRD.

Within three years of diabetes, thickening of the glomerular basement membrane, the typical changes of diabetic glomerulosclerosis appear. Renal blood flow and the glomerular filtration rate (GFR) are characteristically elevated, correlating with an increase in kidney size and weight. Mild albuminuria may be present if glycaemia is not well regulated. Because of renal hyper filtration, serum creatinine and urea nitrogen concentrations are usually slightly reduced.

After 10 to 15 years, the first laboratory evidence of renal damage may appear with the presence of persistent microalbuminuria (30 to 300 mg per 24 hours). In IDDM, the prevalence of hypertension increases markedly in patients with microalbuminuria, and hypertension clearly contributes to the progression of renal disease.

About four years after the onset of clinical diabetic nephropathy, the serum creatinine level rises to 2 mg/dl or greater. Within an additional three years, about one-half of patients will develop ESRD.

The natural history of renal involvement in persons with NIDDM is not well established. Although microalbuminuria has been shown to be associated with the development of clinical diabetic nephropathy, the precise level of microalbuminuria that reliably predicts this condition has yet to be determined. Some individuals with low levels of albuminuria do not develop renal failure. In these persons, albuminuria may be due to the presence of other complicating renal diseases, such as obstructive uropathy, hypertension, or arteriolosclerosis, or may reflect an age-related increase in urinary albumin excretion.

8.2.4. Neuropathy

Persons with diabetes who develop neuropathy may have no symptoms or may experience pain, sensory loss, weakness, and autonomic dysfunction. Neuropathy may result in significant morbidity and may contribute to other major complications, such as lower extremity amputation.

There are three major types of diabetic neuropathy:

- Distal symmetrical polyneuropathy.
- Focal neuropathy.
- Autonomic neuropathy.

Distal symmetrical polyneuropathy. This most common of the diabetic neuropathies is characterized by insidious onset, symmetrical distribution, and progressive course. Although its cause is unclear, distal symmetrical polyneuropathy is believed to result from abnormal neural metabolism, generalized neural ischemia, or both. The onset and course of illness cannot be predicted for an individual patient, but increasing age, male sex, increasing height, longer duration of diabetes, poorer glucose control, hypertension, alcohol consumption, and smoking may be independent risk factors.

Three overlapping clinical syndromes have been described:

- Acute painful neuropathy, an uncommon but extremely unpleasant complication of diabetes, often occurs without evidence of other significant neurologic impairment. Patients develop dysesthesia and paresthesia in the lower extremities. The severe, burning pain is often associated with cutaneous hyperesthesia and is worse at night.

- Small fibre neuropathy may occur after only a few years of diabetes. Patients have varying degrees of pain and sensory loss; they usually feel a burning pain and may develop dysesthesia. Prominent features of small fibre neuropathy are distal loss of temperature sensation and of pinprick or pressure sensation. Vibratory sensation, position sense, muscle strength, and ankle reflexes are generally unimpaired. Neuropathic ulcers occasionally occur at sites of trauma.
- Large fibre neuropathy generally occurs in the setting of small fibre neuropathy. Patients have impaired distal vibration sensation and impaired distal position sense. Ankle reflexes are reduced or lost. In more severe instances, patients develop sensory ataxia

Focal neuropathy. Focal neuropathy is an uncommon condition believed to occur after the acute occlusion of a blood vessel produces ischemia in a nerve or group of nerves. Both sensory and motor components may be present. Near total recovery generally occurs within two weeks to 18 months.

Autonomic neuropathy. This troubling complication of diabetes encompasses multiple disturbances affecting the following systems: sudomotor (possible symptoms include heat exhaustion), pupillary (poor night vision), adrenomedullary (hypoglycemia unawareness), cardiovascular (orthostatic hypotension and painless myocardial ischemia), gastrointestinal (gastroparesis, constipation, diarrhoea, and faecal incontinence), and urogenital (bladder dysfunction and sexual dysfunction).

8.2.4. Stroke

A stroke results when the blood supply to the brain is suddenly cut off, which can occur when a blood vessel in the brain or neck is blocked or bursts. Brain cells are then deprived of oxygen and die. A stroke can result in problems with speech or vision or can cause weakness or paralysis. Most strokes are caused by fatty deposits or blood clots that narrow or block one of the blood vessels in the brain or neck. A blood clot may stay where it formed or can travel within the body. People with diabetes are at increased risk for strokes caused by blood clots.

A stroke may also be caused by a bleeding blood vessel in the brain called an aneurysm, a break in a blood vessel can occur as a result of high blood pressure which is one of the risk factors of diabetes.

9. ORGANS AFFECTED BY DIABETES

According to the American Diabetes Association, nearly 8 percent of the population has diabetes, including both children and adults. As diabetes is a chronic condition of lack of blood sugar control, many organs may eventually be affected by the disease, sometimes severely. Diabetes is the leading cause of many serious disorders such as cardiovascular disease, kidney disease and blindness.

9.1. Heart and Blood Vessels

Cardiovascular disease is a frequent cause of death in diabetics. Increased blood sugar levels have an adverse effect upon lipid levels in the bloodstream, resulting in plaque formation in the blood vessels. The development of atherosclerosis contributes to congestive heart failure (CHF), heart attack and stroke due to narrowing of blood vessels. High blood pressure increases these risks.

9.2. Genitourinary System

High blood sugar levels in diabetics can contribute to the development of kidney disease. Due to the constant stress of filtering high levels of blood sugar, the kidneys may become damaged and leaky, eventually leaking protein into the blood and progressing to end stage renal disease. High blood pressure increases this risk. Some patients with diabetes may develop bladder problems. Nerves leading to the bladder may malfunction and create spasms known as overactive bladder and some patients lose control of the sphincter that holds in urine, resulting in incontinence. Erectile dysfunction is a complaint among some diabetic men, as nerve cells and blood vessels become damaged and can no longer supply and hold blood necessary to the formation of an erection.

9.3. Nervous System

Nerve damage may result from high blood sugar levels. Peripheral diabetic neuropathy causes symptoms such as tingling, pain and numbness in the hands, feet and skin, along with weakness. Autonomic diabetic neuropathy can cause the intestines to stop working correctly and can also result in loss of urinary control, loss of sexual function and changes in the ability of the body to sweat. The development of diabetic neuropathy may include loss of the nervous system's ability to recognize warning signs of low blood glucose levels, heart attack and injury to the feet due to loss of sensation.

9.4. Eyes

High blood sugar levels in diabetes contribute to eye complications, some of which may lead to blindness. Cataracts are also common in diabetics, particularly those with type 2 diabetes. High blood glucose levels can cause eye pressure to build up, resulting in glaucoma. This may cause loss of blood supply to the retina and optic nerve, which can result in blindness. Diabetic retinopathy is caused by damage to the small blood vessels of the retina, resulting in fluid and blood leakage that may cause vision loss. Proliferative diabetic retinopathy may develop if scar tissue forms because of blood vessel damage. New vessels that may grow to replace damaged ones are often weak and brittle and may cause vision loss and vitreous haemorrhage. The scar tissue may also bind to the retina, causing retinal detachment that results in blindness.

9.5. Skin and Feet

Changes to the nervous system may result in oil and sweat gland malfunctioning because the nerves controlling the glands do not work. This may lead to rashes and dry, cracking and peeling skin. If the diabetes causes major blood vessel damage, circulation decreases and wounds don't heal well. Diabetics are also prone to fungal infections of the skin and may develop foot ulcers. If circulation is very poor, wounds in the feet may become infected and unable to heal, which sometimes results in amputation of the feet.

10. DIETARY MANAGEMENT

Diet plays a very important role in management of diabetes as it exerts a direct influence on the blood glucose levels. It is one of the vital components in diabetes control besides the medical, exercise and behavioral aspects of the treatment. The goals of diet therapy are to maintain and prolong a healthy, productive and a happy life. Nutritional assessment is important for setting the practical and acceptable goals for the patient. Only after this we can plan the diet and execute it. Clinical parameters should be monitored from time to time and make the necessary changes if required. Dietary changes can be made which are more acceptable and can easily be followed. The diet should be planned based on the nutritional status of the patient. If the patient is under nourished feed more calories and if over nourished reduce the calories. Calories are mainly obtained from carbohydrate, protein and fat. The following factors should be considered in the prescription of diabetic diet.

1. Body weight, age, sex, activity
2. Economic, social and cultural factors
3. Type of diabetes, mode of treatment and control of diabetes
4. Other factors like pregnancy, obesity, cardiovascular and renal disorders, infections

The objectives in dietary management of diabetes are to:

- Supply optimum nutrition to maintain good health
- Provide calories for maintaining ideal weight and allowing for normal growth and development (especially in case of children)
- Maintain blood sugar control
- Achieve optimum blood lipid levels
- Minimize acute and chronic complications of diabetes mellitus
- Improve the overall quality of life

10.1 Principles of diet

- Low calorie
- Low carbohydrate especially simple sugars
- High protein
- High fibre diet
- Low fat
- Liberal vitamins and minerals

Calories

Control of calorie intake to achieve normal weight is a primary objective in the management of all types of diabetics. Both the type and amount of carbohydrate found in food influence postprandial glucose levels and can also affect overall glycemic control in individuals with diabetes. (Wheeler and Sunyer, 2008).

The calorie allowance is essentially the same as that for normal individuals of the same activity, size and sex. Obese individuals should be placed on a calorie restricted diet until the desirable weight for height and age is attained. Calculation of calorie requirement is done based on the basis of body weight

How to calculate the ideal body weight

Ideal body weight (in kg) can be calculated by subtracting 100 from his/her height (in cms) by the Broca's index.

ie., Ideal body weight = height (cm) – 100

The ideal body weight shows whether the person is overweight (20% above his ideal weight) or under weight (20% below his ideal body weight). Based on this, the daily calorie requirement of an individual per kg body weight is calculated.

Table 8. Caloric requirement based on body weight

Category	Kcal/kg body weight/day
Ideal weight	30
Underweight	40
Overweight	20
Pregnancy	30-35
Disabled	25

This is intended for those who do sedentary work. The intake should be increased with greater physical activity.

Children need higher requirements than those of adults taking care of their growth and development. They can take normal diet except simple sugars. Calorie requirement for children are 1000 kcal + 25 kcal for boys and 1000 kcal + 100 kcal for girls.

Table 9. Distribution of nutrients in total calories

Nutrients	% of total calories
Carbohydrates	60-65
Protein	13-20
Fat	15-25

Calories are distributed so as to coincide with the type of insulin and modified according to each patient's needs in order to achieve the best possible regulation of carbohydrate utilisation.

Table 10. Distribution of calories for each meal

Meal	% of calories
Breakfast	20
Mid morning	10
Lunch	30
Tiffin	10
Dinner	20
Bed time	10

Carbohydrates

Diabetics need not restrict the carbohydrate intake but they can alter the type of carbohydrate in their diet. Complex carbohydrates are better than simple carbohydrates. Simple sugars cause a rapid rise in blood sugar. They are rapidly absorbed and are present in sugar, honey and jaggery. Higher intake of fructose, glucose and sweetened beverages increase type 2 diabetes among men and women of 40-60 years (Montonen *et al.*, 2007). Complex carbohydrates should be included in daily diet in the prescribed amount. It will not increase the blood sugar as simple carbohydrates. It is present in rice, wheat flour, ragi and oats.

Refined carbohydrates should be avoided. Refined carbohydrates have been suggested to deteriorate glucose metabolism in Japanese women with intakes of white rice (Akiko *et al.*, 2010). Studies shown that a special variety of rice is processed which contains more of resistant starch. This high resistant starch containing rice was fed to 40 diabetic patients for three months and effects observed. Results showed that, fasting blood sugar was reduced (Mitra *et al.*, 2007).

10.2 Glycemic index

It is the extent of rise in blood sugar in response to a food in comparison with the response to an equivalent amount of glucose or any other reference food.

$$GI = \frac{\text{Blood glucose area of test food}}{\text{Blood glucose area of reference food}} \times 100$$

Different carbohydrates raise the blood sugar to variable extents. Glycemic index help to determine the extent of rise in blood sugar with different foods. Foods with low glycemic index are recommended for diabetics.

Table 11. **Mean GI of some common foods**

Item	GI
White bread	100
Glucose	138
Honey	126
Corn flakes	119
Whole wheat	99
Raisins	93
Sucrose	86
Orange	66
Grape	62
Apple	53
Ice cream	52
Yoghurt	52
Whole milk	49
Skimmed milk	46
White rice	83
Potato	81
Banana	79
Sweet potato	70
Fructose	30
Soya bean dried	22

Proteins

Proteins do not raise blood sugar during absorption as much as carbohydrate and don't supply as much calorie as fat. Proteins also promote satiety and help both types of diabetics to adhere to the carbohydrate allowance. It also supply essential amino acid needed for tissue repair. For IDDM, 1-1.5 g/kg body weight of protein and for NIDDM, 1 g/kg body weight is recommended. Due to high fibre and low cholesterol, protein from vegetable source is better than animal source. In diabetes with renal problems protein restriction to 0.5 g/kg body weight id prescribed.

Fat

The total fat recommended by WHO is less than 30 per cent of the total calories. It is essential that obese diabetics should not take more than 15-20 per cent of total energy from dietary fat. Excess intake increases body fat and leads to obesity. The best way to maintain ideal body weight is to cut down fat intake. Fat from vegetable sources with polyunsaturated fatty acids are better than from animal sources. Diabetics can take 20g visible fat/day.

The dietary cholesterol intake should be kept below 300 mg/day for diabetics without any complications. If suffering from cardiovascular disease, the intake should not exceed 200 mg/day. Avoidance of excess fat and saturated fats control body weight and are effective in decreasing the risk for type 2 diabetes (Stoeckli, 2004). Inclusion of fish, as a source of omega-3 fatty acids in the diets of individuals with diabetes had a positive effect (Rudkowska, 2009).

Vitamins and minerals

They are the protective factors present in food and are mainly present in fruits and vegetables. Low carbohydrate fruits (apple, guava, orange) and vegetables (except potato, sweet potato, and yam) are prescribed for diabetics. A study on diabetics showed consumption of vegetables lowered the risk of diabetes (Ralt, 2009)

Fibre

Dietary fibre is that part of food which is not digested by the intestines. High fibre meals have shown to give the best glycemic control in diabetics. High fibre foods are of low calorie value and also have a low glycemic index. So diabetics must consume more of fibre rich foods. Fibre is found in a wide range of foods such as whole cereals, pulses, fruits, green leafy vegetables (insoluble fibres). Many soluble fibres such as those present in beans, fenugreek seeds are found to be more effective in controlling blood sugar and serum lipid levels. Intake of 25g of dietary fibre per 1000 calories/day is considered optimum for a diabetic. According to Montonen *et al.* (2003) an inverse association between whole-grain intake and the risk of type 2 diabetes was found in diabetic men and women due to the presence of fibre in the grain.

Salt

Salt should be restricted if hypertensive. Foods like pickles, pappads, dried fruits, preparations containing sodium salts should be restricted. It was found that salt sensitivity is strongly associated with insulin resistance in hypertensive patients when the salt diet was changed from low to high quantity (Yatabe *et al.*, 2010).

Inulin

Inulin is a carbohydrate used to store energy in the roots of certain plants. Inulin is not broken down in the digestive tract, and so low effect on blood sugar and very few calories. Because of its low glycemic index, and because it does not break down to glucose, inulin is ideal for diabetics. Jerusalem artichoke or sunchoke, honey-like sweetener agave syrup, onion, garlic, leek, wild yam and chicory root are food sources of inulin.

Fenugreek seeds

Fenugreek seeds are rich in fibre which is mucilaginous (20-50 % fibre content). It also contains Trigonelline, an alkaloid in fenugreek known to reduce blood sugar. Fenugreek powder reduces blood and urine sugar levels and improves glucose tolerance. It has an action on blood lipids in lowering blood cholesterol. Fenugreek seeds appear to have a significant hypoglycemic activity in type 2 diabetic patients (Bawadi *et al.*, 2009).

Alcohol

Alcohol provides empty calories, stimulates appetite and makes a diabetic obese. It lacks essential nutrients and may therefore promote ketoacidosis, hypertriglycerdemia and alcohol induced hypoglycemia. Hypoglycemic drugs should never be consumed with alcohol. Patients on insulin should take not more than 2 drinks per day (one drinks equals to 12 oz beer, 5 oz wine, 1½ oz whisky). Total food intake should not be reduced when the patient is consuming alcohol.

High alcohol consumption was related with higher incidence of impaired fasting glucose or diabetes in obese men (Won-Gyun *et al.*, 2009)

Artificial sweeteners

Sweeteners have no adverse effect on diabetes control and can be taken in limited amounts. Some of the recommended sweeteners are saccharin, aspartame, acesulfame K which are calorie free.

10.3 Dietary guidelines

- Avoid sweets
- Take cereals and pulses in the prescribed amount
- Use fat in limited amounts
- Include vegetables as and when required
- Take permitted fruits in limited amounts
- Include fibre rich foods as much as possible

10.4 A sample menu

1800 calorie diabetic diet for a reference man of 60kg ideal body weight

Breakfast

- Idli(3), Sambar (1 bowl), Tea(100 ml milk)

or

- Appam(3) , Vegetable curry- ½cup

or

- Idiappam(3), Bengal gram curry - ½cup

Mid morning

- Oats porridge -½ cup

or

- Ragi porridge - ½ cup

or

- Vegetable salad -1 bowl, lime juice 1glass

Lunch

- Rice -1cup, Fish curry-1 small piece, Amaranth thoran-½ cup,Salad-1 bowl, Buttermilk-1glass (50ml curd), Orange-1

or

- Chapathi-3, Chicken curry-1 small piece , Apple-1

or

- Rice gruel -1 cup, Green gram thoran½cup, Mixed vegetable thoran-½cup

Evening tea

- Bread (2 slice) sandwich , Tea (100 ml milk

or

- Upma - ½cup, Robusta -1

or

- Arrowroot biscuit-3 or Vada-1

Dinner

- Chapathi -3, Dhal curry- ½ cup

or

- Wheat dosa -3, Vegetable kuruma - ½cup

or

- Wheat gruel -1 ½ cup, Red gram thoran- ½cup, Mango chutney (with out coconut)

10.5 EXCHANGE LIST

Food exchange lists are groups of measured foods of the same calorific value and similar protein, fat and carbohydrate .One food can be substituted with another food in the meal plan.

OBJECTIVES

- Restrict the food intake according to the insulin prescription
- Variety in the diet
- Easy learning of the principles of diet
- Maintain body weight

List of food exchanges

- Cereal exchange
- Dhal exchange
- Milk exchange
- Meat exchange
- Fat exchange
- Fruit exchange

1. Cereal exchange

Calorie	-	**85 kcal**
Carbohydrate	-	**18-21g**
Protein	-	**1-3g**

- Rice - 25g
- Wheat rava - 25g
- Oats - 25g
- Idli - 1
- Chapathi - 1
- Upma - ½ cup

- Yam - 75 g
- Potato - 100g
- Sweet potato - 75 g
- Tapioca - 50g
- Bread - 2 slice

2. Dhal exchange

Carbohydrate - 15g

Protein - 6g

Calorie - 85 kcal

- Pulses - 25g (½ cup cooked)

3. Milk exchange

Protein - 3g

Carbohydrate - 4g

Fat - 4g

Calorie - 65 kcal

- Cow's milk - 100ml(½ cup)
- Buffalo's milk - 50 ml
- Curd - 100ml
- Skimmed milk - 200ml
- Skimmed milk powder - 18 g

4. Meat exchange

Protein - 7.5g

Fat - 6g

Calorie - 85 kcal

- Beef - 75g
- Chicken - 75g

- Liver - 75g
- Egg - 1medium
- Meat - 50g
- Fish - 75-100g

5. Fat exchange

Calorie - 90 kcal

Fat - 10g

- Oil - 10g
- Ghee - 10g
- Butter - 12g
- Vanaspati - 10g

6. Fruit exchange

Calorie - 40 kcal

Carbohydrate - 10g

- Amla - 4-5
- Apple - 1
- Banana - ½
- Grapes - 20 number
- Guava - 1
- Jack fruit - 3 pieces
- Mango - 2 piece

II.TREATMENT

Dietary control is central to success in treatment of diabetes. It is accompanied, when necessary, by insulin or oral hypoglycemic drugs. A regulated programme of exercise and attention to personal hygiene are important. The many aspects of therapy require a continuing programme of education for the patient together with periodic evaluation by the physician, nutritionist, and other specialists in health care.

11.1 Exercise

Exercise is an essential element in the treatment of diabetes. Regular controlled exercise helps to increase glucose utilisation. It helps to attain ideal body weight by burning calories. It also builds stamina and provides a sense of wellbeing. In addition, it enhances the action of insulin and thus helps to reduce the dose of antidiabetic drugs. Exercise improves circulation throughout the body. Apart from these, exercise reduces stress and thus high blood pressure.

Walking is the best form of exercise especially for the elderly. However, the type and duration of exercise depends on the age and physical status of the individual. Initiate the exercise programme gently and then build it up gradually. Walking, bicycling, jogging, swimming, golfing, gardening, playing tennis and badminton can be adopted. Those on insulin require extra carbohydrate before, during and after the exercise.

In the field of diabetes and exercise, among the epidemiological studies of physical exercise, recent mega-trials such as the Diabetes Prevention Program (DPP) in the U.S. have shown that lifestyle intervention programmes involving diet and/or exercise reduce the progression of impaired glucose tolerance (IGT) to type 2 diabetes. Lifestyle change may reduce the incidence of type 2 diabetes by 28–59% and it enhances the action of insulin (Walker *et al.*, 2010)

11.2 Oral drugs

When diet, exercise or even weight reduction do not improve the diabetic symptoms and blood sugar levels, the use of hypoglycemic drugs becomes necessary. Oral drugs are generally recommended to NIDDM patients. Several types of oral drugs are available. They work by stimulating the pancreas to release additional insulin or to help the cells of the body to utilise the insulin properly. Sulphonylureas and biguanides are the two groups of drugs which are commonly used in NIDDM. Commonly used sulphonylureas are tolbutamide (Rastinon), chlorpropamide (Copamide, Diabinese), glibenclamide (Euglucon, Daonil, and Betanese) and Glipizide (Glynase). Important biguanides are metformin (Glyciphage) and phenformin (DBI).

11.3 Insulin

The discovery of insulin has dramatically changed the lives of people having type 1 diabetes. With this wonder drug diabetics can lead a normal, enjoyable and a productive life. Insulin is measured in units. The doctor will decide the number of units of insulin a diabetic will need per day. Three types of insulin are available. The type varies in how quickly it starts working, time of peak activity and how long it works. The three types are short acting, intermediate acting and long acting. The quantity of carbohydrates should mach the dose of insulin given. Small frequent feedings is advised in IDDM to avoid hypoglycemia

11.4 Education

Education is very important for diabetes because it is a lifelong disorder. In order to enable the patient to lead a healthy and a good quality life free from complications, the diabetics must be educated sufficiently. They should be rigorously counseled so that they can manage their blood glucose level themselves. Patient education can help to reduce the mortalities and morbidities associated with diabetes. The nature of disease, its acute and chronic complications, self monitoring of blood glucose levels, adequate information on diet, knowledge about insulin and drugs, importance of exercise and clarification of common food fads and misbeliefs are some of the areas in which the diabetics are to be educated.

CONCLUSION

Diabetes is a chronic metabolic disorder which affects almost all age groups. India is the second largest nation vulnerable to diabetes mellitus. The global increase in diabetes occurs because of population ageing and growth, and of increasing trends towards obesity, unhealthy diets and sedentary lifestyles. Diet is the corner stone in the management of diabetes. It offers a greater hope in the management of this global threat. The goals of diet therapy are to maintain and prolong a healthy, productive and a happy life.

DISCUSSION

1. Does intake of excess sugar cause diabetes?

Ans. Excess calorie from the sugar is stored in the body as fat due to the impaired carbohydrate metabolism in diabetes. This leads to obesity and is one of the major risk factors in diabetes. So, sugar intake does not directly cause diabetes. But if any of the parents has diabetes, the intake should be restricted.

2. How stress cause diabetes?

Ans. In stress, the blood glucose level is increased to provide a quick source of energy for coping with stress.

3. Is there any relation between hypertension and diabetes?

Ans. Patients with diabetes have elevated blood sugar compared to patients without diabetes. This excess sugar has many consequences, including slow but serious damage to sensitive blood vessels called capillaries. Damage to certain capillaries in the kidneys impairs the kidney's blood pressure regulating abilities, leading to higher blood pressure. Elevated blood pressure can also affect the delicate insulin secreting areas of the pancreas, leading to higher blood sugar. So, diabetics should restrict salt in their diet.

4. There is an Institute of Diabetic Management in Thiruvanthapuram. Give more details about the institute.

Ans. It is a Diabetic Clinic. There are a number of diabetic clinics in various parts of Kerala. These clinics are mainly concentrating on conducting camps for diabetics, providing dietary consultations, education etc.

5. How smoking induces diabetes?

Ans. Smoking constricts blood vessels, raising blood pressure and increasing the risk of coronary artery disease. It also stimulates the release of catecholamines, which have been shown to promote insulin resistance.

6. What is auto immune attack?

Ans. An autoimmune disease results when the body's system for fighting infection, the immune system, turns against a part of the body. In diabetes, its own immune system attacks and destroys the insulin-producing beta cells in the pancreas thinking the beta cells as a foreign body.

7. Why the smell of acetone in the breath of diabetics?

Ans. With deficiency of insulin, carbohydrate is not fully utilised for energy and for this purpose fat is used and lipolysis is greatly increased. The fatty acids released from adipose tissue are oxidised by the liver to form 'ketone bodies'. The appearance of one of these ketones, acetone in the urine produces ketoacidosis. Acetone is excreted by the lungs and gives the acetone smell in the breath of diabetics.

8. Can carrots and beetroots be consumed by a diabetic patient?

Ans. The glycemic index of carrot is 47 and that of beetroot is 64. Though both of these root vegetables provide few calories, carrot with low glycemic index can be taken in moderate amounts. One or two serving of carrot can be included daily in curries or in salads. But beetroot with high glycemic index should be avoided.

9. Suggest any home remedies for controlling diabetes

- Include turmeric, cinnamon, fenugreek seeds, bitter gourd, chewing bitter herbs like (Neem), Indian gooseberry (Amla), Indian plum (Jamun), the holy fruit of India- the Bael fruit, garlic in the diet.
- Boil around fifteen mango leaves in one cup of water. Keep it over night and filter in the morning. Drink every morning on an empty stomach.

10. What is cachexia?

Ans. Cachexia is extreme weight loss accompanied by atrophied muscles, fatigue, loss of appetite and general bodily weakness in anyone who is not consciously trying to lose weight. Fluid loss due to polyuria and high glucose levels can cause weight loss in a diabetic. When those factors are combined in diabetes, a person increases his risk of developing cachexia.

11. Is bitter gourd beneficial for diabetes? Is it practicable for all types of diabetes?

Ans. Bitter gourd contains Gurmarin, a polypeptide that is considered to be similar to bovine insulin, which has been shown in experimental studies to accomplish a positive sugar regulating effect by suppressing the neural response to sweet taste stimuli. Eating bitter gourd over long period of time extensively reduces the glucose levels in the blood and urine. It can be recommended to all types of diabetics.

12. If there is any history of diabetes in the family, at what age onwards we have to control our diet?

Ans. Heredity is the main risk factor for type 2 diabetes. So, if there is any history of type 2 diabetes in the family, the diet should be controlled after 30 years onwards.

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Abstract

Diabetes mellitus or 'madhumeham' has been known for centuries as a disease related to sweetness. World Health Organisation predicts that more than 70 per cent of people in the world live with diabetes in the 21st century. An estimated 285 million people in the world lived with diabetes in 2010 and the number is expected to grow to 438 million by 2030. India has the world's second largest diabetic population (IDF, 2010).

Diabetes mellitus is a chronic metabolic disorder with a strong hereditary basis, associated with high blood sugar and usually with passage of sugar in the urine. Other risk factors include obesity, sedentary life, stress, smoking, ageing and unhealthy eating habits.

The three main types of diabetes are type I diabetes, type II diabetes and gestational diabetes. Type I diabetes affects children with little or no production of insulin. Type II affects overweight or obese adults. The insulin production may be normal or high but is not as effective as normal insulin. Gestational diabetes occur during pregnancy and require insulin injections.

Although, it is not possible to cure diabetes completely, diabetics can lead almost a normal life. Dietary control is central to success in treatment and management of diabetes. The diet should always provide the essentials for good nutrition and adjustments must be made from time to time for changing metabolic needs, growth, pregnancy, or modified activity.

Control of calorie intake to achieve normal weight is a primary objective in the management of all types of diabetes. Both the type and amount of carbohydrate found in food influence postprandial glucose levels and can also affect overall glycemic control in individuals with diabetes (Wheeler and Sunyer, 2008). It is recommended that a diabetic should derive 60 to 65 per cent of calories from carbohydrates, 15 to 20 per cent from proteins and 15 to 25 per cent from fat (Raghuram *et al.*, 2003).

Diets containing high dietary fibre have low calorific value and low glycemic index and therefore diabetics should consume such foods liberally to reduce blood sugar.

Fenugreek seeds appear to have a significant hypoglycemic activity in type II diabetics when they are allowed to drink the extract and chew the seeds of fenugreek due to the presence of fibre and an alkaloid namely trigonelline (Bawadi *et al.*, 2009).

Exercise helps in reduction of body weight and enhances the action of insulin and helps to reduce the dose of drugs. Life style modification through diet and exercise delay the onset of diabetes (Walker *et al.*, 2010).

Diabetes can be kept under control with certain changes in the life style – food intake, exercise and regular intake of prescribed medicines.

FOOD SECURITY- THE INDIAN SCENARIO

By

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DEPARTMENT OF HOME SCIENCE

Seminar Report submitted in partial fulfilment of the requirement for the course

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DECLARATION

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FOOD SECURITY- THE INDIAN SCENARIO

1. INTRODUCTION

A decade on from the first World Food Summit held in Rome, 1996, the problem of food and nutrition insecurity still remains a great threat to a large number of poor and vulnerable people across the world.. At the global level, the South Asian region is the home to more chronically food insecure people than any other region in the world (MSSRF, 2008).

It has been estimated that in India, one out of four persons goes to bed hungry with a high Global Hunger Index value. In the report published by International Food Policy Research Institute in October 2010, India was ranked 67 out of 84 countries in the Global Hunger Index based on child malnutrition, child mortality and proportion of people who are calorie deficient (Kumar, 2010).

Food security exists when "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). According to United Nations (1997), a household is food secure when it has access to adequate food needed for healthy life for all its members.

2. DIMENSIONS OF FOOD SECURITY

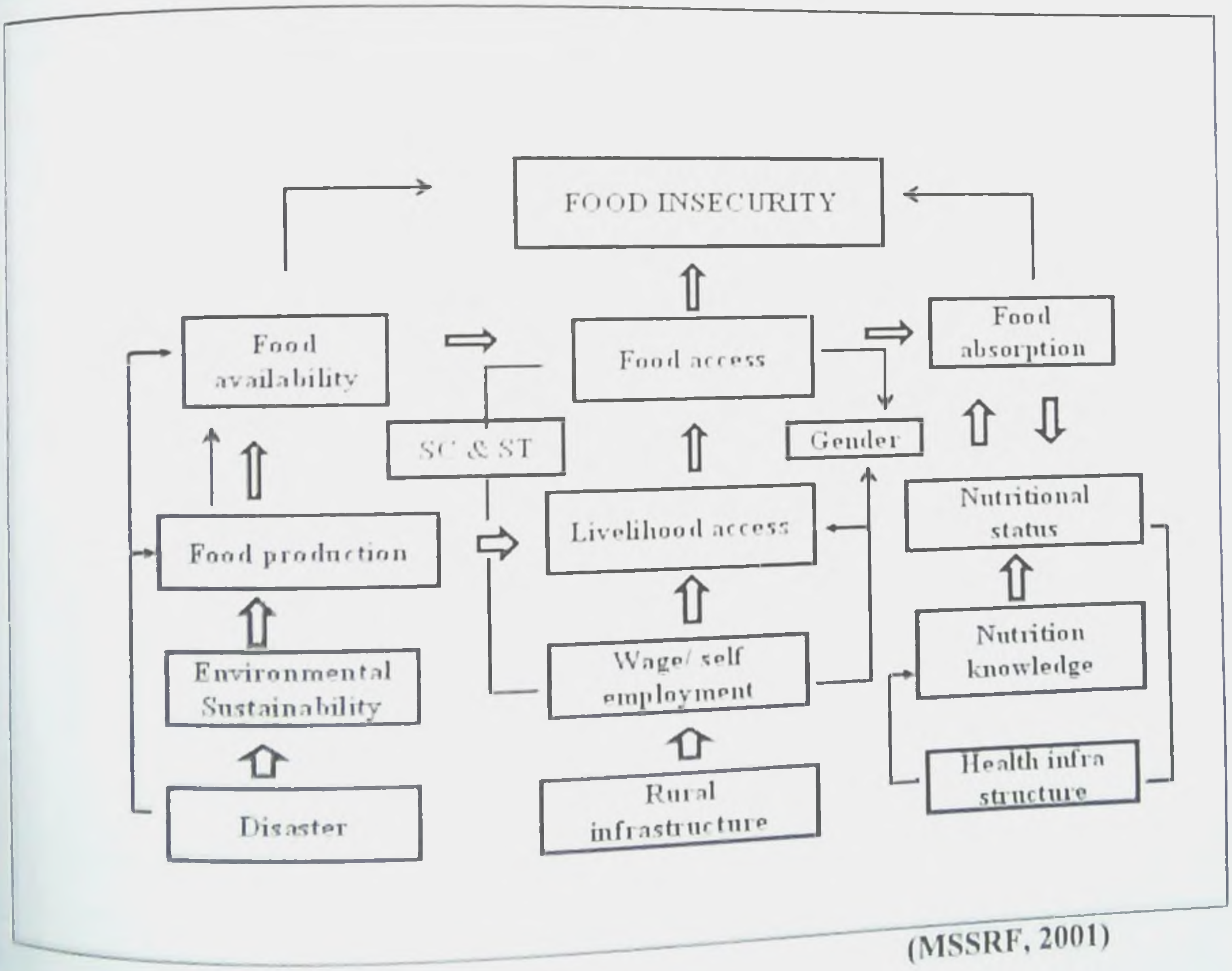
Food insecurity may be present or potential. A state producing sufficient food at present may not be able to produce the same amount in future, due to environmental factors such as land degradation or due to economic factors such as lack of price incentives. A region with inadequate food production would face food insecurity at present. Potential food insecurity is related not only to existing malnutrition of the people in a region but also to the lack of access to safe drinking water, poor sanitation and health condition. Thus, potential food insecurity can occur either due to a potential lack of availability of food or due to a potential lack of livelihood or a potential threat of disease and lack of absorption (MSSRF, 2001).

Food insecurity may be chronic or transitory. Chronic food insecurity refers to a situation in which people consistently consume diets inadequate in calories and essential nutrients due to inability to access food by production purchase etc. Transitory food insecurity is a temporary short fall in food availability and consumption. This is due to fall in income, increase in food prices, shortage of production, natural calamities such as floods, droughts etc.

Food security has three basic components namely availability, access and absorption. Availability of food is a function of food production and access to food is a function of purchasing power and employment. Absorption of food in the body is influenced by nutritional status, education and health care (Swaminathan, 2010).

The concept diagram links the three dimensions of food security. The interaction of these three aspects results in a situation of food insecurity.

Figure1.Concept diagram of food insecurity



(MSSRF, 2001)

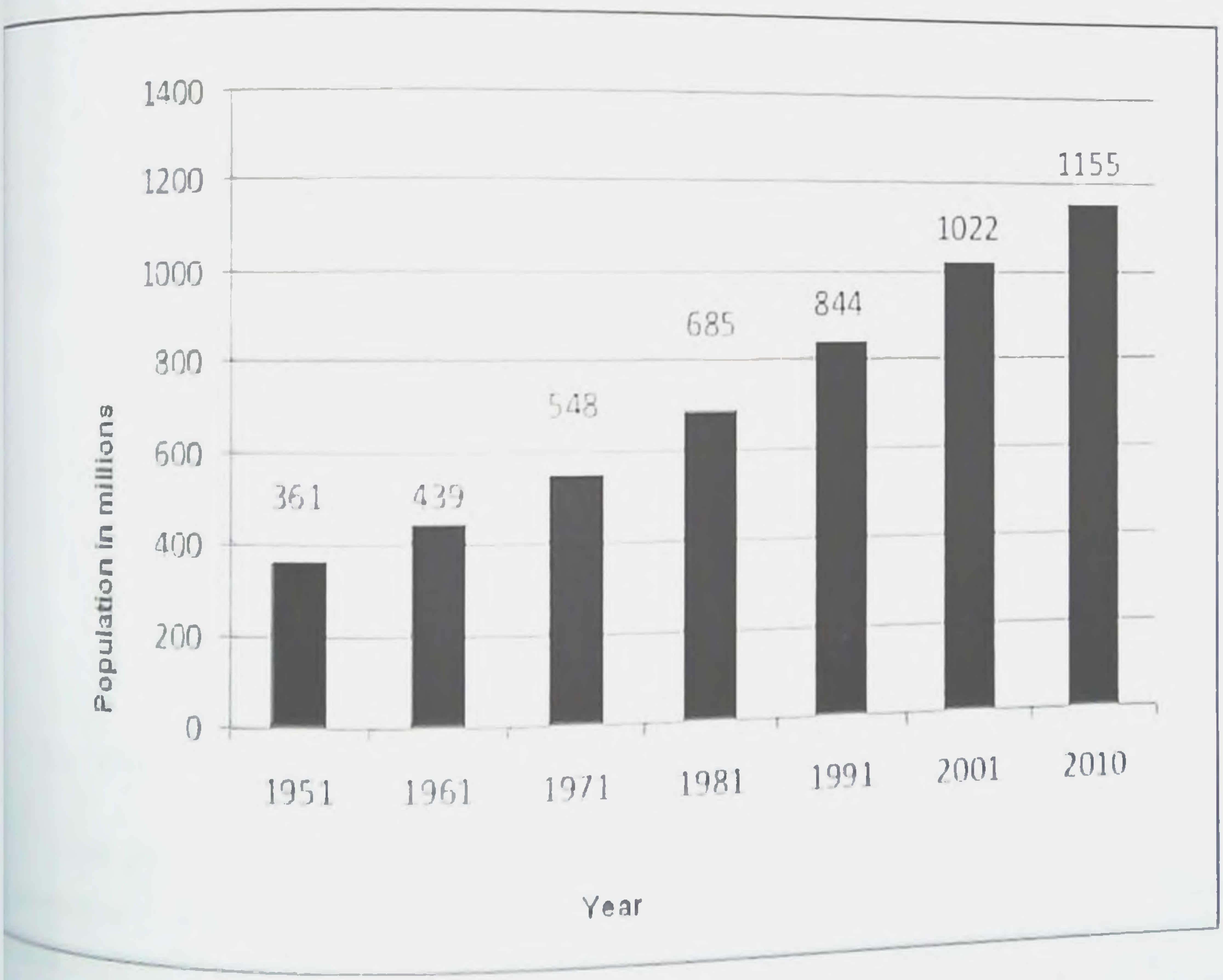
2.1FOOD AVAILABILITY

Food availability is the physical availability of food stocks in desired quantities, which is a function of domestic production, changes in stocks and imports as well as the distribution of food across territories (MSSRF, 2008). Food has to be available in abundance if every body has to eat enough. Food availability may be hampered by growth in population, low levels of production, environmental sustainability and natural disasters.

2.1.1 GROWTH OF POPULATION

India's population is very large in size and is growing rapidly. Though, the food grain production in India is high, it is very difficult for the country to satisfy the hunger of all segments of population. The growth of population is shown in the Figure 2.

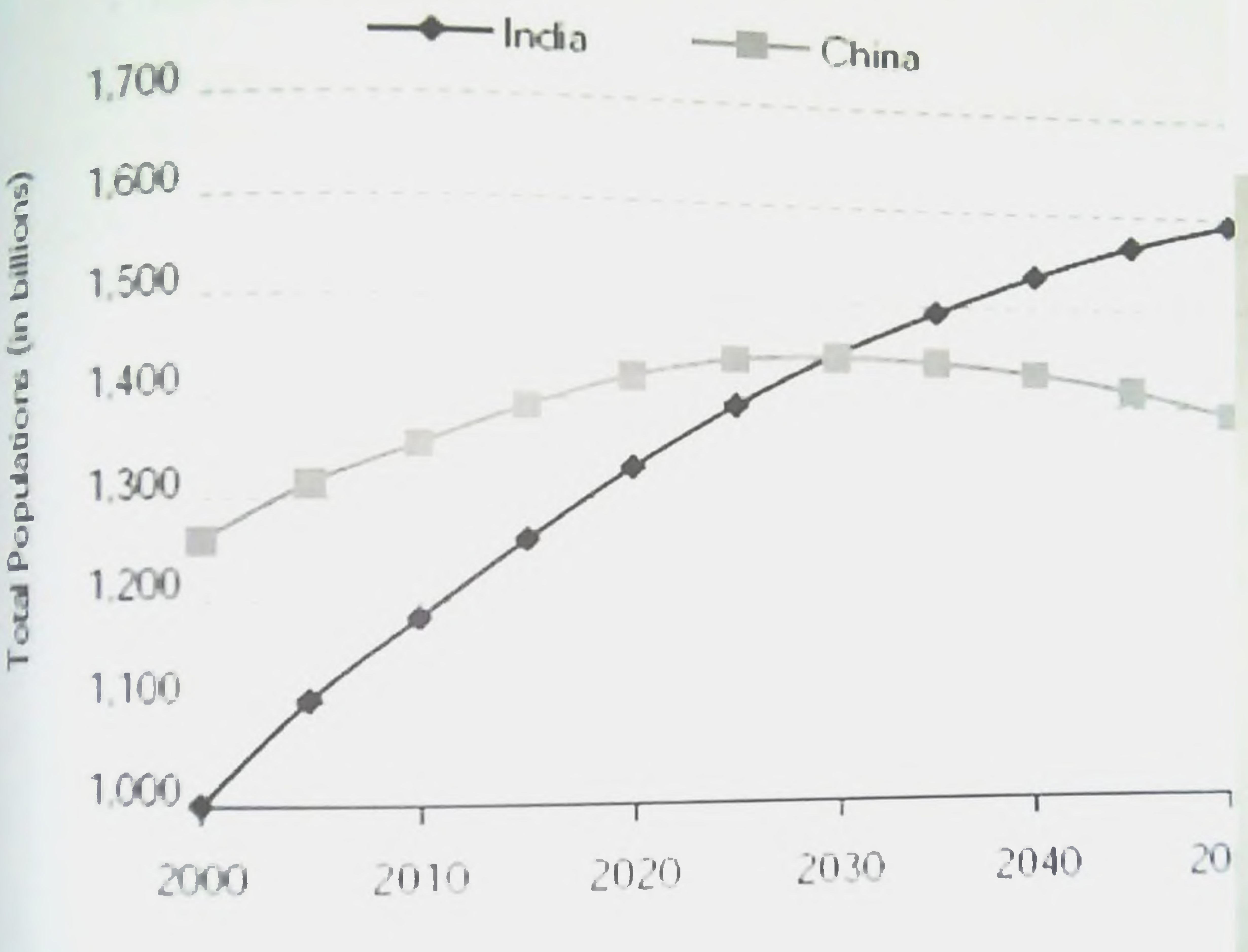
Figure 2.Growth of population in India



(US Census Bureau, 2010)

China is the world's largest nation in case of population. It is estimated that India will overtake China in population by 2030 and is shown in Figure 3.

Figure 3. Comparison of population of India and China over the years



(UN Population Division Medium Variant, 2010)

2.1.2 FOOD PRODUCTION

Food grain production is a vital element to ensure food and nutrition security in India. Availability of food grain is a key element in ensuring food and nutrition security. Without sustained increase over time in domestic food grain production, this is an impossible task.

2.1.2.1 REASONS FOR LOW FOOD PRODUCTION

Ratan and Singh (2010) pointed out the factors for low production of food crops as follows:

- **Lack of availability of quality seeds**

  Quality seed in India always remains in acute shortage.

- **High price of quality seed**

  The production cost of quality seeds are always beyond the purchasing limits of the small and marginal poor farmers.

- **Lack of knowledge of seed treatments**

  Most of the farmers generally do not treat their seed. Further, they do not know the difference between systemic or contact fungicides and insecticides suitable for seed treatment.

- **Lack of knowledge**

  Illiteracy is a limiting factor to get information on latest advancement regarding production techniques and policies.

- **High seed rate**

  Farmers use high rate of seed in the field which increase cost of cultivation, competition between plants for nutrients, light and space which affect the yield of crops.

- **Use of unbalanced fertilizers**

  This increase cost of cultivation and interfere with uptake of nutrients.

- **Lack of irrigation facilities**

  Unavailability of water at certain occasions is a limiting factor that affects productivity.

- **Weak extension system**

  Closer interaction between farmers, extension scientists and production system researchers is needed to remodel our extension system.

- **Lack of public investments in agriculture**

  Public investment is essential to create infrastructure, asset formation and improvement in quality of existing assets.

The trend in food production during 1952-53 to 2009-10 is described in Table 1.

Table 1. Food grain production in India

Year	Area (Million hectares)	Production (Million tonnes)	Yield (Kg/hectare)
1952-53	102.09	59.20	580
1962-63	117.84	80.15	680
1972-73	119.28	97.03	813
1982-83	125.10	129.52	1035
1992-93	123.15	179.48	1457
2002-03	113.86	174.77	1535
2003-04	123.45	213.19	1727
2004-05	120.00	198.36	1652
2005-06	121.60	208.60	1715
2006-07	123.71	217.28	1756
2007-08	124.07	230.78	1860
2008-09	122.83	234.47	1909
2009-10	121.37	218.20	1798

(Tripathy and Mishra, 2011)

According to Ayyappan, Director General of Indian Council of Agricultural Research, India's food production crossed 235 million tonnes during 2010-11 as per the latest estimates and this is the highest since Independence (Anon., 2011).

In terms of food grain production, India is third largest producer of cereals after China and U.S.A, being second in wheat and rice and first in total pulses. In terms of horticultural production, India is the second largest producer of vegetables and fruits. In terms of animal products, India is the highest producer of milk, third in egg production and fifth in total meat production (Ratan and Singh, 2010).

According to MSSRF (2001), a study on per capita net production of various foods among different states in India revealed that cereal production per capita is high in the states of Punjab and Haryana followed by Uttar Pradesh, Himachal Pradesh and Rajasthan. Tuber production per capita is highest in West Bengal, followed by Kerala, Tamil Nadu and Uttar Pradesh. Per capita availability of pulses is high in Madhya Pradesh and Rajasthan. Similarly, per capita per day sugar production is high in Maharashtra. Thus, the production per capita of almost all foods except fruits and vegetables are high. The per capita net production of plant foods is shown in Table 2.

Table 2. Per capita net production of plant foods (g/day)

States	Cereals	Tubers	Pulses	Sugar	Edible oil	Fruits	Veg.
ICMR NORMS	420	75	40	30	22	50	125
AP	363.35	6.87	22.68	30.67	27.78	106.33	66.41
Assam	16.10	58.01	5.84	0.67	4.84	49.83	196.33
Bihar	318.40	42.48	15.90	10.67	0.98	45.17	199.52
Gujarat	221.90	30.46	28.96	54.67	44.01	58.83	109.04
Haryana	1291.4	22.84	45.98	60.00	37.10	11.50	162.98
HP	487.03	50.88	4.17	0.00	1.03	70.17	211.70
MP	454.43	22.21	100.22	3.33	46.62	20.17	85.55
MA	274.13	3.95	43.00	140.67	18.45	55.33	354.33
Orissa	389.27	28.20	21.20	5.33	4.55	55.33	354.33
Punjab	2132.5	85.37	7.67	61.67	10.38	48.00	166.75
RA	458.77	1.02	89.27	1.33	48.19	7.00	15.95
TN	270.31	123.47	9.26	68.00	24.11	84.83	158.05
UP	545.68	116.76	33.62	65.67	7.16	38.17	160.95
WB	413.24	210.85	4.73	0.33	4.32	21.17	438.77
All India	430.33	65.73	31.94	41.00	18.10	58.33	179.22

(MSSRF, 2001)

Regarding the per capita production of animal foods, Punjab occupied the highest position in the production of milk and egg. Fish production is high in Kerala. The per capita net production of animal foods among the different states of India is shown in Table 3.

Table 3. Per capita net production of animal food items (g/day)

States	Milk	Eggs	Fish
ICMR norms	150	45	25
Andhra Pradesh	158.05	26.74	13.01
Assam	81.05	26.74	16.35
Bihar	92.34	4.87	6.35
Gujarat	265.22	3.63	40.32
Haryana	570.60	10.72	3.83
HP	281.32	3.62	2.41
Karnataka	171.47	10.35	15.52
Kerala	139.00	21.46	51.94
M P	178.47	5.21	3.27
Maharashtra	151.72	9.90	15.26
Orissa	48.00	5.78	20.47
Punjab	776.91	37.48	3.23
Rajasthan	270.61	37.48	0.70
Tamil Nadu	170.17	17.54	20.18
Uttar Pradesh	193.69	1.36	2.37
West Bengal	116.39	11.28	31.06
All India	184.33	9.38	14.01

(MSSRF, 2001)

2.1.3 ENVIRONMENTAL SUSTAINABILITY

Instability in production is a cause of short-term food insecurity. Environmental degradation, soil degradation and climate change are long term threats to sustained productivity. Sustainability is not limited to food production but includes environmental sustainability, which is essential for long-term viable crop and animal production.

Sustainability is defined as the use of natural resources or the application of a practice or technology in a manner in which the long term net impact on natural resources is not negative. Friendly practices of production, preservation of forest lands, less exploitation of the static component of ground water etc would sustain production for longer periods.

2.1.4 NATURAL DISASTERS

Natural disaster is an event of 'nature', which disrupts crops, assets and lives. It manifests itself as an interruption in the supply of food and result in transitory food insecurity of the people in the region. The length of insecurity depends upon the severity of the disaster, the preparedness systems in place and the ability of the people to cope with the shock.

CLIMATE CHANGE AND FOOD SECURITY

Threats of climate change looms large over Indian agriculture. Climate change will result in the emergence of new insect pests, shifting the range of various species, decline in food production and increased susceptibility to various diseases. Unfavourable changes in temperature, droughts floods etc affect food production which in turn result in food insecurity.

One degree centigrade rise in the temperature will reduce the duration of wheat and rice in north and western India by a week. This will result in reduction of rice and wheat by 4 to 5 quintals per hectare and 4 to 5 million tons respectively. In Northern parts of India, in December, the night temperature continues to be 7-8^{0}C and day temperature is about 20^{0}C . At this stage, the night temperature should not be more than 4^{0}C and the day temperature should not be more than 14-16^{0}C. High temperature at this stage stunts the growth of crops (Kumar, 2010). Floods and droughts destroy the field and crops.

2.2 FOOD ACCESS

Access is determined by the bundle of entitlements, i.e., related to people's initial endowments, what they can acquire (especially in terms of physical and economic access to food) and the opportunities open to them to achieve entitlement sets with enough food either through their own endeavours or through State intervention or both. While dealing with the issue of food access in the discrimination against females, or discrimination based on class, caste or community, the problem of affordability remains centre-stage. Food prices play an important part in the ability of the house hold to purchase an adequate diet.

If people have access to livelihood, they would in general have access to food and nutrition. Factors that reveal food access and livelihood access such as food consumption, poverty and employment are to be considered. Rural infrastructure is an important indicator that enhances livelihood oppurtunities.

2.2.1 ACCESS TO ADEQUATE FOOD

The recommended daily allowances of various foods proposed by the Indian Council of Medical Research (ICMR) have been used to examine the adequacy of consumption of cereal and non-cereal food items. The National Sample Survey data give information on the quantity of various foods consumed and the calorie intake levels of various per capita monthly expenditure classes. It provides information on the perceptions of people about food adequacy.

Table 4 indicates a decrease in the average consumption of cereals, pulses, meat and sugar in the country during 2004-05. When compared to the previous years, consumption of pulses and pulse products, there has been a drastic reduction in per capita monthly consumption in Rajasthan, West Bengal, Madhya Pradesh and Andhra Pradesh while consumption levels have improved in Kerala, Tamil Nadu and Assam. Average consumption of milk has marginally improved for urban consumers in all the States except Rajasthan and West Bengal. Rajasthan stands out in terms of decline in monthly per capita consumption of all major food items. Consumption of eggs, fish and meat was also below the required norm in almost all the States. However, the status with regard to milk, edible oil and sugar was found to be far better.

2.2.2 NUMBER OF MEALS

The persons reporting zero meals are spread across all expenditure groups, though the concentration is higher among the lower expenditure groups. Though, India is one of the largest producers of the food in the world, nearly 300 million people struggle for meeting two square meals a day and 21 per cent of national population (230 million) are malnourished (Tripathy and Mishra, 2011).

Table 5 indicates the distribution of households by availability of two square meals per one thousand households. In Orissa, 154 households are not getting meals. Orissa is a state in which there is high tribal population who lives in remote areas and may be more vulnerable to transitory food inadequacy in summer and monsoon months. The best situation is seen in Punjab in which one among the thousand household is not getting food. In Kerala, four households are not taking meals throughout the year.

Table 4. Per capita consumption of food items (g/day)

States	Cereal	Pulse	Milk	Oil	Egg	Fish	Meat
ICMR norms	420	40	150	22	45	25	25
AP	350.3	26.7	131.3	20.7	11.0	2.7	3.3
Assam	397.3	25.7	60.0	21.7	11.7	22.7	3.0
Bihar	405.0	29.3	117.0	20.3	4.7	6.0	2.0
Gujarat	276.3	31.3	201.0	35.3	1.7	0.66	1.7
Haryana	305.0	23.3	287.7	18.7	3.0	0.66	0.33
KA	323.3	29.7	146.0	18.3	8.7	4.0	3.7
Kerala	294.3	21.3	109.7	15.7	11.3	65.0	0.33
M.P	366.3	30.3	112.7	21.3	7.3	2.7	1.3
MA	279.7	30.3	131.7	26.3	6.7	3.7	3.3
Orissa	437.0	23.3	67.3	14.0	6.3	12.3	3.0
Punjab	300.3	30.0	317.3	24.7	2.7	0.00	0.66
RA	361.3	17.0	221.3	19.3	1.3	0.33	2.7
TN	316.0	31.7	144.7	18.3	11.3	4.7	3.3
UP	365.0	33.3	174.7	20.3	5.3	1.3	2.0
WB	346.3	18.33	77.7	23.0	18.3	30.0	1.7
All India	331.3	27.3	153.3	22.0	7.3	7.0	2.3

(NSSO, 2007)

2.2.3 FOOD PRICES

Food access depends upon the affordability of adequate food. Thus, food access depends upon the income of the people and the prices prevailing in the market. If income rises at a slower rate than food prices, the purchasing power is affected. The poor can access only smaller amounts of food, thus leading to inadequate calorie consumption. The mismatch between income and price result in food insecurity of the people. The per capita income of various states is given in Table 6.

Table 5 Availability of two square meals/day (per 1000 households)

States (1)	Through out the year (2)	Only some months of the year (3)	Not getting through out the year (4)	Not getting meals Col. (3+4)	Not reported
AP	966	17	12	29	5
Assam	901	61	30	91	8
Bihar	928	51	15	66	6
Gujarat	976	9	4	13	11
Haryana	992	8	0	8	0
KA	960	27	8	35	4
Kerala	910	74	4	78	12
M P	970	25	3	28	1
MA	954	41	4	45	1
Orissa	844.00	149.00	5.00	154.00	2
Punjab	999.00	1.00	0.00	1.00	0
RA	985.00	6.00	0.00	6.00	8
TN	969.00	15.00	9.00	24.00	7
U P	963.00	29.00	5.00	34.00	3
WB	856.00	111.00	30.00	141.00	4
All India	945.00	42.00	9.00	51.00	4

(MSSRF, 2001)

Table 6 Per capita income of various states of India (UNIDOWFIS, 2011)

States	Per capita income (Rs.)
AP	51,025
Assam	27,197
Bihar	16,119
Chattisgarh	38,059
Gujarat	63,961
Haryana	78,781
HP	50,365
J&K	30,582
Jharkhand	30,719
Karnataka	50,676
Kerala	59,179
MP	27,250
MA	74,027
Orissa	33,226
Punjab	62,153
Rajasthan	34,189
T N	62,499
UP	23,132
WB	41,469

In this context, the Public distribution system that provides food at affordable prices is of crucial importance. They help to correct the mismatch of the rate of growth of income and prices to some extent.

2.2.4 DISCRIMINATION BY GENDER

Food access and livelihood access are not available equally to everybody. Gender discrimination prevailing in many societies is translated into denial of access to adequate food. They eat only after they have fed the other members of the family. The bias against females is a result of the 'intangible variable of culture and custom'. This result in preference for male members in food and healthcare allocation within a household. The intra-household food insecurity becomes even more pronounced under conditions of poverty and when there is limited access to resources.

Women and girl children are the worst sufferers of the decline in food, which is compounded by the anti-female bias prevalent in India .Over burdening of women means that they require high energy foods that many of them don't get. There is also discrimination in work participation and wages. Wages of women are less than that of women.

2.2.5 FEMALE LITERACY

Female literacy is the first step towards empowerment. It gives self-confidence, reduces dependency on others and improves knowledge. It helps in getting better deals in the purchase of food, better paid semiskilled jobs. Literacy improves knowledge of nutrition and medical facilities, enabling them to look after their children better and reduces child mortality rates. Finally, the process of education can help a girl child to escape the drudgery of child labour both at home and outside.

The states with the lowest female literacy in rural India are Rajasthan and Bihar at 52.7 and 53.3 per cent respectively. Kerala is way ahead in female literacy at 92.0 per cent.

2.2.6 DISCRIMINATION BY CASTE

Certain sections of the population are deprived of food access and livelihood access due to their disadvantaged position as a Scheduled Caste or Scheduled Tribe. They constitute a high percentage of the lower expenditure groups. The major occupation of the SC population is labour. Their economic condition is bad, consumption level is very low and is below the recommended level of intake. SC and ST lack assets, education, income and land when compared to other castes.

2.2.7 POVERTY

Poverty and food and nutrition security are intricately linked. Food access depends upon purchasing power linked to livelihood access. Livelihood access means assured access to income over long periods. Poverty is the bigger problem than unemployment. The spiral increase in the domestic and international prices of food articles has raised a question on food security in India, where nearly 26 percent of country's citizens are living below poverty line. Though, India has achieved self sufficiency in food production and there is 'food for all', the biggest challenge facing the nation is to ensure 'food to all' to achieve food security.

Daniel *et al.* (2004) observed better house hold food security among high and middle income families due to stable economic status and increased level of education with proper management of available resources. In a study conducted among the households of agricultural labourers of organized and unorganized sectors, Lawrence *et al.* (2005) observed food insecurity without hunger and with moderate hunger among 33 to 40 per cent of the households of unorganized sector.

2.2.8 SELF EMPLOYMENT

Self employment improves the standard of living of the people. It increases the purchasing power and decreases food insecurity. It helps to eliminate the discrimination in wages.

2.2.9 RURAL INFRASTRUCTURE

Infrastructure refers to physical assets such as roads, transport system, water supply, electricity, irrigation facilities, storage facilities, market places for output as well as inputs to agriculture etc. It is not possible to improve livelihood oppurtunities without these communities.

The best states for infrastructure are Himachal Pradesh, Gujarat, Tamil Nadu and Maharashtra. Bihar is the state with the worst infrastructure facilities, followed by West Bengal, Uttar Pradesh, Assam and Orissa.

2.3 FOOD ABSORPTION

Absorption is defined as the ability to biologically utilize the food consumed. This in turn is related to several factors such as nutrition knowledge and practices, stable and sanitary physical and environmental conditions to allow for effective biological absorption of food and health status (MSSRF, 2008). Food absorption relates to food assimilation. Absorption in turn depends upon the state of health of the individual. Food consumption depends upon habits, preferences, perceptions, preferences and knowledge of basic nutrition.

The indicators of absorption are outcome indicators that indicate the health and nutrition status of the population. India houses a huge population of malnourished and several studies have established that high levels of malnutrition have a negative impact on productivity and economic growth. A person who is not healthy cannot assimilate food even if she or he consumes a balanced diet. One's health depends upon sanitation and hygiene of the surroundings. It also depends upon the timely availability of medical facilities to recover from diseases. The outcome of problems connected with absorption in an unhealthy population leads to growth disorders, high levels of morbidity and high levels of mortality of infants, children, mothers, women and men.

2.3.1 MALNUTRITION

It includes protein energy malnutrition and deficiencies of one or more other nutrients.

2.3.2 POPULATION CONSUMING LESS ENERGY

The calorie, a unit of energy, has always been considered as the main measure of food adequacy and is the basis of poverty measurement in India. Actual calorific requirements of an individual depend on factors such as gender, age, body weight and nature of work, all of which vary across individuals. Fixing a norm, therefore, requires a detailed analysis of the population being studied.

The FAO accordingly assigns minimum energy requirement levels to different countries. The figure of 1,890 Kcal per capita per day, 70 per cent of the international norm of 2,700 Kcal used by FAO was taken as a measure of the extent of food inadequacy, and the percentage of rural population accessing less than this figure was included as an indicator in the index of food and nutrition insecurity

Overall, for rural India as a whole, there is a marginal reduction in the percentage of persons reporting a calorie intake less than 1,890 Kcal. In 2004 – 05, Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Punjab, Tamil Nadu, Uttar Pradesh and West Bengal showed a decline in the percentage of persons with a calorie intake less than 1,890 Kcal per consumer unit, with improvements in Jammu and Kashmir and Himachal Pradesh (Table 7).

Table 7 Percentage of population consuming less than 1,890 Kcal /day

States	2004-05
Andhra	12.5
Assam	8.9
Bihar	10.0
Chattisgarh	16.2
Gujarat	17.1
Haryana	7.8
HP	2.8
J & K	2.4
Jharkhand	13.8
Karnataka	20.5
Kerala	17.5
MP	16.0
MA	19.7
Orissa	15.4
Punjab	6.4
Rajasthan	5.2
Tamil Nadu	23.4
UP	8.0
West Bengal	11.9
All India	13.2

(MSSRF, 2008)

2.3.3 PROTEIN CALORIE DEFICIENCY

Protein is needed for body building. Enough calories are essential to achieve protein. The protein calorie deficiency is high in Tamil Nadu and low in Gujarat (Table 8).

Table 8 Population with protein calorie deficiency (%)

States	Deficiency
A P	10.4
Assam	27.9
Bihar	12.3
Gujarat	2.5
Haryana	4.6
H P	6.7
Karnataka	14.9
Kerala	19.9
MP	19.7
Maharashtra	19.7
Orissa	24.1
Punjab	3.0
Rajasthan	15.0
Tamil Nadu	41.4
Uttar Pradesh	NA

(MSSRF, 2001)

2.3.4 ANAEMIA AMONG WOMEN AND CHILDREN

Anaemia has been on the increase in the country as a whole, especially among vulnerable categories such as children and pregnant women (Chandrasekhar and Ghosh, 2007). In Indian settings, iron deficiency is known to be the major cause of anaemia (Indian Medical Association, 2005). It must, however, be noted that infectious diseases in particular, such as malaria, tuberculosis and HIV/AIDS are important factors contributing to the high prevalence of anaemia in many populations. Nutritional deficiencies besides iron, such as folate, vitamin B_{12} and vitamin A, can also cause anaemia, although the magnitude of their contribution is unclear. On the whole, high levels of anaemia may be seen as an indicator of poor health and nutrition.

The data pertaining to anaemia among ever-married women in the age group of 15 – 49 years from the surveys of 2005 – 06 showed that more than fifty per cent of the women in rural India were reported anaemic. The incidence of anaemia among women in the reproductive age group was high in Andhra Pradesh, Chattisgarh, Gujarat, Haryana, Tamil Nadu, Madhya Pradesh and Rajasthan. When compared to other states, the best condition is seen in Kerala.

In case of children with anaemia, if Kerala and Himachal Pradesh are left out, all other States have uniformly very high figures with the worst situation in Bihar.

2.3.5 CHRONIC ENERGY DEFICIENCY (CED)

A typical and frequently used indicator of poor nutrition is the Body Mass Index (BMI). The BMI is defined as the ratio of weight of a person to the square of the person's height, with the weight normally measured in kilograms and the height in meters. BMI is known to be a good predictor of the risk of morbidity and mortality. A level of BMI below 18.5 thus measured indicates a state of CED.

At the State levels, only four States reported a higher level of incidence of CED in 2005 – 06. These are Assam, Bihar, Haryana and Madhya Pradesh. As with the percentage of women with anaemia, Jharkhand is the worst performer in 2005 – 06 in respect of the percentage of women with CED. Jharkhand is followed by Bihar, Chhattisgarh, Madhya Pradesh, West Bengal and Orissa. Surprisingly, West Bengal, which performs a good deal better in respect of some other indicators, does poorly with respect to CED.

2.3.6 STUNTING AMONG CHILDREN

Growth stunting, defined as height for age below the fifth percentile on a reference growth curve, is traditionally used as an indicator of nutritional status in children. Growth stunting is a population-based indicator and can indicate the prevalence of malnutrition or nutrition-related disorders among an identified population of children. Growth stunting results from prolonged or repeated episodes of nutritional deficiency. The percentage of children (6 – 35 months) who are stunted is included as a measure of chronic food and nutrition insecurity.

The worst situation is seen in Chhattisgarh and Gujarat and the best is found in Kerala followed by Tamil Nadu.

2.3.7 ACCESS TO DRINKING WATER

Water is defined as safe if it is free from biological contamination (guinea worm, cholera, typhoid, etc.) and chemical contamination (excess fluoride, brackishness, iron, arsenic, nitrate, etc.). Besides playing a vital role in nearly every function of the body, from protecting the immune system to helping in the removal of waste matter, water is crucial for our nutrition. Access to safe water is thus a fundamental human need and should be considered a basic human right. Access to safe drinking water is crucial for ensuring effective biological utilisation of food taken by an individual. It is a key element of the absorption aspect of food and nutrition security.

According to a Report of the National Commission on Population (2003) on 'Strategies to address unmet needs for drinking water supply and sanitation', as per an estimate, 1.5 million children below age five die and 200 million human days are lost every year due to water-related diseases. Most deaths occur due to water-related diseases, such as diarrhoea and jaundice and unless cases of these two diseases are reduced, the IMR and morbidity rate cannot be reduced.

As per the Census of India, if a household has access to drinking water supplied from a tap or hand-pump or tube well within or outside the premises, it is considered as having access to safe drinking water. Drinking water in Kerala, mostly from wells, is generally not very unsafe, and in any event, not more unsafe than water in other States. More importantly, there is a long tradition of drinking boiled water in Kerala. Yet, going by official data, Kerala has the highest percentage of households without access to 'safe' drinking water, the figure being 83 per cent. This is because the principal source of drinking water in Kerala is the open well, which, by Census definition, is not considered as a source of safe drinking water. The best states with proper drinking water facility are Punjab followed by Himachal Pradesh.

2.3.8 ACCESS TO TOILET WITHIN PREMISES

Direct relationship exists between water, sanitation, health and human well-being. Consumption of contaminated drinking water, improper disposal of human excreta, lack of personal and food hygiene etc. have been the major causes of many diseases in India (GOI, 2003).

In the case of access to 'safe' drinking water, Kerala was an outlier with a very high proportion of the population deprived of access, it is quite the opposite situation when it comes to access to a toilet within the premises. The best condition is observed in Kerala and worst situation are in Chhattisgarh and Jharkhand.

2.3.9 LIFE EXPECTANCY

The long-term out come of food security is ultimately reflected in an improvement in the life expectancy of the population. Assam has the lowest life expectancy at age one with 60.6 years. The best state is Kerala with 73.2 years (Table 9).

Table 9 Life expectancy at age one

States	Life expectancy at age one
Andhra Pradesh	65.2
Assam	60.6
Bihar	63.2
Gujarat	65.1
Haryana	67.6
Himachal Pradesh	68.1
Karnataka	66.6
Kerala	73.2
Madhya Pradesh	61.2
Maharashtra	68.1
Orissa	62.6
Punjab	70.5
Rajasthan	64.6
Tamilnadu	66.1
Uttar Pradesh	62.2
West Bengal	65.8

(MSSRF, 2001)

2.3.10 CHILD HEALTH INDICATORS

Child nutrition is extremely important for better health of infants and children below 5 that will influence their future growth, health, immunity to diseases and mental facilities. The deaths arise due to lack of immunization, medical help, safe drinking water etc. The details on IMR and CMR of various states of India are given in Table 10.

Table 10. Infant mortality rate and child mortality rate

State	IMR	CMR
Andhra Pradesh	47.70	8.00
Assam	50.60	17.60
Bihar	52.32	19.96
Gujarat	44.60	9.90
Haryana	30.20	11.50
Karnataka	40.00	6.20
Kerala	11.60	2.20
Madhya Pradesh	59.66	14.57
Maharashtra	28.40	8.80
Orissa	40.90	19.20
Punjab	42.60	9.20
Rajasthan	65.10	12.00
Tamil nadu	31.00	3.80
Uttar Pradesh	53.47	19.66
West Bengal	46.40	6.80
All India	41.50	10.60

(MSSRF, 2008)

2.3.11 HEALTH INFRASTRUCTURE

To keep the population free from diseases, existence of hospital beds, doctors and primary health centres are essential. Quality of services provided by the hospitals is also important. Bihar and Uttar Pradesh occupy the worst position. Himachal Pradesh has best facilities, Punjab and Tamil Nadu have good health infrastructure

2.3.12 NUTRITION KNOWLEDGE

Inadequate nutrition knowledge and awareness often result in malnutrition or over-nutrition. The NGO's, research foundations and private sectors have taken significant and impressive initiatives towards agriculture development, nutrition security, and poverty reduction.

3 FOOD SECURITY MAP OF INDIA

It gives an overall picture of the food insecurity situation at the state level and is assessed by means of composite index values of food insecurity with seven indicators:

- women with anaemia
- women with CED
- children with anaemia
- children with stunting
- population consuming less than 1890 Kcal
- population not access to drinking water
- population not access to toilet

COMPOSITE INDEX OF FOOD AND NUTRITION INSECURITY

With the selected seven indicators, a composite index of food and nutrition insecurity was computed for rural India. The index is intended as a summary measure of a complex, multidimensional concept, which cannot be captured by a single indicator alone.

To compare the performance of each State with respect to each individual indicator was expressed as a value between 0 and 1 by using the formula,

$$\text{Index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minumum value}}$$

Among the States compared, the most insecure State with respect to any particular indicator will have a 'dimension index' value of 1 while the least insecure State will have a value 0. The States have been placed into one of five categories based on the level of food and nutrition insecurity as very low insecurity, low insecurity, moderate insecurity, high insecurity and very high insecurity.

An example is given with respect to women with anaemia and the index value computed on the basis of the above formula with respect to percentage of women with anaemia is given in

Table 11. The ranking of different States with respect to food insecurity on this index is also given in the same table.

This procedure is carried out for all the seven indicators and the final composite index of food insecurity was computed for each State, by adding the values across all indicators and taking the average value. The final composite index of food insecurity with seven indicators for the year 2004-06 is given in Table 12. The different States have been categorised into different levels of food insecurity like very low insecurity, low insecurity, moderate insecurity, high insecurity and very high insecurity. The details are given in Table 13.

Table 11. Index value and rank of percentage of women with anaemia

States	Indicator	Index value	Insecurity risk
AP	63.7	0.758	6
Assam	69.5	0.898	2
Bihar	68.2	0.867	3
Chattisgarh	59.4	0.654	8
Gujarat	59.2	0.649	9
Haryana	56.9	0.593	10
HP	41.2	0.213	17
J& K	53.6	0.513	13
Jharkhand	73.7	1.000	1
Karnataka	52.5	0.487	14
Kerala	32.4	0.000	19
MP	61.0	0.692	7
MA	51.1	0.453	15
Orissa	64.0	0.765	5
Punjab	37.4	0.121	18
Rajasthan	54.9	0.545	11
TN	53.9	0.521	12
UP	49.8	0.422	16
WB	65.6	0.805	4

(MSSRF, 2008)

Finally, a food insecurity map of Rural India was developed on the basis of the final composite index. The States in darker shade of red indicate very high level of insecurity and the lighter shades of red indicate relatively lower levels of insecurity, with the least red indicating the least insecure.

Table 12. Composite index of food insecurity with seven indicators 2004- 06

States	Composite index	Rank
AP	0.630	9
Assam	0.559	13
Bihar	0.719	4
Chattisgarh	0.792	2
Gujarat	0.707	5
Haryana	0.538	14
HP	0.238	19
J & K	0.354	16
Jharkhand	0.890	1
Karnataka	0.683	7
Kerala	0.246	18
MP	0.751	3
Maharashtra	0.663	8
Orissa	0.700	6
Punjab	0.263	17
Rajasthan	0.565	12
TN	0.508	15
U P	0.604	10

(MSSRF, 2008)

able 13. States fall under level of food insecurity

States	Composite index
AP	0.630
Assam	0.559
Bihar	0.719
Chattisgarh	0.792
Gujarat	0.707
Haryana	0.538
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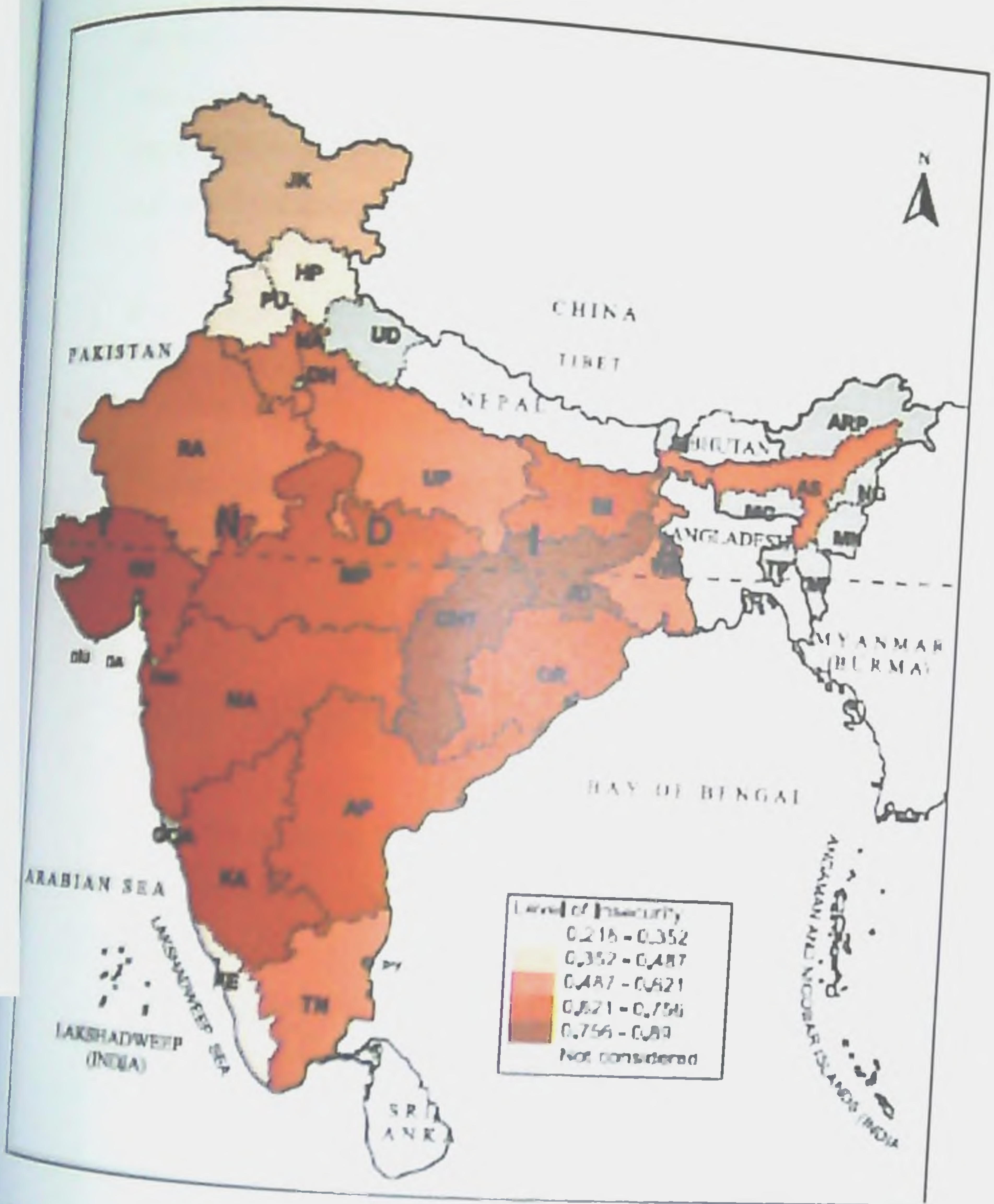
Figure 4 Food security map of Rural India



4. CONCLUSION

Food security is the imperative pre requisite for the economic and social stability of the family, community and nation. Though, India has achieved self sufficiency in food production and there is 'food for all', the biggest challenge facing the nation is to ensure 'food to all' to achieve food security. Among the States, those that fall under very low level of food insecurity are Kerala, Punjab and Himachal Pradesh. The States with very high insecurity are Chhattisgarh and Jharkhand.

DISCUSSION

1. Tamil Nadu attained the lowest position in consumption of calorie, protein etc. Then how the state came in moderate food security index?

   Ans. In the case of all other indicators that are used to assess the level of food security, the condition in Tamil Nadu is better. So, this is assessed only after taking all the indicators together, and not using a single indicator.

2. Which are crops that we can cultivate in consideration of food security in India?

   Ans. Rice, Ragi, Pulses, Vegetables and Roots and Tubers.

3. Is Kerala considered as the best state in food security in India? Why?

   Ans. Yes. Literacy rate, health facilities, Public Distribution System etc. are highest in India.

4. Kerala is in the high food insecurity level in the case of access to safe drinking water. Why?

   Ans. Drinking water in Kerala is mostly from open wells, which, by Census definition, is not considered as a source of safe drinking water. As per the Census of India, if a household has access to drinking water supplied from a tap or hand-pump or tube well within or outside the premises, it is considered as having access to safe drinking water.

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Abstract

Food security exists when "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). The problem of food and nutrition insecurity remains as a great threat to large number of poor and vulnerable people across the world. At the global level, the South Asian region is the home to more chronically food insecure people than any other region in the world (MSSRF, 2008).

It has been estimated that in India, one out of four persons goes to bed hungry with a high Global Hunger Index value. In the report published by International Food Policy Research Institute (IFPRI) in October 2010, India was ranked 67 out of 84 countries in the Global Hunger Index based on child malnutrition, child mortality and proportion of people who are calorie deficient (Kumar, 2010).

Food security has three basic components namely availability, access and absorption. Availability of food is a function of food production and access to food is a function of purchasing power and employment. Absorption of food in the body is influenced by nutritional status, education and health care (Swaminathan, 2010).

Though, India is one of the largest producers of the food in the world, nearly 300 million people struggle for meeting two square meals a day and 21 per cent of national population (230 million) are malnourished (Tripathy and Mishra, 2011).

Food insecurity in rural India is primarily a reflection of rural poverty, and thus overall economic growth and its distributional pattern are important in solving the hunger problem. Those dependent upon low wage income and casual employment do not hope to eat enough throughout the year. Things get worse when drought, climate change and other transitory problems occur. Discrimination by caste and gender are ingrained in society and have a bearing upon livelihood access and food access.

Further, problems of absorption of food into the body occur due to diet imbalances and diseases. Lack of health care facilities, clean drinking water and sanitation worsen the situation which in turn have an impact on life expectancy, maternal mortality, child mortality, infant mortality and malnutrition (MSSRF, 2001).

Food security is in fact the imperative pre requisite for the economic and social stability of the family, community and nation. The deprivation of the basic need represented by food insecurity and hunger are possible precursors to nutritional, health and developmental problems.

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Strategies To Combat Vitamin A Deficiency Disorders

By

SIMI.M.C
(2010-16-103)

M.Sc Home Science
(Food Science and Nutrition)

SEMINAR REPORT

Submitted in partial fulfilment for requirement of the course
HSC 591, Seminar (0+1)

DEPARTMENT OF HOME SCIENCE
COLLEGE OF HORTICULTURE
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CONTENTS

1. INTRODUCTION

Vitamin A deficiency (VAD) is the leading cause of childhood blindness worldwide. It is more prevalent in developing countries, with the World Health Organisation estimates of approximately 228 million children affected by moderate to severe deficiency. At greatest risk are the malnourished children born to vitamin A–deficient mothers, particularly if they are affected concurrently by other biological stresses, such as diarrhoea or measles. Although rare in the United States, vitamin A deficiency has been known to occur as a result of poor dietary intake, liver diseases, and gastrointestinal malabsorption. The spectrum of ocular disease arising from vitamin A deficiency is known as xerophthalmia. Ocular changes include conjunctival and corneal drying (xerosis), corneal ulceration and melting (kerotomalacia), night blindness (nyctalopia) and retinopathy. In addition to its importance in the functions of the eye, vitamin A is necessary for proper immune function. Vitamin A deficiency is associated with a higher degree of morbidity and mortality, mainly because affected children are more susceptible to respiratory and intestinal infections.

Vitamin A Deficiency is a threat to health and lives of million of children in the developing world. Children deficient in vitamin A grow poorly, have poor appetites, have more infections, are more anaemic, are more likely to go blind and are more likely to die in childhood than their peers.VAD increases the risk of death from common childhood infections such as diarrhoeal disease and measles. It is estimated that over 3 million children world wide have clinical signs of VAD and the approximately 250 million children are at risk of VAD. It is most common in India and other developing countries (Krishnaswami, 1998)

2. VITAMINS

Vitamins are organic compounds occurring in small quantities in different natural foods and necessary for the growth and maintainence of good health. Vitamins are required in minute quantities and their deficiency results in structural and functional disorders of various organs in the body (Swaminathan, 1990)

3. CLASSIFICATION

Fat soluble vitamins

Vitamins soluble in fats and fat solvents but insoluble in water.

Eg: Vitamin A, D, E and K

Water soluble vitamins

Vitamins soluble in water but insoluble in fats and fat solvents

Eg: B-complex vitamins, vitamin C etc

4. VITAMIN A

Vitamin A is a fat soluble vitamin which comes in two forms. The first is retinol which is found already pre-formed in animal foods. The other is pro-vitamin A, which is found in plant foods in the forms of compounds called carotenoids. Vitamin A is also known as antixerophthalmic factors, bright eye vitamin and Anti-infective vitamin

5. HISTORY

Vitamins are the discovery of twentieth century scientists. Vitamin A or retinol was the first essential fat soluble vitamins discovered by Mc Collum and Davis in 1913. Mc Collum and Simmonds in 1917 demonstrated that xerophthalmia was due to lack of a fat soluble vitamin. Steen Bock in 1919 discovered the vitamin A activity of carotenoids. Karser in 1931 obtained the structure of vitamin A .In1937, Khon and Morris synthesised vitamin A.

6. ABSORPTION AND STORAGE

Vitamin A alcohol or esters are absorbed as retinyl esters in the small intestine. Vitamin A esters are hydrolysed in the lumen of the intestine to free vitamin A alcohol prior to its absorption through mucosal membrane. Vitamin A alcohol (retinol is absorbed through the mucosal membrane as vitamin A palmitate This vitamin A palmitate passes via·the lymphatic system to the blood stream and then to the liver .

Vitamin A is stored in the kupffer cells of liver. When vitamin A is mobilised from the liver, the stored vitamin A ester is hydrolysed to free vitamin A alcohol, which is transported to the different tissues by the blood. Liver can store about 2to 3 lakhs IU of vitamin A.

7. VITAMIN A IN THE BODY

Retinoids and caroteinoids are transported from the intestine with chylomicrons. These lipoproteins deliver the retinoids and caroteinoids to body tissues.

In the liver some caroteinoids can be converted in to retinol. To move from liver stores to the tissues, preformed vitamin A must be bound to Retinol Binding Protein (RBP). In the body the different forms of vitamin A have different functions. Retinol and retinal can be inter converted from one to other. Retinol is the form that is important for vision. Retinoic acid, which is made from retinol or retinal affects gene expression and is responsible for cell differentiation, growth and reproduction. Caroteinoids that are not converted to retinods function as antioxidant (Sherman, 1952).

8. FORMS OF VITAMIN A

Vitamin A is present in the form of

- Retinol (vitamin A)
- Retinal (vitamin A aldehyde)
- Retinoic acid (vitamin A acid)
- Retinyl esters
- Carotene (provitamin A). 1 Alpha carotene
  2 β – carotene
  3 Gamma carotene

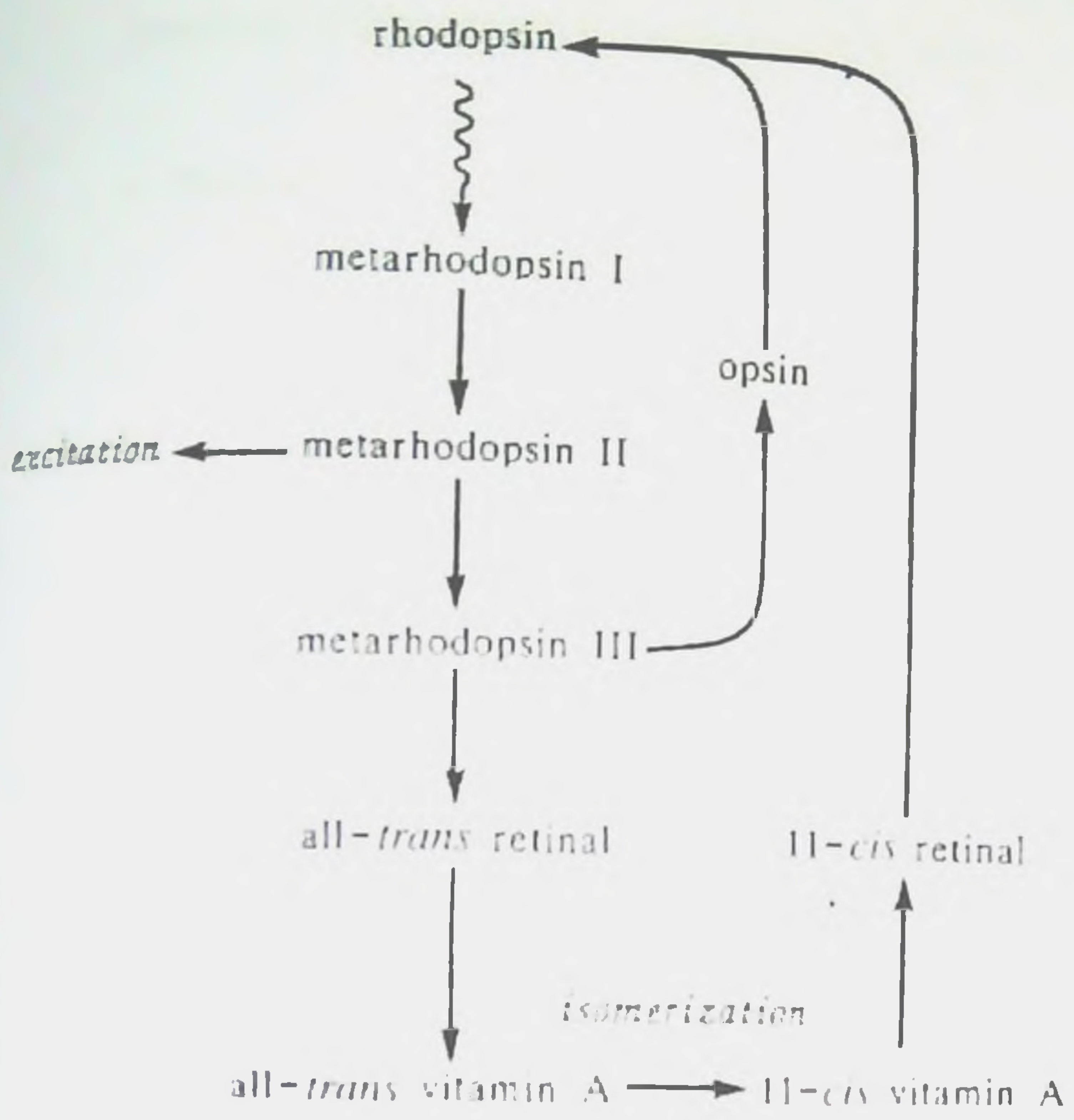
Vitamin A in its pure form is a pale yellow substance soluble in fats. Retinol is the generally accepted chemical name for vitamin A

9. FUNCTIONS OF VITAMIN A

1. Vitamin A and vision

Vitamin A places a critical role in vision in dim light. In the eye, the retinal form of the vitamin A combines with the protein opsin to form the visual pigment rhodopsin. Rhodopsin helps to transfer energy from light in to nerve impulse that is send to be brain. This nerve impulse allows us to see when vitamin A is deficient there is a delay in the regeneration of rhodopsin in which causes difficulty in adopting in dim light after experiencing a bright light.

Visual cycle



2. Regulating gene expression

In the body retinoic acid, a form of vitamin A enters specific target cells. Inside the nucleus of these target cells, retinoic acid binds to regulatory regions of DNA This binding changes the amount of messenger RNA (mRNA) that is made by the gene. The change in mRNA changes the amount of protein that is produced.

3. Cell differentiation

Cell differentiation is the process where by immature cells change in structure and function to become specialised. Vitamin A affects cell differentiation through its effect on gene expression. This means that, it can turn on or off the production of certain proteins that regulate functions within cells and through out the body.

4. Maintenance of epithelial tissue

Epithelial tissue on body surface contains cells that produce mucus for lubrication. When mucus secreting cells die, the new cells do not differentiate properly and instead they produce a protein called keratin. As the mucus secreting cells die and are replaced with keratin producing cells, the epithelial surface become hard and dry. This process is known as keratinisation. The hard, dry epithelial cells do not have the protective capabilities of normal epithelium. There by increasing the chances for infection.

5. Reproduction, growth and immunity

The ability of vitamin A to regulate the growth and differentiation of cells makes it essential through out life for normal reproduction, growth and immune function (Obered,1987).

Poor overall growth is an early symptom of vitamin A deficiency in children. When vitamin A is deficient, the activity of specific immune cells can not be stimulated. This impaires immune function, increases the risk of illness and infection due to defective epithelial tissue barriers.

6. Other functions

1. Essential for normal bone formation
2. Mucopolysacharrides and sulphate metabolism
3. Mucoprotein and glyco protein synthesis

10. β – CAROTENE

β –carotene is undoubtedly the major source of vitamin A. Carotene was first isolated from carrot by Wackenroder in 1831. Moore in 1930 suggested that the convertion of β-carotene to vitamin A takes place in the liver. Duel and coworkers in 1947 proved that β-carotene when administrated orally is probably converted in to vitamin A in the intestinal wall β – carotene occurs in plant foods along with alpha and gamma carotene.

Functions

1. β- carotene as a source of vitamin A

β –carotene is an active precursor of vitamin A which is found only in orange and yellow coloured fruits and vegetables, dark coloured green leafy vegetables etc.

2. Role in other mechanisms

A. Oxidant –reductant

β –carotene is an uncommon type of biological redox reagent, one that reduces oxidation products, best at low partial pressures of oxygen which are relevant to many physiological tissues.

It can function as an antioxidant or a reductant depending upon reaction conditions. It is known to decrease lipoprotein and DNA oxidation, which is oxidized initiate atherogenesis and cancer or other degenerative diseases (Rajammal *et al*., 1987)

B .Gap junction communication

Gap junctions like cells within an organism to form a communicating system, allowing small molecules to pass through cells. β-carotene and vitamin A both can structure gap junction formation between cells. Prevention of cancer may also occur through these gap junctions, by maintaing carcinogen initiated cells in functional communication with non- transformed cells. Preventing their transformation, in a corrected ability to inhibit neoplastic transformations.

C. Immunological response

It has been implicated in T and B cell proliferation

D. Enzyme regulation

Lipoxigenase which is involved in arachidonic acid metabolism is known to be initiated by β-carotene.

II. VITAMIN A DEFICIENCY DISEASES (VAD)

Nutritional blindness due to xerophthalmia is an important public healthy problem among young children in India (Grosvenor and Smolin, 1997), the term xerophthalima comprises all ocular manifestations of VAD (Bamji *et al.*, 1998)

WHO recommends the following classification of xerophthalmia

1. Night blindness (XN)

2. Conjunctival xerosis (X1A)

3. Bitots spots (X1B)

4. Corneal xerosis (X)

5. Keratomalacia

6. Cornial scar (XS)

7. Xerophthalmia fundes (XF)

1. Night blindness

When vitamin A is decreased there is a delay in the regeneration of rhodopsin which causes difficulty in adapting to dim light after experiencing a bright light. This condition is called night blindness

2 .Conjunctival xerosis

It manifest as dry patches of non-wettable conjuctiva. It may be associated with various dryness of thickening, wrinkling and pigmentation of the conjunctiva.

3. Bitots spots

It is an extention of the xerotic process. These spots are raised, muddy and dry triangular patches.

4. Cornial xerosis

It is diagnosed by the presence of haziness or dryness of cornea. Generally, the changes take place at the lower portion of the eye. The cornea takes ground glass appearance. Subsequently corneal ulcers may occur.

5. Keratomalacia

Xerosis of the conjunctiva and cornea lead to keratomalacia .In this condition softening and dissolution of the cornea occurs

6. Xerophthalmia

The perforation of the cornea leads to prolepsis of the iris, extrusion of the lens and infection of the whole eyeball and at last it leads to total blindness.

7. Follicular hyperkeratosis

This is mainly due to hyperkeratinisation of epithelium lining, the follicle. The skin becomes dry and rough.

12. PREVALANCE OF VAD

Currently, the prevalence of severe forms of VAD such as corneal xerosis and keratomalacia has become extremely rare. The prevalence of milder forms such as bitots spots, conjuctival xerosis and night blindness exist in varying degrees in different parts of the country. According to National Institute of Nutrition (NIN, 2004) survey indicate that the overall prevalence of night blindness and bitots spots in India among children under six years is 0.8 percent and 0.3 percent respectively.

13. ASSESSMENT OF VAD

1. Dark adaptation test
2. Serum plasma vitamin A levels
3. Relative dose response test(RDR)
4. Modified version of RDR test (MRDR)
5. Dried blood spot method.

1. Dark adaptation test

In early stages of VAD the individuals can not see objects in dim light. This test carried in one of the following two ways.

In the first method, the subject is kept in a dark room for some time asked to identify an object which is dimly illuminated. The intensity of light will be increased till the subject is able to see the object.

In the second method, the visual purple is bleached by exposure to bright light for some time and the time regenerated is measured by the ability of the subject in seeing a dimly illuminated object.

The studies carried out under the Medical Research Council, U.K (1949) on experimental vitamin A deficiency, human subjects showed that dark adaptation test is a sensitive measure for detecting early vitamin A deficiency.

2. Serum plasma vitamin A levels

In vitamin A deficiency serum levels of vitamin A are low. Studies carried out by Gopalan and co workers (1960) in India have shown that serum vitamin A levels are reliable index of VAD in children.

The suggested guidelines for the interpretation of data are:

< 20μg/ dl-deficiency, high risk

20-30μg/dl-low, moderate risk

>30μg/dl-acceptable, low risk

3. Relative dose response test (RDR)

In this test percentage increase in serum vitamin A level, five hours after a small dose of 450-1000 μg of retinal is measured. The post dose increase in serum vitamin A is inversely related to vitamin A status, because in vitamin A deficiency retinol binding protein (RBP) accumulates in the liver and availability of exogenous vitamin A results in release of holo RBP. Raised circulatory levels of vitamin A are maintained depending upon the amount of accumulated un bound RBP.

$$\text{RDR\%} = \frac{\text{plasma retinol at 5 hour} - \text{plasma retinol at 0 hour}}{\text{Plasma retinol at 5 hour}} \times 100$$

>20%-suggestive vitamin A deficiency
>14%-marginal
0-14% - normal

4. Modified version of RDR test (MRDR)

In this test dehydroretinol (vitamin A) is administrated instead of vitamin A .The prescribed dose is 100µg / kg body weight for children. The advantage of this method is only one post- oral- dose sample of blood need to be drawn and ratio of vitamin A and A_2 is measured.

Ratio of vitamin A / A_2 > 0.06 suggestive vitamin A deficiency

3. Dried blood spot method

This method was suggested by National Institute of Nutrition (NIN) in 2004. In this method first we collect the blood sample in a special type of filter Paper using finger prick. This filter paper can be dried and transpanted under cold condition and this measure serum vitamin A levels

Table 1 RDA

Group	Retinol(micro gram/d)	Beta carotene(micro gram/d)
man	600	2400
woman	600	2400
Pregnant woman	600	2400
lactation	950	3800
infants	350	1400
Boys(10-18)	600	2400
Girls(10-18)	600	2400

(ICMR,1990)

SOURCES

Vitamin A is found only in foods of animal origin, some fruits and vegetables contain compounds, called caroteinoids, that can be converted into vitamin A. Food sources of preformed vitamin A include calf liver, milk, and eggs.

Table 2 Source of vitamin A

Sources	Vitamin A (µg /100g)
Fish liver oil	6000-100000
Liver	6000-10000
Butter and ghee	600-800
Egg , milk	300-500

(Swaminathan, 1990)

Table 3 Sources of β – carotene

Sources	β - carotene (µg/100g)
Red palm oil	25000-30000
GLV	1500-6000
Carrot	1500-2000
Ripe mango	800-2000
Ripe papaya	800-2000
milk	50-60

(Swaminathan, 1990)

14. TOXICITY

Hyper vitaminosis occurs with massive in take of vitamin A. Excessive ingestion of carotene containing food stuffs such as carrot, papaya or mango may produce carotenemia (Anita and Abraham, 1997)

Symptoms

Early symptoms

- Loss of appetite
- Nausea
- Vomiting
- Irritability
- Fatigue
- Weight loss
- Inflammation
- Cracking of lips
- Itching and hair loss

Later symptoms

- Enlargement of liver and spleen with jaundice
- Ascites
- Head ache
- Pain in joints and bones
- Stunted growth

15. AETIOLOGY

1. Inadequate in taken of vitamin A

The primary cause of VAD is inadequate intake of vitamin A or its precursors in the diet (NIN, 2000)

2. Lack of awareness

Due to lack of awareness, the community does not make use of the primary health care services like diarrhoea control programme, immunisation programme, vitamin A supplementation and other basic health services (Sabarwal, 1999)

3. Infections

Infections diseases like measles, diarrhoea, respiratory tract infections and infestations like ascariasis and giardiasis interfere with the absorption of vitamin A (Begum, 2005)

Among these measles is more significant not only on lowering the vitamin A status but also leading to increased nutritional blindness in children as well (Srilakshmi, 2005)

4. Protein caloric malnutrition (PCM)

Recent studies indicate that protein deficiency may cause impaired synthesis of retinol binding protein, the protein that carrier's retinol binding protein from the liver (Bourne, 1953)

16. PREVENTION AND CONTROL

Vitamin A deficiency is one of the simplest preventable nutritional disorders (Kamalamma, 1996). There are several strategies for control vitamin A deficiency.

1. Supplementation

2. Food fortification

3. Dietary modification

4. Nutritional awareness

1. Supplementation

National Vitamin A Prophylaxis Programme

This programme started in 1970 and the target group are children between one and five years of age for a six month dose of 2,00,000 IU vitamin A and six to eleven month old infants for a 1,00,000 IU dose. Therapeutic doses are given to those with detected deficiencies and the programme promotes improved dietary intake of foods rich in vitamin A (Joshy, 2002).

After 1992, this programme was linked with the routine immunization Programme. The first dose of 1, 00,000 IU vitamin given to children of 9 months along with measles immunisation and the second and subsequent doses of 2, 00,000 IU of vitamin A are given every six months until the children complete three years of age.

2. Food fortification

Fortification or enrichment of widely consumed foods with vitamin A another strategy to prevent vitamin A deficiency. In India, foods like vanaspathy bread, milk, and wheat flour are fortified with vitamin A. In other countries like Guatemala and Costa Rica Sugar is used as a vehicle for fortification and in Indonesia and Philippines field trails are conducted with monosodium glutamate.

3. Dietary modification

The most rational and sustainable long term solution to control VAD Is to include foods rich in vitamin A or its precursors in the daily diet (NIN,2004b) The major inexpensive dietary sources of provitamin A are dark green leafy vegetables, deep yellow and orange coloured fruits and vegetables. Preformed Vitamin A is found only in animal foods such as egg, fish, and animal liver and dairy products.

4. Nutritional awareness

It is an important tool to increase awareness and improve consumption of vitamin A rich foods.

Nutritional awareness can be given mainly through:

- Individual contact through home visit
- Group contact through simple talk
- Demonstration and discussions
- Hospital visit
- Nutrition rehabitalisation training (Sreedevi,1997

CONCLUSION

Vitamin A is an essential micronutrient for vision, growth, reproduction, cell differentiation and gene expression. But, still vitamin A deficiency is an extremely challenging problem in India and other developing countries. In the view of the changing scenario regarding the child health in the country,region specific strategies are required for improvement in the nutritional status, dietary intake, immunisation status,and for virtual elimination of nutritional blindness.

1. What is golden rice?
   It is a genetically modified variety of rice which is rich in β-carotene.

2. What is food fortification?
   Food fortification is the public health policy of adding micronutrients to food stuffs to ensure that minimum dietary requirements are met.

3. What is tansferrin?
   Transferrin is a protein found in blood plasma and in milk.

4. What is tonned or double tonned milk?
   Whole buffalo milk is adding to skim milk. This is tonned milk.
   Mixing cows or buffalo milk with fresh skim milk. This is double Tonned milk.

5. What is the method of retaining β-carotene?
   Cooking in the presence of oil helps in retaining β- carotene better.

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ABSTRACT

Micronutrient deficiencies have been recognised as one of the major public health problems of developing countries. Vitamin A is the most limiting nutrient in Indian dietaries and hence vitamin A deficiency is wide spread in India. Vitamin A deficiency disorder spectrum has the unique distinction of being one of the most important causes of 'Preventable blindness' the world over.

Vitamin A is an important micronutrient for maintaining normal growth, regulating cellular proliferation and differentiation, controlling development, and maintaining visual and reproductive functions. Vitamin A plays a vital role in the normal functioning of ocular epithelial cells and in the regeneration of visual pigment rhodopsin. Hence deficiency of vitamin A is closely linked with vision. The deleterious consequences of severe vitamin A deficiency disorders (VADD) are night blindness followed by conjunctival xerosis, bitot's spots, corneal xerosis, keratomalacia and total blindness

Inadequate dietary intake of vitamin A rich foods is the major cause of VADD. Poverty and high cost of vitamin A rich non vegetarian foods, lack of awareness about low cost, nutrient rich food sources, frequent infections like diarrhoea, inadequate breast feeding and faulty weaning practices are the other contributing factors of VADD.

Vitamin A deficiency is estimated to affect approximately 127 million children under the age of five around the world. Approximately 250,000-500,000 children in developing countries become blind each year owing to vitamin A deficiency, half of them dying within 12 months of losing their sight estimates that around 7 million preschool children in the world were affected with xerophthalmia. The global prevalence of xerophthalmia was found to be 9.8 million among pregnant women .

Periodic vitamin A supplementation is the most widely implemented intervention for controlling vitamin A deficiency in the developing world. Food fortification with vitamin A is already practiced in tackling VADD to benefit poor groups, whose diets are most deficient. ICDS (Integrated Child Development Services) has taken effective steps to impart nutrition education among the rural poor through anganwadi centres. Promotion of household nutrition gardening at rural areas ensures the sufficient availability of low cost β-carotene rich vegetables and it lead to nutrition security of the society

NUTRITION, DIET AND CANCER

By

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NUTRITION, DIET AND CANCER

INTRODUCTION

Cancer is one of the dreaded diseases and is the second most important cause of death in most affluent countries. The relationship between diet and health has been recognised throughout recorded history. Disease prevention through healthy preparation of foods and eating habits has been discussed for thousands of years. Since the 19th century, Western scientific methodologies have been applied to the study of diet and diseases with intent of reducing the disease burden from non-communicable diseases (NCD) such as cancer, coronary heart disease (CHD) and other condition endemic to societies after the advent of industrialisation.

The word cancer is derived from the Latin word 'crab', so ascribed by Hippocrates (500 B.C.) for its invasive and intrusive properties. It was Yong He Yan (960 A.D.) of the song dynasty who first related diet and cancer. He stated that poor nutrition was the cause of oesophageal cancer. Lambe in 1815 warned against the danger of excess consumption of food in general and meat in particular. Roger Williams in 1908 observed that excessive feeding especially meat, deficient exercise and probably lack of sufficient vegetable food are the predisposing factors for cancer.

The role of diet takes special importance in countries like India which are fast moving towards industrialisation and westernisation. Dietary factors may be potentiating the role of other risk factors. Most of the cancers have some relationships with diet, predominant among them are cancers of upper aero digestive tract (mouth, throat), oesophagus (food pipe and lungs), stomach, large intestine, and breast cancer in women.

Cancer is the term used to refer malignant neoplasms and tumours. Neoplasia means cell in a tissue proliferate without control on growth. Cancer is caused due to mutations or abnormal activation of cellular genes that control cell growth and cell mitosis (Sreelakhmi, 2000). The abnormal genes are called oncogenes. It may spread to other parts of the body through the lymphatic system or the blood stream. When these cells remain localised, it is called benign tumour and when it invades and spreads to other tissues of the body it is called a malignant tumours or in simple terms 'cancer'.

Under normal conditions, the normal growth, multiplication, repair and death of cells are biologically programmed. However gene mutations can lead to uncontrolled growth.

HOW CANCER DEVELOPS?

INITIATION

When normal cells are exposed to carcinogens and carcinogens are allowed to enter the cell, it alters DNA.

PROMOTION

When there is enhancement of cancer development, cells begin to multiply in an uncontrolled manner.

PROGRESSION

Tumour formation takes place. It may spread to others tissues or organs, thus the cells released and carried to other part of body are called metasis.

PREVALANCE OF CANCER IN THE WORLD

In the world every year 7.6 million cancer deaths occur. Breast cancer is the leading cause of cancer death in females, accounting for 23 per cent of total cancer cases and 14 per cent of cancer deaths whereas lung cancer is the leading cancer in males comprising 17 per cent of total new cases and 23 per cent of cancer deaths (American Cancer Society, 2011).

PREVALANCE OF CANCER IN INDIA

Incidence of gallbladder cancer in women in New Delhi is 10.6 per 100,000 of population, world highest rate for women for this cancer. District in central south and northeast India had world highest incidence of cancer associated with tobacco, which is chewed as well as smoked. Aizwal district of north east state of Mizoram has world highest incidence of cancer in men of lower pharynx (11.5 per 100,000 people). The incidence of mouth cancer among men in Pondicherry was 8.9 per 100,000, one of the highest rates in world for men. Rate of stomach cancer is high among men in Bangalore and Chennai. Belt of thyroid cancer in women is high in coastal district of Kerala, Karnataka and Goa (WHO, 2005).

RISK FACTORS OF CANCER

Under normal conditions, the growth, multiplication, repair and death of cells are biologically programmed. However gene mutation can lead to uncontrolled growth. These mutations can be spontaneous or induced. Spontaneous mutations occur following an injury eg. Burn injury or due to prolonged stimulation by hormone like oestrogens, thyroxine, this result in increased cell multiplication and increases the chances of gene mutations.

Mutations may be induced by infective agents like viruses, physical agents like radiations and by chemicals. Chemicals may be those which are formed during the normal metabolism like oxygen free radicals, methyl groups, hydroxyl ions or may be those which gain entry from outside through the food. These include nitrosamines, aromatic hydrocarbons, aromatic amines and others. Some of the risk factors are as follows

Infective agents

In developing countries, up to 23% of malignancies are caused by infectious agents. eg. Hepatitis B and C virus (liver cancer). Human papilloma virus(cervical and ano-genital cancer). *Helicobactor pyroli* (stomach cancer). Physical agents involve X-rays, other ionizing radiations emitted by radioactive substances.

Chemical agents in foods

Chemicals can be classified as those naturally present in foods, formed during processing preparation and storage and those added as food additives. These include nitrosamines, aromatic amines, and others. These substances attack the DNA and form complexes called DNA adducts. These act as ultimate carcinogen.

Physical agents

This includes ionising and non ionising radiations. Repeated and prolonged exposure to the sunlight results in skin cancer in light skinned people living near the tropics-Australians Radiation exposure in middle age causes cancer.

Stress

There is a relationship between the onset of cancer and emotional deprivation. Depression may affect the body's hormones and may inhibit the immune system's ability to counter disease.

Heredity

Family history of cancer plays a significant role in determining personal risk. Individuals of cancer- prone families need to pay particular attention to the avoidance of carcinogens and typically need closer cancer surveillance than other people.

Obesity and lack of physical activity

Obesity and lack of physical activity are associated with increased risk of various cancer sites, including breast and endometrial cancer. Maintaining ideal weight through physical exercise has been associated with decreased risk of breast cancer.

Dietary factors

Dietary factors also play a significant role in cancer risk. At least one-third of annual cancer deaths in U.S are due to dietary factors. A recent review on diet and cancer estimates that up to 80 percent of cancers of large bowel, breast, and prostate are due to dietary factors. In January 1892, scientific American printed the observation that "cancer is most frequent among those branches of human race where carnivorous habits prevail." India is a developing country with most diverse populations and diets in the world.

Diet is an important factor in cancer aetiology because

- Diet may be direct or indirect source of carcinogens.
- Carcinogens can be formed during storage, cooking, or preservation of foods.
- Diet may contain inhibitors.
- Food stuffs may act s a substrates for the formation of carcinogens in the body

Dietary factors influencing cancer

Cancers	Dietary factors
oesophagus	Alcohol, tobacco, low intake of fruits and vegetables
stomach	Nitrates and nitrosamines, pickle and salted foods, smoked and fried foods, foods rich in starch with very little fruits and vegetables
Colon and rectal	Refined carbohydrates, low fibre, low vegetable intake, high meat intake
Nasopharyngeal	Salted fish
Larynx	Tobacco , alcohol
Lung	Tobacco, low intake of green and yellow vegetables
Bladder	Chemicals, artificial sweeteners, coffee
Breast and cervical cancer	High intake of fat, low intake of fruits and vegetables
Pancreas	Tobacco, coffee and meat
Liver	Mycotoxins and alcohol
prostate	High meat intake and low fibre intake

The various dietary aspects which play a role in cancer are described here. It is sub-divided into two groups- those that causes cancer and those that are protective. The former includes-

- Excess energy and fat intake
- Meat
- Alcohol
- Tobacco
- Coffee
- Mycotoxins
- Food additives

Protective agents includes

- Dietary fibres
- Bioactive components present in foods
- Micronutrient

EXCESS ENERGY AND FAT INTAKE

Caloric

An excess of calories in humans is associated with increased risk of cancer. Excess carbohydrates act as a modifier of carcinogens of carcinogens. On excess calorie intake, there is high risk of endometrial and breast cancer. This is due to the increased conversion of androgens into estrogens in adipose tissue. Obesity may possibly associate with gall bladder cancer and colon cancer. Obesity and lack of physical activity are associated with increased risk at various cancer sites, including breast and endometrial cancer. Energy balance, which includes maintaining ideal weight through physical exercise, has been associated with decreased risk of breast cancer.

Dietary fat

Diets high in saturated fats have been associated with increased risk for cancer (World Cancer Research Fund, 1997). Diets high in fat have been linked to increased risk of various cancers, particularly breast, colon, prostate and possibly pancreas, ovary and endometrium. A high fat intake increases intestinal anaerobic bacteria and biliary steroids secretion. Anaerobic bacteria are capable of synthesising estrogens, which are believed to be potential carcinogens in mammary glands. Bile acids are degraded by intestinal micro flora to secondary bile acids, deoxylithocolate, lithocolate, etc. which may act as carcinogen in colon. According to Willet *et al* (1992) increased intake of total saturated and monounsaturated fats is associated with increased risk of colon cancer.

Fatty foods affect the body in many ways and have a strong influence on hormonal activity in the body. High-fat diet increases the amount of estrogens, female sex hormones, in the blood. It is known that many breast tumours are" fuelled" by estrogens. Estrogens are normal and essential hormones for women and men, but the more oestrogen there is greater the driving force behind some kinds of breast cancer. On high-fat diets, oestrogen levels increase. When women adopt low- fat diets, oestrogen levels drop noticeably in a very short time, vegetarians have significantly lower oestrogen levels than non- vegetarians, in part because of lower fat content of their diet.

Dietary fat intake and calorie intake is highly correlated. Dietary fat is the most concentrated source of energy. So reduction in fatty acid should also accompanied by reduction in calories and body weight.

According to Jedrychowski *et al* (2004) fish oil lowers the risk of cancer by 32 per cent. Fish oil, in general is anti-inflammatory agent and protects body from cancer development.

High content of omega-3 fatty acids in fish oil also play a role in cancer prevention. Omega-3 fatty acids are known to play an essential role in inter-cell communication, prevents inflammation.

MEAT

These are integral part of the diet of non-vegetarians in western countries. Studies by Usha and Sujatha (1985) shows that vegetarians had decreased incidence of cancer at number of sites.

Meat, especially red meat (i.e. meat of cow, lamb and pork) is a concentrated source of fat. High intake leads to obesity (Dept. of health, 1994). In this condition, fat cells in the body convert circulating sex steroids into estrogens. Oestrogen stimulates cell multiplication in breast, endometrium and colon. Thus increasing the risks of cancer at these sites. The fat of meat can also dissolve many carcinogens like benzopyrene which accumulate to alarmingly higher levels.

Processing of foods is an achievement of modern food technology. But it has its own adverse effects. For example, the processed foods such as cured and smoked meat. Bacon, ham, sausages, salted and dried fish contain preformed carcinogens, nitrosamines. They include N- nitrosodimethyl amine (NDMA) and N-nitrosomethyl benzyl amine (NMBZA) (NIN, 1994).

ALCOHOL

It was observed in 19th and 20th centuries that the patients with cancers of oesophagus were alcoholics or worked in the alcohol trade. Consumption of alcohol differs in different parts of the world and within countries. Alcoholic drinks in general are identified as carcinogenic by International agency for research on cancer.

Higher consumption of alcohol causes hepatic injury and cirrhosis and lead to formation of hepatoma because the metabolism of alcohol lead to generation of free radicals and acetaldehyde that binds DNA and proteins, destroy folate and seems to contribute cirrhosis of liver.

Alcohol stimulate carcinogenesis in the induction of cytochrome , which is associated with production of free radicals and enhanced activation of pro carcinogens found in beverages, which leads to nutritional deficiencies

TOBACCO

Tobacco chewing and smoking are the two important risk factors of oral cancer in India. Lung cancer risk of regular smokers to non smokers is between 20-30 fold. More than 50% of cancer in men and 20% in women are related to tobacco. Tobacco related cancer is in the oral cavity, pharynx, larynx and oesophagus. Men who smoke have 27 times higher chances for oral cancer than who do not smoke (WHO, 2005).

MYCOTOXINS

They are toxic substances produced by fungi. Among various mycotoxins, aflatoxin is a toxic metabolite produced by fungus *Aspergillus flavus*. The fungus grows on improperly stored foods, particularly on grains, groundnuts, corn, coconut and pepper. Aflatoxin on oxidation in liver forms epotoxins which affects the DNA of liver cells and forms DNA adducts which induces cancer in the cells.

Aflatoxin

⇓

Epoxide +DNA (liver cells)

⇓

DNA adducts (carcinogen)

FOOD ADDITIVES

Different food additives are identified as the source of carcinogen. All non permitted synthetic food colours are mutagenic and most of them have been identified as potential carcinogens. Metanil yellow, a non permitted food colour was common adulterant in foods like laddu, turmeric etc. Sudan dye and lead chromate are other non permitted food colours which in high amounts will do harm. It causes different types of allergic reactions, damage to liver, kidney and that can lead to carcinogenicity. Jonnalagadda *et al.*, 2004 reported that processed meats, non-alcoholic beverages, and ready to eat foods and sugar confectionaries contains food colours in higher concentrations of above 1000ppm while the allowed amount is 100ppm.

Monosodium glutamate (MSG) commonly called aginomotto is known to cause brain cancer. Artificial sweeteners, like saccharine, aspartame, cyclamates develop bladder cancer. Aspartame is associated with brain cancer. Refined carbohydrates like sugar high fructose corn syrup, white flour are devoid of nutrients. Refined carbohydrates provide too much calories and can lead to obesity and cancer.

CARCINOGENS IN FOODS

Carcinogens can be defined as substances that cause rapid uncontrolled division of cell.

TRANS FATTY ACIDS

They are the imitation of fat in shortenings and margarines and most commercial baked foods. They are commonly seen in all processed foods and snack foods. They increase the requirement of essential fatty acid. They competes with EFA (essential fatty acids) in incorporation of total fatty acids, by altering the membrane bound enzymes and receptors. Trans fatty acids are strongly associated with cancer of lungs and reproductive organs.

RANCID FATS

Industrial processing and poor storage creates rancidity in vegetable oils. This rancid fats are a pool of free radicals and so known as potent carcinogens.

POLYCYCYLIC AROMATIC HYDROCARBONS

Cooking food at very high temperature, especially directly over the flame, generates chemicals which are carcinogenic in nature. Benzopyrene is produced by heat induced chemical reaction on fat. It is formed due to incomplete combustion of oils and smoke which will get deposited on food. Cooking by direct smoking over the flame cooking over high temperature etc can lead to formation of there carcinogens. Most of the processed foods are prepared by these unhealthy cooking methods, so they are identified as the carriers of this carcinogen

SODIUM NITRATES

Nitrosamines are derived from the reaction of nitrate with a corresponding amine. They produce carcinogenic compounds nitrosamine and nitrosamides, which are carcinogenic. Of 300 nitroso compounds tested, 95% are found to be carcinogenic. It can either preformed as germinated barley, meat, meat products, salted fish etc. It can be formed from its precursors eg. Green leafy vegetables, spices, which are sources of nitrates. Fresh vegetables, fruits, and milk, are found to be free from these but it can be formed in these foods when they are grilled roasted, baked in an open air system. Nitroso compounds are formed during acidic conditions and chlorine acts as a catalyst. So pickling is one of the sources of cooking favours the formation of nitroso compounds. Hamburgers, hot dogs, Alcoholic beverages contain nitroso compounds in higher levels.

such fast foods have become the most favourite food of youngsters today. All these foods contain cured and smoked meat and contain high amounts of nitroso compounds.

PROTECTIVE AGENTS IN FOODS

Protective agents present in food stuffs are

- **Dietary fibre**
- **Bioactive compounds present in foods**
- **Micronutrients**

DIETARY FIBRE

Dietary fibre cannot be seen or tasted but it can work wonders for our body. Dietary fibre is known as cancer fighter found only in the cell walls of plant foods. This protective effect is due to

- Tendency to add bulk to the digestive system
- Shortening of amount of time that wastes travel through colon
- Increased fibre decreases chances for intestinal walls get affected by toxic substances
- When bacteria in lower intestine break down fibre, butyrate is produced which inhibits growth of tumours of colon and rectum
- High fibre diets are often lowers the absorption of fat
- Fibres binds with oestrogren and prevents breast cancer

There are two types of fibres in our diet, soluble fibre and insoluble fibre. Soluble fibre dissolves in water and is found in a variety of fruits, vegetables, legumes and grains. It cuts cholesterol, adds to the feeling of fullness and slows the release of sugars from food into blood. Good sources of soluble fibres are oats, bran, apple, citrus fruits, straw berries, dried beans, rye flour, potatoes, raw cabbage etc.

Insoluble fibre does not dissolve in water and is found in grain bran, fruits pulp, and vegetable peels and skins. This type of fibre strongly linked to cancer protection and improved waste removal.

BIOACTIVE COMPOUNDS PRESENT IN FOODS

Plant foods such as cereals, pulses, fruits and vegetables like onion, garlic, scallions and chives are an important group with anti-carcinogenic effect. They have a distinct flavour and aroma as well as medicinal effects. Their anti-carcinogenic activity can be attributed to-

- Inhibition of bacterial conversion of nitrate to nitrite, the precursor of nitrosamine
- Activation of detoxification enzyme system

ISOTHIOCYANATES

They are found in cruciferous vegetables and spices. They protect against cancer by-

- Inhibiting enzymes that activate carcinogens
- By inducing detoxifying agents
- They speed up their removal from body (Arab and steck, 2000).
- Effective in fighting lung and oesophageal cancers.

LYCOPENE

Lycopene is a part of carotenoid family; it is a pigment present in most fruits and vegetables. The mechanism of action involves-

- Act as a free radical fighting antioxidant. So that they cannot attach to the cells and disintegrate the immune system
- Potential nitrosamine inhibiting agent
- Studies show that lycopene helps to prevent prostate, lungs and stomach cancers (Giovannucci *et al.*,1999).

FLAVANOIDS

Comprise one of the largest groups of secondary plant metabolites. More than 400 flavanoids have been identified of which some are flavanols, flavones, flavanones, catechins, biflavins. Most of these flavonoids are structurally polyphenols having antioxidant activity. Flavanoids and tannins are similar to some other antioxidants, like ascorbic acid and tocopherol. The antioxidant effect is attributable to radical seavenging activity of flavanoids.

The major functions are the following-

- Structurally flavanoids are having anti oxidant activity
- Blocks heterocyclic aromatic amines from promoting gastric and colorectal carcinogenesis (Susata, 2001).
- Important in protecting DNA from high rates of mutation.

D-LIMONINE

- This is a terpenoid and major component of citrus fruit peel
- Used as a flavouring agent.
- Induces the enzyme, glutathione-s- transferase.

PHENOLIC COMPOUNDS

They include ellagic acid found in fruits and nuts like straw berries, raspberries, blackberries, walnuts. They inhibit nitrosation reaction by trapping nitrate to form n-nitrophenolic compound.

PHYTIC ACID

Found in high amounts in seasame seeds, limabeans, peanuts, and soyabean and also in cereals, nuts, seeds, and pulses. It controls cell proliferation.

SAPONINS

Saponins are found abundantly in soyabean(5% of dry weight). They exhibit cytotoxic effects and growth inhibition against a variety of cells. They bind to bile acids and regulate their recirculation. They have known mutagenic inhibiting activity.

ALLIUM VEGETABLES AND CANCER

GARLIC

Garlic posses strong antioxidant activity due to presence of antioxidant "allicin". The reported health benifits include chemoprotective, antibiotic, and cholesterol lowering properties. Garlic compounds (ajoene) have been shown to inhibit tumerogenesis thus reducing the risk of cancer (saxsena, 1998).

BROCCOLI

Broccoli is known as the crown jewel of nutrition for its vitamin and fibre richness and is low in calorie. Multiple cancer fighting properties owing to vitamin C, beta carotene and fibre contents. It is rich in phytochemicals- Indole, carbinol, and sulphoraphane. Indole and carbinol breaks down oestrogen. A medium sized stalk of broccoli provides 20 per cent of daily value of vitamin C, 15 per cent of daily value of vitamin A, in the form of beta carotene.

SPICES AND CANCER PREVENTION

TURMERIC

Among the most studied in recent years is turmeric, an ingredient in the common Indian curry and a spice that has been shown to be a potent antioxidant and anti-inflammatory agent with additional promise as a chemo-preventive agent. A study in human revealed the potential of turmeric in suppressing and destroying the blood cancer cells. Turmeric has been shown to suppress tumour initiation, promotion and metasis in experimental studies (Aggarwal *et al.*, 2003).

GINGER

- Known to produce substances that protect stomach lining.
- Prevents the formation of gastric ulcers.
- Stimulate gastric activity and stimulates the bowel to empty quickly.
- Promotes digestion.
- Deactivates carcinogens.
- Enhance tissue level of protective enzymes.

OTHER SPICES

CUMIN SEEDS AND BASIL LEAVES- significantly decreased the incidence of both squamous cell carcinoma and hepatomas. Cumin seeds contain pthalides which increases anti cancer protective enzymes.

POPPY SEEDS- Significantly inhibited benzopyerene-induced squamous cell carcinoma.

CLOVES- Contain eugenol which has anti mutagenic effect.

SOYABEAN AND CANCER PREVENTION

Soya food prevents cancer as well as diseases associated with estrogen deficiency. The isoflavanoid genistein is a phytoestrogen found in abundance in soya food. In soyabean oil active antioxidant is tocopherol. Other antioxidant components are isoflavines, glycosides, phospholipids and phenolic acids.

WHOLE GRAINS AND CANCER PREVENTION

They are concentrated sources of dietary fibre resistant starch and oligossachrides, fermentable carbohydrates etc. Whole grains are rich in antioxidants trace elements and phenolic compounds. They are significant sources of phytoestrogens. They mediate glucose response.

GREEN TEA AND CANCER PREVENTION

The green tea which is a popular drink in China has in fact shown to have an anti-mutagenic effect. This is due to presence of two specific compounds Kahweol palmitate and cafestol palmitate. This compound increases the activity of enzyme glutathione-s-transferase. This enzyme has an important role to play in pathogenesis of cancer. It can reduce or detoxify potent carcinogens. Green tea contains antioxidant known as catechin. Daily consumption of c 2 cups of green tea reduces the risk of oesophageal cancer among non smokers and drinker's (W.s. 2003).

MICRONUTRIENTS

The main micronutrients present in vegetables and fruits and showing strong anti-carcinogenic effect include

- Vitamin A
- Vitamin C
- Vitamin D
- Vitamin E
- Selenium

CAROTENOIDS/VITAMIN A

Zigler *et al*.,(1989) examined the role of carotene rich foods and found that these foods reduce the risk of lung cancer.

They are anticancer nutrient that support normal cell differentiation of tissue and internal linings. They prevent cancer cell formation by inhibiting the binding of carcinogen to cell wall. Beta carotene may protect DNA in the nucleus of the cell by decreasing the bonding of chemicals to the membrane around the nucleus. Both nutrients are antioxidants and can scavange free radicals.

Decreased levels of vitamin A are associated with increased rates of cancer of lungs mouth, oesophagus, bladder, cervix, and stomach. The major sources of beta-carotene are fruits and vegetables such as carrot, sweet potato, spinach and broccoli. Direct sources of vitamin A are non- vegetarian foods such as fish, eggs and liver.

VITAMIN C

Vitamin C is involved in cancer defence functions and it is highly protective against cancer.

Anti cancer aspects of vitamin C are listed below-

- Antioxidant activity
- Stimulate lymphocytes to produce interferon which decreases virus reproduction
- Reduces production of nitrosamine and dietary nitrates and nitrites
- Reduces stomach oesophageal and bladder cancers by means of its multiple protective effects on mucous membrane
- Along with folic acid vitamin C minimises cervical dysplasia, and cancer.

Various epidemiological studies on the role of vitamin C in cancer prevention revealed that vitamin C has significant roles in protection against cancer and tumerogenesis (Black *et al*., 1994). High maternal intake of vitamin C offers protection against childhood brain tumours (Krishnaswamy and Jagadeesan, 1999). Vitamin C is found in citrus fruits particularly citrus fruits and green leafy vegetables, sprouted pulses etc.

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VITAMIN D

Vitamin D is required for mineral absorption in the body. Strongly protective against breast cancer and colon cancer. Vitamin D is essential for prevention of skin cancer.

VITAMIN E

Function well with adequate levels of selenium as selenomethionine. This act as antioxidants and cell membrane protectors. It reduces the carcinogen production and strengthens immune cells and cell membranes against the penetration of viruses and toxic chemicals. Vitamin E inhibited tumours in experimental animals and been linked to reduced risk of oral, stomach, and other cancer in epidemiological studies. Blot *et al.* (1993) studied the effect of alpha tocopherol among smokers and indicated the intake of these nutrients through food was found to be associated with decreased risk of lung cancer. Vitamin E has also been suggested to play a role in the prevention of nitrosamine induced upper gastrointestinal tract tumours by inhibiting the nitrosation of dietary amines in stomach.

The major functions of vitamin E in cancer defence mechanism-

- Vitamin E act as antioxidant and cell membrane protector
- Reduces the carcinogenic production
- Strengthens immune cells and cell membranes against penetration of viruses and toxic chemicals
- Prevents nitrosamine formation

The major sources of tocopherol are unprocessed oils, animal fat, butter, egg yolk etc

SELENIUM

It helps to regulate the glutathione peroxidase, a strong antioxidant enzyme. Low selenium levels in the body are clearly associated with increased rates of leukaemia and cancers of breast, lungs, colon, rectum, prostate, ovary, skin, and pancreas. Selenium given in combination with vitamin C, vitamin E and zinc was found to be protective against the development of oral lesion who practice smoking (Wolf,1989) The major food sources are whole grains, legumes and green leafy vegetables.

ANTICARCINOGENIC PHYTOCHEMICALS

Phytochemical classes	Food sources
carotenoids	Yellow/orange vegetables dark green vegetable
Dithiolthiones Glucosinolates/indoles isothiocyanates	Cruciferous vegetables
Allium compounds	Onion, garlic ,leeks, chives
coumarins	Vegetables and citrus fruits
Flavanoids	Most vegetables and fruits
Plant sterols	vegetables
Isoflavanoids	soyabean

CANCER PREVENTING DIET

Some dietary changes have preventive effect for many types of cancer. Higher intake of vitamin rich vegetables and fruits, strengthen the immune system and help to knock out cancer cells.

- The diet should contain high nutrients, low fat and high fibre.
- Low fat intake, about 20% of total calories.
- More fat should be mono and poly unsaturated fats with reduction of saturated fat intake and little or no consumption of refined or heated oils.
- Complex carbohydrates can come up to 60% of the diet.
- Protein intake should be 15% of diet
- Fibre should be 40g/day.

SOME DIETARY SUGGESTION FOR CANCER PREVENTION

- Avoid obesity
- Cut down total fat intake
- Eat more fibre foods.

- Cut down total fat intake
- Eat more fibre foods.
- Include cruciferous vegetables
- Include foods rich in vitamin A and vitamin C
- Avoid alcohol consumption
- Lower intake of processed foods
- A variety of foods should be used moderately

CONCLUSION

Not all health problems are avoidable, but you have more control over your health than you may think. Research shows that a large percentage of cancer-related deaths maybe even the majority—are directly linked to lifestyle choices such as smoking, drinking, lack of exercise, and an unhealthy diet. Avoiding cigarettes, minimizing alcohol, and getting regular exercise are a great start to an anti-cancer lifestyle. But to best support your health, you also need to look at your eating habits.

What you eat and don't eat has a powerful effect on your health, including your risk of cancer. Without knowing it, you may be eating many foods that fuel cancer, while neglecting the powerful foods and nutrients that can protect you. If you change your diet and behaviors, you can minimise your risk of disease and possibly even stop cancer in its tracks. Change of diet is among the factors that may be responsible for the changing disease rates.Prompt action has to be taken to spread the message of healthy life style and practices.

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DISCUSSION

1. Which type of cancer is more prevalent in Kerala and why?
   Oral cancer is more prevalent in Kerala because of higher liquor consumption in kerala.

2. Why green tea is prescribed in cancer prevention rather than black tea?
   Green tea contains antioxidants like catechins which helps in cancer prevention black tea also contain antioxidant but in less amount than green tea because of difference in harvesting and processing of green and black tea. so green tea is more effective against prevention of cancer.

3 Is meat harmful to our health and how it causes cancer?
   Yes, excess consumption of meat will increases cancer risk because it is a concentrated source of fat. High intake leads to obesity. In this condition, fat cells in the body convert circulating sex steroids into estrogens. Estrogens stimulate cell multiplication in breast, endometrium and colon. Thus increasing the risks of cancer at these sites.

4. How stress causes cancer?
   Excess stress will lead to production of T-cells in our body that lead to uncontrolled multiplication of cells and this will lead to cancer development.

5. Will cooked meat cause cancer and how?
   Yes, cooked meat is harmful and causes cancer, because meat is rich in createnine, cooking of these foods produces carcinogenic substances like aromatic hydrocarbons

6. What is full form of PUFA?
   Poly-unsaturated fatty acids

7. Which antioxidant is present in turmeric other than tumercin?

Curcumin is present which act as an antioxidant and inhibit the growth of fungi and bacteria.

8. Will wine cause cancer?

   Yes wine will cause cancer if taken in excess amount.

9. Lactation reduces the cancer risk Why?

   During lactation oestrogen level will be reduced and as a result breast cancer risk is also reduced

10. Why does the addition of milk in tea reduce the risk of cancer?

    Yes addition of milk in tea reduces risk of cancer because milk has protective effects it will bind with tannins and inhibit the formation of carcinogens in our body.

11. What kind of diet is prescribed for cancer patients?

    Diet should be rich in nutrients, low in fat and protein should be given moderately and liquid and soft diet should be given.

12. Give name of any protein powder that is available in market?

    Amway Nutrilite

Abstract

Cancer is one of the most dreaded diseases and is the second most important cause of death in affluent countries. Cancer is the term used to refer malignant neoplasms and tumours. Neoplasia means cells in a tissue proliferate without normal control on growth. Cancer is caused by activation of cellular genes that control the cell growth and cell mitosis.

The prevalence of cancer in world is estimated as 7.8 million. Cancer of oral cavity is an important contributor to cancer morbidity and mortality in India.

Diet is an important factor of cancer aetiology and cancer prevention. Diet is a complex composite of nutrients and non-nutrient food constituents and many nutrients have relationship with the formation of cancers. Excess calorie intake can lead to obesity and cancer incidence. Higher the body weight, higher is the risk of colorectal cancer, breast, prostate, and ovarian cancers. High intake of fat is associated with increased incidence of cancers.

Carcinogen in foods includes poly hydroxyl aromatic amines, nitrates and nitrosamines, artificial sweeteners, food additives etc. Some of these are produced during cooking, processing, and storage of foods. Unhealthy habits like tobacco chewing, smoking, and alcoholism, which are widely prevalent in India remains a predisposing factors for different types of cancers.

Other constituent in foods like dietary fibre, selenium, beta-carotene, vitamin C, vitamin E etc. have significant protective function against cancer. Isothiocynates present in cruciferous vegetables like broccoli, cauliflower, turnips etc have been proved to be effective against lung cancer and oesophageal cancers. Lycopene, an important antioxidant, and major colouring pigment in tomato helps to prevent prostate, lung and stomach cancers. Phytochemicals present in plant foods act as powerful antioxidants protecting cells and organs from damage caused by free radicals, neutralising their damaged effects.

The consumption of fruits and vegetables in daily diet contribute various micronutrients, which have many biological effects. The non-nutrient components of these protective foods are also as important as micronutrients. Expected benefits of incorporating a wide variety of fruits and vegetables and whole grains liberally in routine diet may lower the risk of cancer but also reduce the risk of other chronic diseases.