PHYTOCHEMICAL ANALYSIS AND ANTIOXIDANT POTENTIAL OF BANANA (*Musa* spp)

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled "PHYTOCHEMICAL ANALYSIS AND ANTIOXIDANT POTENTIAL OF BANANA (*Musa* spp)" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled "PHYTOCHEMICAL ANALYSIS AND ANTIOXIDANT POTENTIAL OF BANANA (*Musa* spp)" is a record of bonafide research work done independently by Mrs. SIJI.S (2014-16-103) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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EXTERNAL EXAMINER

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Dedicated to

MY FAMILY

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LIST OF ABBREVIATIONS USED

µg	*Micro gram*
AAE	*Ascorbic acid equivalent*
AOAC	*Association of Official Analytical Chemistry*
AUC	*Area Under the Curve*
BMI	*Body Mass Index*
Ca	*Calcium*
cm	*Centimeter*
Cl	*Chlorine*
DA	*Dopamine*
DNA	*Deoxy ribo nucleic acid*
DPH	*Dopamine Hydrochloride*
DPPH	*Diphenyl picryl hydrazine*
EDTA	*Ethylene Diamine Tetra Acetic acid*
et al	*and others*
Fig	*Figure*
g	*Gram*
GAE	*Gallic Acid Equivalent*
GI	*Glycemic Index*
h	*Hour*
Hg	*Mercury*
HIV	*Human Immuno Deficiency Virus*
HRS	*Horticultural Research Station*
IAUC	*Incremental Area Under The Curve*
IC_{50}	*Inhibition Curve*
K	*Potassium*
KAU	*Kerala Agricultural University*
Kcal	*Kilocalorie*
kg	*Kilogram*
M	*Molarity*

Meq	*Milli Equivalent*
min	*Minutes*
ml	*Milli litre*
mg	*Milligram*
nm	*Nano meter*
QE	*Quercetin*
RDA	*Recommended Dietary Allowance*
RNA	*Ribonucleic acid*
rpm	*Rate Per Minute*
TFC	*Total Phenol Content*
TNAU	*Tamil Nadu Agricultural University*
TPC	*Total Phenol Content*
TSS	*Total Soluble Solids*
%	*Percentage*

Introductin

1. INTRODUCTION

Fruits are parts of plants, which can be consumed either raw or in processed form. Tropical and subtropical fruits and vegetables are becoming more important food item in both producer and non producer countries. According to Kumar and Manimeglai (2003) fruit has been a major food for mankind from time immemorial and fruit constitute an important item in our diet.

Kaur and Kapoor (2002) are of the opinion that diets rich in fruits and vegetables are associated with lower incidence of disease risks, including cardiovascular and cancer. They also argue that processing or cooking can enhance the health promoting effects of fruits and vegetables. Sharma (2004) reported that India with its wide range of soil and agro- climatic conditions grows different kinds of horticultural crops and is considered as one of the horticultural rich countries of the world.

Now a day's consumption of fruits has been increased due to its nutritional and therapeutic effects on the human health due to the presence of phytochemicals and antioxidants. Studies revealed that a healthy eating habit with increased consumption of fruits plays an important role in the prevention of chronic diseases, such as heart diseases, cancer, stroke, diabetes, Alzheimer's diseases and cataract (Willett, 2002; Wright et al., 2008).

Free radicals are involved in both the process of aging and the development of cancer. To deal with the free radicals, the body equipped with an effective defense system which includes various enzymes and high and low molecular weight antioxidants. The best sources of antioxidants are fruits and vegetables. The consumption of fruits and vegetables has been inversely associated with morbidity and mortality from degenerative diseases (Terry *et al*., 2001).

Aurore *et al*. (2009) reported that banana, an herbaceous climacteric fruit, represents one of the most significant fruit crop in world export trade after

coffee, cereals, sugar and cocoa and is one of the most important fruit crops grown throughout Kerala (Shanmughavelu *et al*., 1992).

The word "banana" is a general term comprising a number of species or hybrids in the genus *Musa* of family Musaceae. Bananas are cultivated commercially under tropical and subtropical conditions in all the states of India, except in those having extreme winter such as Himachal Pradesh, Jammu and Kashmir. Tamil Nadu is the top banana producing state. In India more than 600 varieties are known, but often many of the varieties carry a lot of synonyms. The Tamil Nadu Agricultural University reported 115 varieties (Lohi, 2010).

The banana is of great nutritional value. It is a good source of calories, vitamins and minerals. People of South India, traditionally use banana as a wholesome food.

Bananas are one of the most popular food in the world contain various antioxidant compounds such as gallocatechin and dopamine which protects the body against the ill effects of free radicals. Since banana fruits are widely available, they have been used as food without apparent toxic effect.

Hence, the present study "Phytochemical antioxidant analysis and antioxidant potential of banana (*Musa* spp)" was attempted with the objective to study the phytochemical, nutrient, chemical composition and antioxidant potential of the selected banana varieties and to assess its therapeutic value.

Review of literature

2. REVIEW OF LITERATURE

Medicinal plants and its products continue to be an important aid for alleviating the ailments of human kind (Joseph and Raj, 2010). Literature available on different aspects related to the study entitled "Phytochemical analysis and antioxidant potential of banana (*Musa* spp)" is reviewed under following headings.

2.1 Production details of banana

2.2 Nutrient composition of banana

2.3 Bioactive compounds and antioxidant properties

2.4 Therapeutic properties

2.5 Miscellaneous properties

2.6 Value added products from banana

2.1 PRODUCTION DETAILS OF BANANA

India ranks first in production and third in area among fruit crops (DAC, 2014). The banana production in India in 2013-2014 is 297.24 lakh tons. Tamil Nadu is the top banana producing state (5655.00 thousand tons) followed by Maharashtra (4830.60 thousand tons) and Gujarat (4225.49 thousand tons). Total production of banana in Kerala was 472.93 tons (NHB, 2014).

Nationally, Kerala occupies 50 per cent of the total area of banana and maximum quantity of the fruit is sold locally. Banana reaches their greatest importance as a staple food crops in the parts of East Asian where annual consumption is over 200 kg/ capital year (Valmayor, 1994).

2.2 NUTRIENT COMPOSITION

Banana is nutritious and easily digestible than any other fruits. Bananas are popular for their aroma and texture besides rich in potassium and calcium and low in sodium content (Sharrock and Lustry, 2000).

2.2.1 Moisture content

Marriott *et al.* (1981) reported that moisture content in banana increases ripening process due to breakdown of starch into sugars.

Banana and plantain contain 70 – 80 per cent moisture. 80 percent of the solids in ripe banana consist of sucrose, glucose and fructose (Forsyth, 1999).

Josh (2001) observed that an average banana contains 75 per cent moisture, 25 per cent starch and 1 per cent fiber in the edible part of banana.

According to Khawas *et al*. (2014) moisture content varied from 4- 6 per cent, lipid content from 0.3- 0.8 per cent from in the eight different banana cultivars studied.

2.2.2 Carbohydrate

Banana is a high calorie fruit providing 67-137 kcal/100g. The resistant starches in banana and non starch polysaccharides have low glycemic index or low digestibility (Lehmann and Robin, 2007). 100g of ripe banana provides approximately116 kcal of energy.

2.2.3 Protein

Even though the amount of protein present in banana is low, the quality of protein is better and almost all the essential amino acids are present.

The protein content of different varieties shows wide variations. In the raw stage, Robusta has a lower protein content of 0.5 percent and Kunnan 1.74 per cent (KAU, 2001).

Banana proteins (1-2.5%) are depending on genome type, variety, altitude and climate and increase during ripening process (Akaninwor and Sodje, 2005).

2.2.4 Fiber

Bananas contain both soluble and insoluble fiber. Insoluble fiber, which is not broken down during digestion, promotes digestive system healthy (Eastwood and Kritchevsky, 2009). An adult requires 25 to 35 grams of dietary fiber daily and a medium –sized ripe banana provides 12 percent of this requirement (Ching *et al.*, 2001).

2.2.5 Fat

The fat content is very low in banana which varies from 0.1-0.7 per cent (Uma and Sathimoorthy, 2002).

2.2.6 Vitamins

Banana fruit pulp is rich in vitamins especially vitamin A, B and vitamin C. Banana is a rich source of vitamin B_6 (pyridoxine) providing 28 per cent of RDA whose bioactivity is high. Green bananas are also good source of vitamins B and C (Alkarkhi *et al.*, 2011).

Vitamin A content varies between varieties. A small banana of 100 g will provide about 1 per cent of our daily requirement.

Plantains and bananas have similar levels of the B vitamins such as thiamine, niacin and riboflavin. Both bananas and plantains are rich in vitamin B_6. A portion of 100 g of either will provide 25 per cent of an adult woman's recommended daily allowance and 23 per cent of that of an adult man (Blades, 2003).

Bananas are modest source of folate. A small banana provides 5 per cent of the daily requirement of folic acid, and a large banana gives about 10 per cent of the RDA (Jennings, 2000).

2.2.7 Minerals

Fresh banana is a rich source of potassium. 100g fruit provides 358 mg of potassium which is 10 per cent of our daily requirement (Menton, 2004). Amount of iron is high, whereas copper is found in very small quantity (Aurore *et al*., 2009).

Red banana is rich in potassium. In the raw stage, the variety Karpooravalli contains highest calcium, phosphorus and iron content. Whereas, in the ripe stage, Nendran contains more calcium and phosphorus (KAU, 2001).

2.2.8 Iron

Both plantains and bananas are poor sources of iron. This low intake will be exacerbated by the low iron absorption inevitable when the iron is derived from vegetable sources. The adult daily recommended intakes are 9 mg for men and 28 mg for menstruating women where the diet provides less than 10 per cent of its calories from animal foods (Rui, 2013).

2.2.9 Sodium

Another feature of bananas and plantains which is of significance in dietary terms is their low sodium content. The trace level of sodium in the banana makes it a good candidate for low sodium diets.

2.3 BIOACTIVE COMPOUNDS AND ANTIOXIDANT PROPERTIES

Bioactive compounds in plants are compounds by plants, having pharmacological effects in man and animals (Frohne, 2004). Bioactive compounds in plants can also be defined as secondary plant metabolites diluting pharmacological or toxicological effects in man and animal (Cooper *et al*., 1995). Phenols are secondary metabolites in plants possess many therapeutic properties, such as antioxidant, antimutagenic, anticarcinogenic, free radical

scavenging activities and also decrease cardiovascular complications (Yin *et al*., 2008).

Astringent taste of unripe banana is due to phenolic compounds. Bananas are rich in dopamine, an antioxidant. Browning is caused by polyphenol oxidase, monophenol monoxygenase and o-diphenoloxidase activities on dopamine, which produces tannins resulting in brown spot on peel.

Banana contains various antioxidant compounds such as vitamin C, vitamin E, β-carotene, flavonoids dopamine and gallocatechin which can protect the oxidative stress (Qusti *et al*., 2010; Someya *et al.,* 2002).

A study conducted by Merlene *et al*. (2012) using 4 varieties of locally available Rasthali, Karpooravalli, Manjalvazhapazham and Pachaivazhapazham banana varieties in Tamil Nadu revealed that green banana contain phenolic content of 180µm GAE/mg followed by yellow variety(154µg GAE/mg). The authors also reported that Rasthali had highest content of flavonoid (4.7µm) followed by Pachaivazhapazham (3.58µm).

Tannins in general are having antimicrobial and antioxidant activities. At low concentrations, it can inhibit bacterial growth and act as an antifungal agent at higher concentrations (Parimala and Shoba, 2013).

Oxidative stress is significantly reduced after a single banana meal in healthy human due to the presence of dopamine and ascorbic acid present in banana (Yin *et al*., 2008).

2.4 THERAPEUTIC PROPERTIES

Medicinal bananas are used as a remedy to treat more than 20 different illness which include

2.4.1 Diabetes mellitus

A study conducted by (Kaimal *et al*., 2009) revealed that *Musa* AAA (Chenkadali) has antioxidant and hypolipidaemic properties and can be used for treating diabetes mellitus

M.paradisiaca increases glycogenesis in the liver and lowers fasting blood glucose levels (Usha *et al*., 2004). The high potassium and sodium content of banana has a strong correlation with glycemic effect (Rai *et al*., 2009)

2.4.2 Gastro intestinal disorders

2.4.2.1 *Constipation*

According to Rai (2002) ripe plantains have mild laxative property and are useful in children as a remedy for constipation.

2.4.2.2 *Anti diarrhoeal activity*

Muhammed *et al*. (2001) reported that banana diet is good for treating bacillary dysentery due to the presence of pectin. Banana flakes has also been widely used in the treatment for diarrhoea (Emery *et al*., 1999). The Green banana posses anti- diarrhoeal activity (Rabbani, 2010).

2.4.2.3 *Peptic ulcer*

Banana can be used as an antacid to protect against ulcers (Goel *et al*., 2002). Ripe bananas are highly beneficial in the treatment of ulcerative colitis, being bland, smooth, easily digestible and slightly laxative

According to Goel *et al*. (2000), consumption of banana pulp powder had significant anti-ulcerogenic activity.

2.4.3 Blood Pressure

Whelton and Thompson (2006) reported that bananas contains large amount of potassium which has a role in controlling blood pressure. Daily consumption of banana can lower systolic pressure by 3mm Hg and diastolic pressure by 2mm Hg (Ascherio *et al*., 2000).

2.4.4 Hyperlipidaemia

Hypo cholesterelemic activity of *Musa paradisiaca* was reported by Saraswathy and Gnanam (1997) and Usha *et al*. (2004).

2.4.5 Cancer

Bananas can reduce the risk of kidney cancer (Rashid, 2005). Research findings proved that regular consumption of banana in the first two years of life can reduce the risk of childhood leukemia (Kwan *et al*., 2004). The protective role of resistant starch in the intestine, towards intestinal bacteria was proved to prevent intestinal cancer.

Intake of dietary fiber can reduce the incidence of colorectal cancer. Lohi (2010) reported that ascorbic acid (vitamin.C) was found maximum (0.350mg/ g) in Nendran fruit compared to other vitamins. It is highly essential for collagen synthesis, wound healing and blood vessel maintenance. Someya *et al*. (2002) stated that vitamin 'C' in banana act as natural antioxidant against cancer.

2.4.6 Anti allergic activity

The pulp of the ripe banana *M.sapientum was* reported to have significant anti allergic activity (Tewtrakul and Jtharai, 2008).

2.4.7 Bone and teeth

Calcium and phosphorus are important nutrients which are essential for daily diet of human. Phosphorus combined with calcium is

responsible for forming the structure of bone and teeth. Lohi (2010) reported that Nendran contained 0.188 mg/g of calcium.

Banana is also rich in phosphorus which helps to overcome the brittleness of bone and teeth and problem affecting muscle and nerve function (Potty, 2005).

2.4.8 Anaemia

The deficiency of iron causes anaemia in human beings. Lilli *et al*. (1998) stated that bananas contain iron and stimulate the production of haemoglobin in the blood. Being a traditional and local food, banana can be used to treat anaemic people (Pereira and Marcelo, 2014). Lohi (2010) reported that 0.015 mg/g of iron is present in the fruit of Nendran.

2.4.9 Morning sickness

Jyothirmayi and Rao (2015) reported that eating a banana in between meals can reduce morning sickness.

2.4.10 Anti microbial activity

Jyothirmayi and Rao (2011, 2012 and 2014) reported significant antimicrobial and phytochemical activity in banana due to alkaloids, aldehydes, ketones, terpenes and phenols. Bacteriostatic activity of banana was also studied by Zainab et al. (2013).

2.4.11 Pre-menstrual syndrome

Jyothirmayi and Rao (2015) and Partha and Hossain (2007) reported that bananas contain vitamin B_6 which helps to alleviate symptoms of pre-menstrual syndrome.

2.4.12 Wound healing

Banana can decrease the wound area, scar area due to the presence of antioxidant compounds like hydroxyproline, hexuronic acid, hexosamine and superoxide dismutase (Agarwal, 2009).

2.4.13 Depression

Banana contains tryptophan which can be converted in to serotonin in the body. Hence, it can be recommended for depressed patients (Tavakkoli *et al*., 2014).

2.4.14 HIV

A study conducted by Swanson (2010) proved that lectin isolated from bananas can be used to prevent the sexual transmission of HIV-1.

Cheung (2009) reported that banana lectin can be used as anti-HIV and antitumor agent due to its thermostability and trypsin stability.

2.4.15 Asthma treatment

Asthma can be cured by ripe banana fruits (Potty, 2005)

2.4.16 Anti viral activity

Extracts of *M.acuminata* can be used as an antiviral therapy (Martins, 2009).

2.4.17 Alzheimer's disease

Banana can reduce the risk of oxidative stress induced neurodegenerative disease like Alzheimer's disease (Heo *et al*., 2008)

2.4.18 Overweight

Daily consumption of banana can lead to overweight (Roy, 2014).

2.5 MISCELLANEOUS PROPERTIES

Lohi (2010) found that the Nendran fruit consisted of 0.0028 mg/ g thiamin and plays a vital role in the activities of various enzymes and is involved in the functioning of the nerves, muscles and heart. The deficiency of this vitamin causes the skin disease, beri-beri.

2.5.1 Quit smoking

Banana helps to give up smoking. The presence of B_6, B_{12}, potassium and magnesium helps the body to recover from the effects of nicotine withdrawal (Sirisha, 2014).

2.5.2. Skin protection

Banana contains vitamin B, E and beta carotene which is generally used in anti-aging creams (Sirisha, 2014).

2.5.3 Good for eye sight

Banana contains alpha and beta carotene which can keeps eyes very healthy (Sirisha, 2014).

2.5.4 Good pre biotic food

Banana contains fructo oligosaccharides and is considered as good pre biotic food (Sangeetha *et al*., 2005).

2.5.5 Nutritional boost for sports persons

Bananas are good source of energy for endurance and recreational athletes (David *et al*., 2012).

2.5.6 Brain booster

Bananas also contain potassium and helps in learning, boost memory by making pupils more alert. Children who consume a potassium rich breakfast often do better on tests than children who do not (Kumar *et al*., 2012).

2.5.7 Immunity booster

Bananas contain vitamin B_6, which serves as an immunity booster (ITFN, 2014).

2.5.8 Hair Care

Bananas help in softening the hair and protect its natural elasticity by preventing split ends and breakage due to the presence of potassium, natural oils and vitamins (Bipasha, 2014).

2.5.9 Stress

Potassium regulates the heartbeat and reduces stress (Roy, 2013).

2.6 VALUE ADDED PRODUCTS FROM BANANA

According to Nirmal *et al*. (1999) "value added products are raw or pre processed commodities whose value has been increased through the addition of ingredients or processes that make them more attractive to the buyer or more valuable by consumer". Value added processing of agricultural commodities makes an important contribution to agricultural development and income of the country.

Keeping banana as a whole fruit for a long time is not feasible due to its poor shelf life quality (Devadas *et al*., 2006). Processing of banana is less compared to other fruits such as potato, apple, orange and tomato (Aurore *et al*., 2009)

Some of the value added products of banana are:-

2.6.1 Banana flour

Banana flour is a good source of resistant starch. It acts as a prebiotic and promotes the growth of good bacteria in the gut.

2.6.2 Banana figs

Good quality figs can be produced from sweet banana variety like karpooravalli. A study by Shanmugavelu *et al*. (1992) reported that figs can be stored for months in cardboard cartons lined with polythene. It can be consumed directly as snack or as tit –bits in cakes, ice-creams and desserts.

2.6.3 Banana puree

Puree is the standardized natural fruit pulp. The preparation of banana puree was outlined by Charles *et al*. (1994), which required a heat treatment of pulp with the addition of preservatives such as sodium-bisulphate, citric acid and potassium sorbate.

The puree prepared can be used for making infant foods and other value added products. Frozen bananas are pureed to make smoothies or a healthful substitute for ice-creams.

2.6.4 Banana chips

Good quality chips can be prepared from banana and very famous. Research works at KAU showed that Tamil Nadu variety Nendran is available throughout the year in Kerala and is good for chips making rather than the local variety (KAU, 1997).

Satyavati *et al*. (1998) reported that Nendran bananas harvested between 85 to 95 days after the emergence of inflorescence are most suitable for deep fat frying into chips.

Another study at TNAU about the suitability of banana varieties for chips manufacturing at HRS, Periyakulam found that only Robusta could compare with Nendran (Shanmugavelu *et al.*, 1992).

2.6.5 Banana cheese

Jordan *et al.* (2001) developed fruit cheese from banana with added pectin.

2.6.6 Banana jellified milk

Chaffai (1990) studied about the production of banana jellified milk (BGM) which is a Flavoured Jellified milk (FGM), and is consumed widely as a dessert. It is made of pasteurized or sterilized milk added with sucrose and flavouring materials (chocolate, vanilla and banana).

2.6.7 Confectionaries

2.6.7.1 *Toffee*

Bananas can be used for the production of new product called toffee which is a halwa-like hard product prepared from the pulp of the fruit (PHPB, 2015).

2.6.7.2 *Candies*

These are prepared by concentrating fruits in syrup by repeated boiling until the fruit is heavily impregnated with sugar followed by drying to overcome stickiness (PHPB, 2015)

2.6.8 Banana sweet chutney

Spicy sweet chutney having a consistency similar to jam can be prepared by cooking the pulp of ripe fruit with sugar, spices and vinegar. The product has a shelf life up to one year (PHPB, 2015).

2.6.9 Banana biscuits

Good quality and nutritious banana biscuits can be prepared by mixing maida, banana flour, baking powder, milk powder and saturated fat and baking in an oven at 175^0C (Surendran *et al*., 2003)

2.6.10 Canned banana

Lal *et al*. (1998) reported that canned banana can be prepared using banana fruit alone or in combination with other fruits. According to the authors, banana varieties such as Pachabale, Chandrabale, Nendran, Chenganpurikodan, Poovan and Vannan were highly suitable for canning.

2.6.11 Beverages

Beverages from banana are not popular in the country. But in the western countries good quality beverages are preparing from banana. Preparation of quality beverages will help to promote the banana processing industry. According to Manan *et al*. (1993) fruit based beverages are delicious and popular and also rich in minerals, vitamins and other nutrients.

2.6.11.1 *Fermented beverages*

Banana fruits can also be used for other value added products like fermented alcoholic beverages like 'wine' and 'brandy' with characteristic banana flavor

2.6.11.1.2 *Wine*

Diluted pulp treated with peptic enzymes is fermented by using suitable yeast and processed by standard cellar operations for the production of wine.

Brathwaite *et al*. (2001) also undertaken a study to produce wines by utilizing the surplus bananas and to investigate the effects of pectolase, sodium meta-bisulphate, and length of fermentation on the quality attributes of the prepared wines.

2.6.11.1.3 *Vinegar*

Pooja and Soumitra (2013) reported that vinegar can be prepared from ripe or rejected bananas by the addition of starch (2 percent), sugar (16 per cent) and baker's yeast.

2.6.12 Weaning food

Banana is widely used to make weaning foods. Banana based weaning food mix with good shelf-life and acceptability has been developed by Susan (1992) and Sheelaprasad (1988).

Materials and methods

3. MATERIALS AND METHODS

The methodology for the present study entitled " Phytochemical analysis and antioxidant potential of banana (*Musa* spp.)" is undertaken to study the phytochemical, nutrient, chemical composition and antioxidant potential of the selected banana varieties and to assess its therapeutic value.

The methodology and procedures employed for the study have been presented under the following headings:-

3.1 Selection of banana varieties

3.2 Chemical and nutrient composition

3.3 Phytochemical analysis

3.4 Antioxidants and antioxidant activity

3.5 Sensory evaluation

3.6 Therapeutic value

3.7 Analysis of data

3.1 SELECTION OF BANANA VARIETIES

Eight ripe banana varieties used for table purpose were selected for the study

The varieties selected were (plate 1 to 4)

Palayankodan (AAB)

Rasakadali (AB)

Robusta (AAA)

Poovan (AAB)

Nendran (AAB)

Plate 1. Types of banana varieties selected

Palayankodan (AAB)

Rasakadali (AB)

Plate 2. Types of banana varieties selected

Robusta (AAA)

Poovan (AAB)

Plate 3. Types of banana varieties selected

Nendran (AAB)

Kadali (AA)

Plate 4. Types of banana varieties selected

Red banana (AAA)

Padatti (AAB)

Kadali (AA)

Red banana (AAA)

Padatti (AAB)

The banana varieties were procured at the time when the characteristic fruit colour developed for each type. They were collected from Instructional Farm, Vellayani and local markets of Trivandrum.

3.2 CHEMICAL AND NUTRIENT COMPOSITION

Chemical and nutrient components such as TSS, acidity, total carbohydrates, proteins and total minerals present in the ripe bananas were estimated as per the following methods.

3.2.1 Total soluble solids

The total soluble solids in the bananas were estimated by means of refractometer as ^{0} Brix in 0.1% graduations (AOAC, 1990).

3.2.2 Acidity

The acidity of banana samples was estimated by volumetric titration method described by Sadasivam and Manickam (2004).

3.2.3 Total carbohydrate

Total carbohydrate content was determined using anthrone method as described by Sadasivam and Manickam (2004).

3.2.4 Proteins

The nitrogen content of banana samples was estimated by micro Kjeldahl's wet digestion method. The values of nitrogen contents were multiplied by the factors 6.25 to get crude protein content (AOAC, 2000).

3.2.5 Total minerals

Total mineral content was estimated as per the method described by Raghuramalu *et* al. (1983).

3.2.5.1 *Sodium*

Sodium was estimated by the method suggested by Jackson (1973) using flame photometer.

3.2.5.2 *Potassium*

Potassium was estimated using flame photometer by the method outlined by Jackson (1973).

3.2.5.3 *Calcium*

Calcium was determined using EDTA method outlined by Sadasivam and Manickam (2008).

3.3 PHYTOCHEMICAL ANALYSIS

3.3.1 Preparation of the extract

The fresh and ripened fruits were removed from dust particles and peeled off. They were cut into small pieces, from which a 25g fruit sample was taken and ground well with the help of and mortar and pestle and the extraction of

banana was done using petroleum ether, methanol and distilled water as solvents. Extracts were centrifuged at 5000rpm for 20 minutes. The supernatant extracts were kept overnight for incubation at room temperature.

3.3.2 Total alkaloids

Method suggested by Harborne (1973) was used for estimating alkaloids.

3.3.3 Total flavonoids

Flavonoid contents of samples were done using spectrophotometric method suggested by Karadeniz *et al.* (2005).

3.3.4 Saponins

Method suggested by Obdoni and Ochuko (2001) was used for estimating saponins.

3.3.5 Total phenols

The total phenolic compounds of the banana samples were determined by the method given by Slinkard and Slingleton (1997).

3.3.6 Tannins

The tannin content of banana samples was estimated by the method described by Sadasivam and Manickam (2008).

3.4 ANTIOXIDANTS AND ANTIOXIDANT ACTIVITY

3.4.1 β carotene

Method suggested by Sadasivam and Manickam (2008) was used for the estimation of β carotene

3.4.2 Ascorbic acid

Ascorbic acid was estimated titrimetrically using 2, 6 dichloro indophenol dye (Ranganna, 2001).

3.4.3 Dopamine

Dopamine was estimated spectrophotometrically using the method suggested by (Li *et al*., 2009) using dopamine hydrochloride as standard.

3. 4. 4 Total Antioxidant Activity

The total antioxidant activity was determined through phosphomolybdate method (Buratti *et al.*, 2001). The banana extract was dissolved in phosphomolybdate reagent and incubated in water bath for 90 min. It was allowed to cool and absorbance was measured at 765 nm against the blank.

3.4.5 DPPH Radical Scavenging Activity

Determination of 1,1-diphenyl-2-picrylhydtazyl was carried out using the method described by Ribeiro *et al.* (2008)

The percentage inhibition of DPPH radical was calculated by comparing the result of the test with control (methanol and 1ml DPPH) using the formula (Schlesier *et al.*, 2002).

$$\text{Percentage inhibition} = \frac{(\text{Absorbance of control} - \text{Absorbance of test})}{\text{Absorbance of control}} \times 100$$

3.5 SENSORY EVALUATION

Sensory quality evaluation plays an important role in the acceptability study of any new product. Sensory evaluation is designed" to reflect common man's preference, so as to maintain the quality of a food at a given standard for the assessment of process variations, cost reduction, product improvement,

market development and market analysis" (Manay and Swamy, 2002). The overall acceptability of the banana was assessed through organoleptic evaluation. Organoleptic quality consists of judging the quality of foods by means of human sensory organs- eye, nose and mouth.

The primary consideration for selecting and eating a food commodity subjectively, is after assessing the sensory qualities of fruit for its appearance, colour, flavor, taste and texture which is discussed below (Piggot, 1988).

Trained judges were selected for sensory evaluation, based on following criteria, i.e. those who

- ✓ Had affinity for banana consumption
- ✓ Possessed the ability to identify basic tastes
- ✓ Were able to detect smell and aroma/flavour
- ✓ Were non-smokers and non pan chewers
- ✓ Had the ability to express their judgment (Plemmons and Resurrection, 1998).

The organoleptic evaluation was conducted by a selected panel of judges using a score card.

3.5.1 Selection of Judges

Panels of 10 judges were selected using the triangle test at laboratory level comprising of both students and staff from the Department of Home Science. The best banana varieties were identified based on the quality attributes assessed through sensory evaluation .

3.5.2 Preparation of Score card

The sensory attributes such as appearance, colour, flavour, taste and texture were assessed by assigning scores as described by Sudha *et al*. (2007). The score card used for the evaluation of following quality attributes of banana is given in Appendix I.

3.5.3 Appearance

Quality of fruits can be ascertained to a great extent by its appearance. Consumer's fruit selection criteria are mainly based on the external appearance, which is strongly influenced by colour. Appearance of the banana varieties was assessed using a score card. .

3.5 4 Flavour

Odour, taste and mouth feel are the three components of flavour. Flavour of the banana varieties was assessed using a score card.

3.5.5 Texture

The texture or firmness of the pulp of banana, is an important harvest quality attribute in the assessment of quality at harvest. It could be used as maturity ripening index also. Texture analysis is important in the evaluation of fruit's susceptibility to physical or mechanical damage. Texture of the fruits was assessed using a score card.

3.5.6 Taste

Food is valued mostly for its taste. A score card was used for assessing the taste of each banana sample. Taste is also an important feature for acceptability and was measured using a score card.

3.5.6 Overall acceptability

Overall acceptability of the banana varieties were measured using a five point score card (Appendix I) and also by hedonic rating on a nine point scale suggested by Meilgaard (2006) where 9 represents "extremely like" and 1 "extremely dislike" (Appendix II).

3.6 THERAPEUTIC VALUE

The therapeutic value of banana varieties was assessed by determining its glycemic index.

Blood sugar levels raises after eating foods having carbohydrates (sugar and starches). Carbohydrate foods affect blood sugar levels differently. The glycemic index compares the increase in blood sugar levels after taking a carbohydrate food and a reference food, usually glucose.

For determining glycemic index, 10 healthy individuals were selected and they were asked to attend the tasting session after 10-12 hours over fast. The subjects were asked not to take large meals, drink alcohol or exercise vigorously on the previous day, and to avoid cycling. On the first day, subjects were given the standard or reference carbohydrate. I.e. 50g glucose dissolved in 100ml of water. Blood was taken at 0, 30, 60, 90 and 120 minutes by finger prick method using a glucometer and was measured (plate 5).

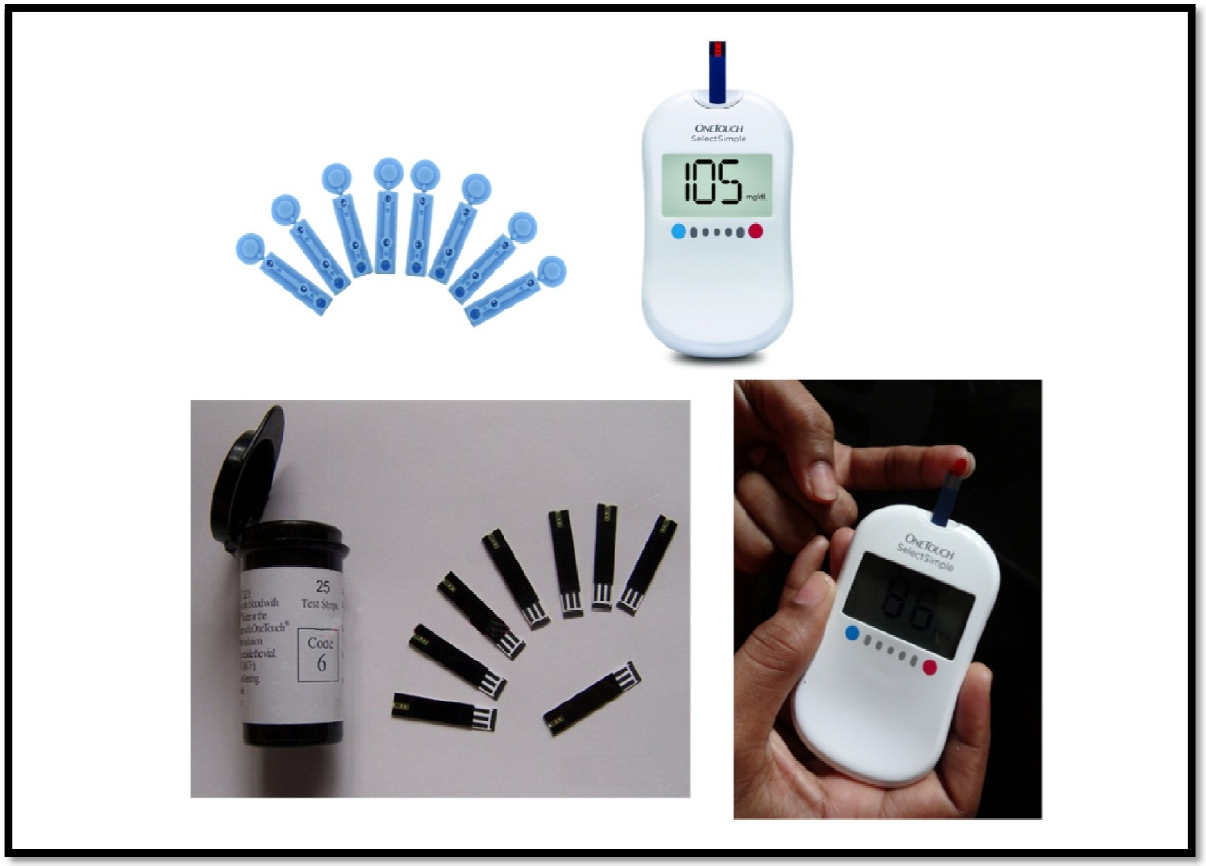
Equal quantity of bananas having 50g carbohydrate was given for testing against the reference carbohydrate (glucose) on the consecutive days. Blood glucose curve and the incremental area under the curve (IAUC) were calculated by the trapezoidal rule (Gibaldi and Perrier, 1982).

Calculation of Glycemic Index

Glycemic index was calculated by dividing the IAUC of the test food by the IAUC of the reference food multiplied by 100 for each individual using the following formula (Wolever and Boume,1990).

The average GI of the ten individuals is taken as the GI of a test food.

Plate 5. Monitoring of blood glucose level



3.7 ANALYSIS OF DATA

All the analyses were done in triplicates. In order to obtain suitable interpretation the generated data was subjected to statistical analysis like One-way Analysis of Variance (ANOVA) at 0.05% significant level and Kruskal Wallis test. Graphical interpretation of analyzed data was also adopted.

Results

4. RESULTS

Results of the present study entitled "Phytochemical analysis and antioxidant potential of banana (*Musa* spp.)" is presented under the following headings.

4.1. Chemical and nutrient composition

4.2. Phytochemical analysis

4.3. Antioxidant activity

4.4. Sensory evaluation and

4.5. Therapeutic value

4.1 CHEMICAL AND NUTRIENT COMPOSITION

To assess the chemical/ nutrient composition of the banana varieties in the fresh form, the following parameters were determined i.e. TSS, acidity, total carbohydrate, protein, total minerals such as sodium, potassium and calcium.

The estimation of chemical and nutrient composition produces reliable data on food items like fruits, vegetables, grains etc.

4.1.1 Total Soluble Solids

TSS is widely used during fruit and vegetable processing to determine the concentration of sugar in the products. The data on TSS content is presented in Table 1.

Table 1. TSS content of banana varieties

Treatments	Name	TSS (^{0} Brix)
T_1	Palayankodan (AAB)	18.53
T_2	Rasakadali (AB)	23.83
T_3	Robusta (AAA)	20.30
T_4	Poovan (AAB)	20.10
T_5	Nendran (AAB)	22.00
T_6	Kadali (AA)	23.90
T_7	Red banana (AAA)	21.60
T_8	Padatti (AAB)	17.83
	CD(0.05)	0.659

Total soluble solids (TSS) of banana varieties ranged between 17.83^0 Brix and 23.90^0 Brix. As indicated in Table 1, TSS was found to be more in Kadali (23.90^0 Brix) followed by Rasakadali (23.83^0 Brix) and Nendran (22^0 Brix). It was also noticed that Padatti exhibited minimum TSS (17.83^0Brix). When the data was statistically analyzed, it was found that significant difference was found to exist between the varieties. It was also observed that Robusta and Poovan were on par. Similarly Nendran and Red banana are also on par.

4.1.2 Acidity

Acidity indicates flavour as well as wholesomeness of the products (Mehta *et al*., 2002).

Table 2.Acidity of banana varieties

Treatments	Name	Acidity (%)
T_1	Palayankodan (AAB)	0.72
T_2	Rasakadali (AB)	0.71
T_3	Robusta (AAA)	0.47
T_4	Poovan (AAB)	1.28
T_5	Nendran (AAB)	0.84
T_6	Kadali (AA)	0.46
T_7	Red banana (AAA)	0.48
T_8	Padatti (AAB)	0.94
	CD(0.05)	0.125

Acidity of the selected banana varieties is depicted in the Table 2and significant differences were observed in the acidity of banana varieties studied. The varieties Kadali (0.46%) and Robusta (0.47%) were found to be less acidic whereas, maximum acidity was noticed in Poovan (1.28%). The varieties Red banana (0.48), Kadali (0.46) and Robusta (0.47) were found to be on par.

4.1.3 Total carbohydrate

Carbohydrates are an important part of our diet since they are the body's primary source of energy. Carbohydrates mainly come from plant foods such as grains, fruits and vegetables.

Table 3. Total carbohydrate content of banana varieties

Treatments	Name	Carbohydrate (g/100 g)
T_1	Palayankodan (AAB)	31.10
T_2	Rasakadali (AB)	30.73
T_3	Robusta (AAA)	22.63
T_4	Poovan (AAB)	38.77
T_5	Nendran (AAB)	41.33
T_6	Kadali (AA)	32.13
T_7	Red banana (AAA)	21.70
T_8	Padatti (AAB)	26.66
	CD(0.05)	1.439

It was clear from the above table that carbohydrate content was noticed to be higher in the variety Nendran (41.33g/100g) followed by Poovan (38.77g/100g) which was significantly different from all the other varieties. The carbohydrate content of Palayankodan, Rasakadali, Robusta were found to be 31.10g, 30.73g and 22.63g respectively. The statistical analysis of the data revealed that the carbohydrate content of Palayankodan (31.10g/100g) was on par with Rasakadali (30.73g/100g) and Kadali (32.13g/100g).

4.1.4 Protein

Proteins are nitrogen- containing substances formed by amino acids. Vegetable proteins provide good source of protein and will reduce the intake of

saturated fat and cholesterol (Aiking, 2011). The protein content of the banana varieties is depicted in Table 4.

Table 4. Protein content of banana varieties

Treatments	Name	Protein (g/100g)
T_1	Palayankodan (AAB)	1.14
T_2	Rasakadali (AB)	0.91
T_3	Robusta (AAA)	1.33
T_4	Poovan (AAB)	1.37
T_5	Nendran (AAB)	1.11
T_6	Kadali (AA)	1.37
T_7	Red banana (AAA)	1.34
T_8	Padatti (AAB)	1.28
	CD(0.05)	0.213

Significant difference existed between the varieties in terms of protein content. From the above table, it was observed that protein content of banana varieties ranged between 0.91- 1.37g/ 100g. Poovan and Kadali exhibited highest protein content (1.37g/100g) followed by Red banana (1.34g/100g). The protein content of Robusta, Poovan, Kadali, Red banana and Padatti were on par with each other. The lowest protein content was noticed in Rasakadali (0.9g/100g) which was on par with Nendran (1.11g/100g.

4.1.5 Total minerals

Mineral constituents are important for various metabolic activities of the fruit.

Table 5. Total mineral contents of banana varieties.

Treatments	Name	Total minerals (g/ 100g)
T_1	Palayankodan (AAB)	0.182
T_2	Rasakadali (AB)	0.58
T_3	Robusta (AAA)	0.17
T_4	Poovan (AAB)	0.48
T_5	Nendran (AAB)	0.68
T_6	Kadali (AA)	0.33
T_7	Red banana (AAA)	0.70
T_8	Padatti (AAB)	0.30
	CD(0.05)	0.121

The total mineral content of banana varieties ranged between 0.17g – 0.70g/100g. The results of the ANOVA table revealed significant differences in the total mineral content of the banana varieties studied. Mineral content of Red banana, Nendran and Poovan were found to be 0.70g, 0.68g and 0.48g/100 respectively whereas, it was found to be less in Robusta (0.17g/100g) and Palayankodan (0.18 g/100g).The statistical analysis of data revealed that Red banana was on par with Nendran and Padatti was on par with Kadali.

4.1.5.1 *Sodium*

Sodium is the most important mineral in the body. It is a mineral that exists in the body as 'Na' ion. The body acquires sodium through diet, mainly in the form of salt (sodium chloride).

Table 6. Sodium content of banana varieties.

Treatments	Name	Sodium (mg/100g)
T_1	Palayankodan (AAB)	208.33
T_2	Rasakadali (AB)	260.00
T_3	Robusta (AAA)	241.66
T_4	Poovan (AAB)	221.66
T_5	Nendran (AAB)	183.33
T_6	Kadali (AA)	170.00
T_7	Red banana (AAA)	190.00
T_8	Padatti (AAB)	203.33
	CD(0.05)	40.441

Table 6 depicts sodium content of banana varieties. The analysis of the data revealed significant differences among the varieties in terms of sodium content. Variety Rasakadali and Robusta exhibited high content of sodium (260 mg/100g and 241.66 mg/100g respectively) whereas Kadali (170 mg/100g) and Nendran (183.33mg/100g) recorded lesser amount of sodium The sodium content of the banana varieties fell between 170 mg- 260 mg/100 g.

4.1.5.2 *Potassium*

Potassium is one of the important macro- mineral needed for muscle contraction and fluid and electrolyte balance in the body. The potassium content of the banana varieties is shown in Table 7.

Table 7. Potassium content of banana varieties

Treatments	Name	Potassium (mg/100g)
T_1	Palayankodan (AAB)	351.66
T_2	Rasakadali (AB)	403.33
T_3	Robusta (AAA)	415.00
T_4	Poovan (AAB)	261.66
T_5	Nendran (AAB)	546.66
T_6	Kadali (AA)	408.33
T_7	Red banana (AAA)	415.00
T_8	Padatti (AAB)	413.66
	CD(0.05)	14.675

Potassium content of banana varieties ranged between 261.66 mg-546.66 mg/100 g. The data also revealed significant differences between the varieties in terms of potassium content. It was also proved that varieties Rasakadali (403.33 mg/ 100g), Robusta (415 mg/100g), Kadali (408.33mg/ 100g) and Red banana (415 mg/100g) were on par with each other.

4.1.5.3 *Calcium*

Calcium is a major mineral required for the mineralization of bone, teeth and shells.

Table 8.Calcium content of banana varieties

Treatments	Name	Calcium (mg/100g)
T_1	Palayankodan (AAB)	1.35
T_2	Rasakadali (AB)	0.79
T_3	Robusta (AAA)	0.85
T_4	Poovan (AAB)	0.80
T_5	Nendran (AAB)	0.62
T_6	Kadali (AA)	0.48
T_7	Red banana (AAA)	0.35
T_8	Padatti (AAB)	0.85
	CD(0.05)	0.187

Calcium content of banana varieties is depicted in the Table 8. From the above table, it may be noted that the calcium content ranged from 0.35-1.35 mg/100g. Calcium content was found to be more in Palayankodan (1.35mg/100g). The lowest Ca content was noticed in variety the Red banana (0.35mg/100g). When the data was analyzed, it was found that significant difference was found to exist between the varieties. It was also noted that the varieties Robusta, Poovan and Padatti were on par with each other.

4.2 PHYTOCHEMICAL ANALYSIS

Phytochemicals are plant chemicals and are defined as “bioactive non nutrient plant compounds in fruits, vegetables, grains and other plant foods that have been linked in reducing the risk of major chronic diseases” (Liu, 2004).

To assess the phytochemical composition of the banana varieties, the

following parameters were determined i.e. total alkaloids, flavonoids, saponins, total phenols and tannins.

4.2.1 TOTAL ALKALOIDS

Alkaloids are natural products synthesized by animals, plants, bacteria and fungi. Almost all the alkaloids have a bitter taste.

Total alkaloid content of the banana varieties was observed to range between 0.84 – 3.76 per cent. As indicated in Table 9, the varieties Nendran (3.76%) and Padatti (3.72 %) were found to be having maximum alkaloid content. When the data was analyzed statistically, it was found that significant difference was found to exist between the varieties. It was also noticed that the varieties Padatti and Nendran; varieties Rasakadali, Robusta and Poovan and varieties Kadali and Palayankodan were on par with each other. The variety Red banana recorded least content of alkaloid (0.84%).

Table 9. Total alkaloid content of banana varieties

Treatments	Name	Alkaloid (%)
T_1	Palayankodan (AAB)	1.54
T_2	Rasakadali (AB)	2.51
T_3	Robusta (AAA)	2.77
T_4	Poovan (AAB)	2.68
T_5	Nendran (AAB)	3.76
T_6	Kadali (AA)	1.44
T_7	Red banana (AAA)	0.84
T_8	Padatti (AAB)	3.72
	CD(0.05)	0.446

4.2.2 FLAVONOIDS

Flavonoids are one of the commonly seen phenolic compounds. This includes “flavones, flavonols, isoflavonols, anthocyanins, anthocyanidins, and catechins” (Ferreria and Pinho, 2012). Flavonoids are derived from amino acids such as phenyl alanine and tyrosine having a three ringed structure (Rong, 2010).

Table 10. Flavonoid content of banana varieties

Treatments	Name	Flavonoid (mg/100g)
T_1	Palayankodan (AAB)	8.12
T_2	Rasakadali (AB)	9.49
T_3	Robusta (AAA)	7.88
T_4	Poovan (AAB)	9.41
T_5	Nendran (AAB)	8.26
T_6	Kadali (AA)	6.35
T_7	Red banana (AAA)	3.58
T_8	Padatti (AAB)	4.03
	CD(0.05)	0.531

Flavonoid content of banana varieties is shown in Table 10. Significant difference was observed in the total flavonoid content of banana varieties studied. Comparing the flavonoid content of banana varieties studied, it was

observed that variety Rasakadali(9.49mg/100g) and variety Poovan (9.41mg/100g) were having maximum flavonoid content and variety Red banana (3.58mg/100g) and variety Padatti (4.03mg/100g) showed least amount of flavonoid content.

4.2.3 SAPONIN

Saponin content of banana varieties is depicted in Table 11.

Table 11. Saponin content of banana varieties

Treatments	Name	Saponin (%)
T_1	Palayankodan (AAB)	0.35
T_2	Rasakadali (AB)	0.62
T_3	Robusta (AAA)	0.35
T_4	Poovan (AAB)	0.65
T_5	Nendran (AAB)	0.77
T_6	Kadali (AA)	0.82
T_7	Red banana (AAA)	0.73
T_8	Padatti (AAB)	0.22
	CD(0.05)	0.041

Saponin content of banana varieties was found to be ranged between 0.22 -0.82 per cent. Significant difference was noticed in the saponin content of banana varieties studied. Varieties Kadali, Nendran, Red banana and Poovan were having saponin content of 0.82%, 0.77%, 0.73% and 0.65% respectively.

The saponin content was found maximum in variety Kadali (0.82 per cent) and minimum in variety Padatti (0.22 per cent) (Table11). It was also observed that variety Nendran (0.77) was on par with variety Red banana (0.73) and variety Palayankodan (0.35) was on par with variety Robusta (0.35).

4.2.4 Total phenols

Phenols are the secondary metabolites in plants which act as defense mechanisms against pathogens, parasites and predator. It also provides many health benefits and reduces the risk of chronic diseases (Rui, 2013).

Table12. Total phenol content of banana varieties

Treatments	Name	Total phenol (mg/100g)
T_1	Palayankodan (AAB)	3.73
T_2	Rasakadali (AB)	6.76
T_3	Robusta (AAA)	2.13
T_4	Poovan (AAB)	7.19
T_5	Nendran (AAB)	4.79
T_6	Kadali (AA)	11.66
T_7	Red banana (AAA)	4.92
T_8	Padatti (AAB)	3.49
	CD(0.05)	0.993

As indicated in Table 12, phenol content was found to be more in varieties Kadali (11.6 mg/ 100g), Poovan (7.19 mg /100g), and Rasakadali (6.76

mg/100 g). The total phenol content of the banana varieties was found to be ranged between 3.73 – 11.66 mg/100g.

When the data was statistically analyzed, it was found that significant differences existed between the varieties. It was also found that the varieties Rasakadali (6.76) and Poovan (7.19) and varieties Palayankodan (3.73), Red banana (4.92) and Padatti (3.49) were on par with each other.

4.2.5 Tannins

Tannins are water soluble polyphenols present in plant foods, responsible for reduced feed intake, growth rate and protein digestibility in experimental animals (Jackson, 2003) .Hence, foods having tannins are of low nutritional value. Moreover, interactions between tannins and proteins lead to astringency (Cieslik *et al*., 2004).

Table 13.Tannin content of banana varieties

Treatments	Name	Tannin (mg/100g)
T_1	Palayankodan (AAB)	4.28
T_2	Rasakadali (AB)	2.09
T_3	Robusta (AAA)	3.93
T_4	Poovan (AAB)	3.30
T_5	Nendran (AAB)	4.40
T_6	Kadali (AA)	2.60
T_7	Red banana (AAA)	1.66
T_8	Padatti (AAB)	2.27
	CD(0.05)	0.363

As observed in the present study, variety Nendran (4.40 mg/100g) and Palayankodan (4.28mg/100g) showed maximum tannin content and was significantly different from the other varieties. The tannin content found to be minimum for the variety Red banana (1.66mg/100g) followed by variety Rasakadali (2.09mg/100g). The analysis of the data showed that tannin content of the varieties Palyankodan (4.28mg*)* and Padatti (2.27mg) were on par with each other.

4.3 ANTIOXIDANT ACTIVITY

Antioxidants are compounds which protects the body by retarding the oxidation process through scavenging free radical produced during many natural events (Wood *et al*., 2006; Gulcin *et al*., 2007).

4.3.1 Beta carotene

Beta carotene, a strong antioxidant can neutralize free radicals and reactive oxygen molecules which may lead to the development of cardiovascular disease and cancer. The data on beta carotene is presented in the Table14.

Significant differences ($p < 0.05$) were seen among the banana varieties in terms of the β carotene content. Beta carotene is an important antioxidant present in fruits in different concentration. The results revealed that highest beta carotene was found to be maximum in variety Red banana (21.19µg/100g). The beta carotene content of banana varieties ranged between 2.94 µg/100g– 21. 19 µg/100g) and were significantly different from other varieties. The lowest beta carotene content was found in variety Nendran (2.94 µg/100g).

Table 14. Beta carotene content of banana varieties

Treatments	Name	Beta carotene (µg/100g)
T_1	Palayankodan (AAB)	7.97
T_2	Rasakadali (AB)	3.93
T_3	Robusta (AAA)	4.08
T_4	Poovan (AAB)	3.55
T_5	Nendran (AAB)	2.94
T_6	Kadali (AA)	16.02
T_7	Red banana (AAA)	21.19
T_8	Padatti (AAB)	3.08
	CD(0.05)	0.552

4.3.2 Ascorbic acid

Table 15. Ascorbic acid content of banana varieties

Treatments	Name	Ascorbic acid (mg/100g)
T_1	Palayankodan (AAB)	2.19
T_2	Rasakadali (AB)	2.18
T_3	Robusta (AAA)	1.52
T_4	Poovan (AAB)	4.26
T_5	Nendran (AAB)	3.36
T_6	Kadali (AA)	3.50
T_7	Red banana (AAA)	5.35
T_8	Padatti (AAB)	1.73
	CD(0.05)	0.382

Ascorbic acid content of the banana varieties was observed to range between 1.52 - 5.35 mg/100g. As indicated in Table 15, the highest ascorbic acid content was noticed in Red banana (5.35 mg) and the lowest in Robusta (1.52 mg). When the data was statistically analyzed, it was found that significant differences were found to exist between the varieties. It was also proved that varieties Palayankodan and Rasakadali and varieties Robusta and Padatti were on par with each other.

Table 16. Total antioxidant capacity of banana varieties

Treatments	Percentage of total antioxidant capacity of banana varieties														
	100(µg/ml)			200(µg/ml)			300 (µg/ml)			400(µg/ml)			500(µg/ml)		
T_1	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
T_2	65.9	72.4	74.3	70.2	85.6	94.3	68.6	73.2	77.8	70.3	82.9	87.3	72.3	85.6	98.6
T_3	54.2	74.3	81.3	78.6	79.7	80.3	75.6	84.6	87.9	47.9	54.6	79.8	60.3	64.3	74.5
T_4	69.3	73.5	91.3	49.34	65.0	74.6	57.6	64.3	77.7	51.3	68.6	74.5	58.6	65.7	71.3
T_5	59.3	73.0	88.5	72.3	78.9	85.9	68.6	74.9	88.3	54.6	78.3	93.5	43.9	78.9	85.9
T_6	58.6	72.1	79.6	68.7	71.6	79.6	74.9	85.4	91.3	49.3	68.1	75.6	58.9	74.6	91.3
T_7	54.5	69.6	75.6	69.3	75.9	79.3	58.5	67.2	74.3	61.3	74.6	79.3	56.6	87.5	88.4
T_8	53.6	68.6	75.6	74.2	78.9	81.0	51.3	68.9	70.2	55.8	69.7	72.0	65.9	74.6	76.3
	55.7	66.8	82.6	64.6	78.8	84.3	70.3	84.9	90.5	52.3	59.3	78.9	74.6	83.2	90.2

T_1 –Palayankodan, T_2 –Rasakadali, T_3 – Robusta, T_4 – Poovan, T_5 – Nendran, T_6 – Kadali, T_7 - Red banana, T_8 – Padatti

S1- Petroleum ether, S2- Methanol, S3- Water

4.4.3 Total antioxidant activity

The total antioxidant activity of banana varieties was studied by phosphomolybdenum method and the antioxidant activity was expressed in terms of µg of ascorbic acid equivalents per gram of solvents used for the extraction of banana varieties.

The banana varieties analyzed for antioxidant capacity are presented in Table 16. It was revealed that antioxidant activity was higher for petroleum ether extract followed by methanol extracts when compared to aqueous extract.

The percentage of antioxidant activity of variety Palayankodan in petroleum ether extract was ranged between 65.9- 72.3(µg AAE/mg). In the case of methanolic extraction, it ranges between 72.4- 85.6µg AAE/mg. Where as in the case of aqueous extraction, it ranges between 94.3-98.6 µg AAE/mg.

In the case of variety Rasakadali, percentage of inhibition ranges from 54.2- 60.3(µg AAE/mg). In methanolic solvent it ranges from 74.3-64.3(µg AAE/mg) and in aqueous extraction it was 81.3- 74.5(µg AAE/mg).

The antioxidant activity of the banana varieties ranged between 41.2-49.2 µg/ml, 44.4-51.6 µg/ml and 46.4-54.8 µg/ml in petroleum ether, methanol and aqueous medium respectively. Highest antioxidant activity was reported in variety Padatti with an IC_{50} value of 41.2 µg/ml and 46.4 µg/ml in petroleum ether and aqueous medium respectively. Where as in methanol solvent, highest activity was exhibited by variety Red banana with an IC_{50} value of 44.4 µg/ml.

Total antioxidant activity of the banana varieties is presented in Table17.

Table 17. Total antioxidant activity of banana varieties

Treatments	Name	IC_{50} values (µg/ml)		
		Petroleum ether	Methanol	Water
T_1	Palayankodan (AAB)	48.0	49.2	53.6
T_2	Rasakadali (AB)	43.6	51.6	54.0
T_3	Robusta (AAA)	49.2	50.0	52.2
T_4	Poovan (AAB)	44.0	49.2	49.2
T_5	Nendran (AAB)	44.0	46.0	48.4
T_6	Kadali (AA)	44.6	46.4	54.8
T_7	Red banana (AAA)	43.6	44.4	51.2
T_8	Padatti (AAB)	41.2	46.0	46.4

The concentration of sample that could scavenge 50% free radical (IC_{50}) was used to determine antioxidant capacity of sample compared to standard. The varieties having lowest IC_{50} had the highest antioxidant capacity. According to Blois (1992), "sample that had IC_{50}<50 ppm, was consider as very strong antioxidant, 50-100 ppm strong antioxidant, 101-150 ppm medium antioxidant, while weak antioxidant with IC_{50}>150 ppm".

Table 18. DPPH scavenging capacity of banana

	Percentage of DPPH radical scavenging capacity of banana varieties														
	100(µg/ml)			200(µg/ml)			300 (µg/ml)			400(µg/ml)			500(µg/ml)		
Treatments	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
T_1	61.4	75.4	78.5	84.3	89.5	95.0	69.6	70.1	76	47.5	48.2	85	43.3	45.1	43
T_2	79.5	87.1	92.1	65.8	87.5	89.6	71.0	86.3	89.5	70.5	82.6	84.3	58.0	61.3	67.8
T_3	89.1	92.1	97.8	59.6	64.3	72.1	87.6	72.6	74.2	56.3	57.6	58.6	37.7	40.9	54.6
T_4	78.2	88.5	95.2	45.3	58.9	69.5	65.6	68.8	74.9	45.6	54.9	68.3	49.3	52.2	59.6
T_5	65.4	71.3	74.2	57.5	72.6	76.3	56.3	78.9	79.6	54.5	56.3	64.5	52.6	54.7	60.3
T_6	81	88	90.3	65.5	78.6	85.6	65.5	69.3	75.4	65.2	68.3	71.3	54.6	59.9	62.3
T_7	89.3	79.5	92.3	75.3	76.9	81.6	62.2	74.9	82.3	55.6	61.6	71.1	50.1	56.3	61.9
T_8	78.2	84.3	88.7	64.1	82.2	87.6	56.8	70.3	71.2	65.5	70.6	73.3	51.3	65.6	69.9

T_1 –Palayankodan, T_2 –Rasakadali, T_3 – Robusta, T_4 – Poovan, T_5 – Nendran, T_6 – Kadali, T_7 - Red banana, T_8 – Padatti

S1- Petroleum ether, S2- Methanol, S3- Water

4.4.4 DPPH radical scavenging activity

Antioxidants inhibit lipid per oxidation through free radical scavenging activity (Blokhina *et al*., 2003). The DPPH radical scavenging activity was used for screening antioxidants from fruits and vegetable juices and extracts (Sanchez, 2002).

In the present study, free radical scavenging capacity of banana varieties were studied by the DPPH assay in different solvents such as petroleum ether, methanol and water. Table 18 illustrates the results of DPPH activity of the banana varieties. The IC_{50} value was calculated from the graph (it was noted as the concentration of sample needed to scavenge the free radicals at 50 per cent inhibition).

Table 19. DPPH radical scavenging activity of banana varieties

Treatments	Name	IC_{50} values (µg/ml)		
		Petroleum ether	Methanol	Water
T_1	Palayankodan (AAB)	50.8	52.4	54.4
T_2	Rasakadali (AB)	45.6	48.4	53.8
T_3	Robusta (AAA)	43.6	50.4	50.8
T_4	Poovan (AAB)	50.0	48.4	52.0
T_5	Nendran (AAB)	51.2	55.2	55.6
T_6	Kadali (AA)	46.8	53.6	58.0
T_7	Red banana (AAA)	48.0	56.8	57.6
T_8	Padatti (AAB)	46.0	51.3	58.8

The study revealed that the variety Robusta had the highest DPPH radical scavenging activity with an IC_{50} value of 43.6 µg/ml in petroleum ether and 50.8 µg/ml in aqueous mediun respectively. Where as in methanol solvent the highest activity was noticed in the variety Rasakadali and Poovan with an IC_{50} value of 48.4 µg/ml. The best DPPH scavenging activity was noticed in variety Nendran in petroleum ether (51.2 µg/ml), Red banana in methanol (56.8µg/ml) and Kadali in aqueous medium (58.0µg/ml).

4.4.5 Dopamine

Dopamine and dopamine derivatives are a group of biogenic amines involved in various biological functions (Juan *et al*., 2003). .

The dopamine content of the different banana varieties was observed to range between 3.2- 13.3 mg/100g. As indicated in Table 20, the highest dopamine content was observed in variety Robusta (13.3 mg/ 100g) and the lowest for variety Rasakadali (3.2mg/ 100 g). When the data was statistically analyzed it was found that significant difference was found to exist between varieties. It was also proved that varieties Nendran, Kadali and Padatti were on par with each other.

Table 20. Dopamine content of banana varieties

Treatments	Name	Dopamine (mg/100g)
T_1	Palayankodan (AAB)	8.4
T_2	Rasakadali (AB)	3.2
T_3	Robusta (AAA)	13.3
T_4	Poovan (AAB)	5.3
T_5	Nendran (AAB)	6.1
T_6	Kadali (AA)	7.2
T_7	Red banana (AAA)	11.0
T_8	Padatti (AAB)	7.2
	CD(0.05)	0.051

4.4 SENSORY EVALUATION

4.4.1. Organoleptic evaluation of selected banana varieties

Scientific assessment of sensory analysis of food is becoming important in evaluating the acceptability of the food product. When the quality of the food is judged by human sensory organs, it is said to be sensory analysis (Simi, 2002). Thakkar and Shah (2009) opined that sensory analysis is a technique that uses man as a measuring instrument. Numerical scoring test is used to evaluate particular characteristics of one or more samples indicating the rating as excellent, very good, good, fair and poor (Manay and Swami, 2002). Accordingly, selected banana varieties were assessed orgnoleptically by a panel of ten judges using a score card on a five point scale. The data is presented in the Table 21.

Table 21.Mean rank scores obtained for selected banana varieties

Treatments	Name	Appearance	Flavour	Texture	Taste	Overall Acceptability
T_1	Palayankodan (AAB)	25.1	34.7	44.6	40.3	34.5
T_2	Rasakadali(AB)	58.7	54.3	60.9	63.4	59.2
T_3	Robusta (AAA)	46.6	33.2	42.2	36.6	38.5
T_4	Poovan(AAB)	25.5	38.9	47.4	40.8	40.8
T_5	Nendran (AAB)	51.6	41.3	27.2	44.3	46.0
T_6	Kadali(AA)	23.5	35.6	24.4	21.3	25.7
T_7	Redbanana (AAA)	49.3	46.9	47.5	46.9	47.9
T_8	Padatti(AAB)	43.5	38.9	29.6	30.2	31.2
	K value	26.62	7.59	22.62	21.27	15.66
	C.D (0.05)	23.75				

4.4.1.1 Appearance

The mean ranks for appearance pertaining to the eight selected banana varieties ranged between 23.5 – 58.7. The highest mean rank score (58.7) was obtained for variety Rasakadali and lowest mean rank score for variety Kadali (23.5).

4.4.1.2 Flavour

The flavour of a food product is referred as aroma. Flavour is perceived by humans when volatiles from a food in or near the mouth enters the nasal cavity and are sensed by the olfactory located in the roof, septum and superior

turbinate of the nasal cavity (Meilgaard *et al*., 1991). Odours can reach the olfactory mucosa in two different ways. First, they can be inhaled through the nostrils. Second, during chewing or swallowing they can travel from the mouth to the nasal cavity (Menella, 1998).

Flavour is due to volatile compounds such as esters, alcohols, aldehydes and carbonyl compounds.

As per the flavour evaluation, the flavour of banana varieties differed in mean rank, score which ranged from 33.2- 54.3. The highest mean rank score was recorded by the variety Rasakadali (54.3) followed by variety Red banana (46.9) and lowest by the variety Robusta (33.2)

4.4.1.3 Texture

Texture is a complex and important sensory attribute because it is often cited as the reason for disliking rather than liking a food item (Cardello, 1994). According to Gail and Thomas (1991) the components of texture are mechanical properties which include hardness, cohesiveness, adhesiveness, denseness and springiness; geometrical properties which include smoothness, gritty, grainy, chalky/ powdery, fibrous and lumpy/ bumpy and moisture properties which include moistness, moisture, and moisture release, oily and greasy.

The variety Rasakadali exhibited highest mean rank score (60.9) where as the variety Kadali (24.4) showed least mean rank score with respect to the quality attribute texture.

4.4.1.4 Taste

The taste is the major attribute which determine the acceptability of a food. Taste is the sensation produced when a substance in the mouth reacts chemically with receptors of taste buds. According to Srilakshmi (2010), the taste sensations are categorized as sweet, salt, sour or bitter.

The quality attribute taste of eight banana varieties was assessed and their scores were recorded. The mean rank score for taste parameter in the eight banana varieties ranged between 21.3- 63.4. Maximum mean rank score for taste was obtained for variety Rasakadali (63.4) followed by the variety Red banana (46.9) and least mean rank score was secured by variety Kadali (21.3).

4.4.1.5 Overall Acceptability

The overall acceptability of the banana varieties depends on the sum total of the scores obtained for the various parameters viz performance of the banana varieties on the whole, considering the judges perception on different sensory attributes.

The overall mean rank score for different banana varieties ranged from 25.7- 59.2. Over all acceptability scores clearly depicted that, among the eight varieties, maximum mean rank score was secured for variety Rasakadali (59.2) followed by Red banana (47.9) and Nendran (46.0). Least preference for overall acceptability was obtained for variety Kadali (25.7) and varietyV_8 (31.2).

4.2 Hedonic rating of the banana varieties

The hedonic rating was used to measure the consumer acceptability of

food products (Srilakshmi, 2010). Hedonic rating was also carried out for all the eight varieties on nine point scale from 'like extremely' to 'dislike extremely'. The scores obtained by hedonic rating is presented in the Table 22.

Table 22 : Hedonic rating of banana varieties

Rating scale	Scores	Scores of the bananas							
		T1	T2	T3	T4	T5	T6	T7	T8
Like extremely	9	09(1)	27(3)	18(2)	27(3)	18(2)	-	27(3)	-
Like very much	8	24(3)	40(5)	24(3)	24(3)	40(5)	-	48(6)	24(3)
Like moderately	7	35(5)	14(2)	28(4)	14(2)	21(3)	21(3)	7(1)	28(4)
Like slightly	6	6(1)	6(1)	6(1)	12(2)	-	24(4)	-	6(1)
Neither like or dislike	5	-	-	-	-	-	15(3)	-	5(1)
Dislike slightly	4	-	-	-	-	-	-	-	-
Dislike moderately	3	-	-	-	-	-	-	-	-
Dislike very much	2	-	-	-	-	-	-	-	-
Dislike extremely	1	-	-	-	-	-	-	-	-
Max score	90	74	87	76	77	79	60	82	63
Mean preference score		7.4	8.7	7.6	7.7	7.9	6.0	8.2	6.3
Per cent score		82	96	84	86	88	67	91	70

(Figures in parenthesis indicate number of judges); n=Number of judges=10)

Based on hedonic rating per cent score for each banana varieties was calculated and ranking was done in the Table 23.

Table 23. Ranking of banana varieties based on hedonic rating

Treatments	Name	Scores obtained
T_1	Palayankodan(AAB)	82
T_2	Rasakadali(AB)	96
T_3	Robusta (AAA)	84
T_4	Poovan (AAB)	86
T_5	Nendran (AAB)	88
T_6	Kadali (AA)	67
T_7	Red banana (AAA)	91
T_8	Padatti(AAB)	70

As indicated in the table 23, variety Rasakadali got maximum score (96) followed by variety Red banana (91) and Nendran (88). Hence, these three varieties were more acceptable to the judging panels.

4.5 Therapeutic value

4.5.1 Glycemic index (GI) of the banana varieties

The term "glycemic index" measures the glycemic response of carbohydrate foods were compared to a reference carbohydrate (glucose or white bread). The GI is, therefore, an index or ranking of the postprandial glycemic response to different source of carbohydrate in comparison with a reference carbohydrate (Wolever, 1990).

To find out the glycemic index of the banana varieties, ten subjects were selected from the College of Agriculture, Vellayani. The subjects were in the age between 20-25 years and having a weight between 45-60 kg and height between150-165 cm. Their BMI ranged between 17.9-23.5. Out of ten subjects, nine were having normal BMI and the remaining one was under weight. Among the selected subjects, two of them were vegetarians and the remaining were non-vegetarians.

All selected subjects were administered with 50g of glucose and blood sugar levels were monitored at 0, 30, 60, 90,120, 150 min. On the next day the subjects were given banana whose carbohydrate content was equivalent to 50g of glucose. Blood sugar levels were monitored. Area under the curve both test and reference food was calculated.

Table 24. Area under the curve of the test food and reference food

Food		Area under the curve (mm^2) (mean values)
Glucose (Reference food)		221
Test food	Palayankodan (AAB)	155
	Rasakadali (AB)	160
	Robusta (AAA)	174
	Poovan (AAB)	157
	Nendran (AAB)	175
	Kadali (AA)	169
	Red banana (AAA)	159
	Padatti (AAB)	138

Figures indicate mean values of ten subjects

Based on AUC, the glycemic index of the test food (bananas) was computed which is depicted in Table 24.Compared with bananas glucose covered more area under the curve. Among the test foods Nendran (V5) had highest area followed by Robusta when compared to other varieties.

Table 25. Glycemic Index of the test food

Food		GI
Glucose (Reference food)		100
Test food	Palayankodan (AAB)	66.10
	Rasakadali (AB)	65.60
	Robusta (AAA)	61.20
	Poovan (AAB)	66.10
	Nendran (AAB)	68.40
	Kadali (AA)	66.10
	Red banana (AAA)	62.40
	Padatti (AAB)	60.70

The above table revealed that the lowest glycemic index was noticed in variety Padatti (60.70) followed by Poovan (61.00). The highest glycemic index (68.40) was found in variety Nendran. The glycemic index of reference food was higher than the supplemented varieties.

5. DISCUSSION

Results of the present study entitled "Phytochemical analysis and antioxidant potential of banana (*Musa* spp.)" has been discussed under the following headings.

5.1 Chemical and nutrient composition

5.2 Phytochemical analysis

5.3 Antioxidant activity

5.4 Sensory evaluation and

5.5 Therapeutic value

5.1 CHEMICAL / NUTRIENT COMPOSITION OF SELECTED BANANA VARIETIES

Banana, a wonderfully sweet fruit with firm and creamy flesh that enclosed prepackaged in a yellow jacket, available for harvest throughout the year, consists mainly of sugars and fibers which make it a source of immediate and slightly prolonged energy source (Idise *et al.*, 2011).

Banana is a good source of nourishment and a well- balanced diet to people of all ages around the world (Jyothirmayi and Rao, 2015). Aline and Marcelo (2015) reported that banana pulp can be used as natural source of antioxidants and pro- vitamin A due to carotenoids, phenols, amine compounds and bioactive compounds. The chemical and nutrient composition of the selected banana varieties were discussed under the following heads:

5.1.1 Total soluble solids

5.1.2 Acidity

5.1.3 Total carbohydrate

5.1.4 Protein

5.1.5 Total minerals

5.1.5.1 Sodium

5.1.5.2 Potassium

5.1.2.3 Calcium

5.1.1 Total soluble solids

Sweetness can be measured by determining Total Soluble Solids (TSS) in the fruits (Kader, 1992). TSS can serve as a useful index in the determination of fruit maturity and ripeness. According to Lu (2004) total soluble solid (TSS) is an important quality attribute for many fresh fruits during ripening.

In the present study, highest TSS was observed for variety Kadali (23.90^0 Brix) and the lowest for variety Padatti (17.83^0 Brix). The study is in agreement with the findings of Sandipkumar and Shanmugasundaram (2015) who had found that TSS content was increased up to 22.24^0 Brix during the period of storage in Monthan banana, and the magnitude of increase of total soluble solids in banana is dependent on cultivar. Tapre and Jain (2012) also reported an increase in TSS content during ripening of fruits.

In a study conducted by Sreedevi and Suma (2015) found that TSS was higher in organically cultivated Palayankodan (T1-18.73, T2-17) and increases on ripening.

5.1.2 Acidity

According to Sadler and Murphy (2010), titrable acidity is measured for the determination of total acid content present in a food. In fruits, acidity decreases with ripening of fruits. Acids play an important role in the post harvest quality of fruits and vegetables (Bainbridge *et al*., 1996).

In the present study, varietal difference in terms of titrable acidity were observed to be statistically highly significant. The variety Kadali was found to

be less acidic (0.46%) when compared to other varieties. The study is in line with the result of Tapre and Jain (2012) and Khawas *et al*. (2014). Titrable acidity values reported by Ndungo (1998) varied from 4.8 to 6.9 meq/100g. A study conducted by Caulibaly *et al*. (2007) also observed titrable acidity in the range of 1.66 to 3.33 meq/100g in hybrid bananas.

Sakyi *et al*. (2008) found changes in titrable acidity during ripening. Sreedevi and Suma (2015) in their study on "A comparative quality analysis of banana (Var. Palayankodan)" reported that acidity content of inorganically cultivated Palayankodan was higher when compared to organically cultivated Palayankodan.

Khandker *et al*. (2012) also reported that titrable acidity of banana fruit decreased as storage period increased.

5.1.3 Total carbohydrate

The carbohydrates are pivotal nutrients required for a balanced diet. Experts recommend 45 per cent to 65 per cent of total calories from carbohydrates (Riboli and Horel, 2003). Lohi (2010) revealed that the total carbohydrate and soluble sugars occupied the maximum proportion of 240 mg/g and 86 mg/g, respectively in the Nendran fruit.

The present study revealed that highest carbohydrate content was noticed in variety Nendran (41.33 g/100g) and lowest in variety Red banana (21.70g/100g). The study is in accordance with the findings of Tonna *et al*. (2013) who had reported CHO content of 22g/ 100 g in Cavendish banana.

A study conducted by Tamil and Mukunthan (2012) had reported that variety Moris (13.4mg) contained high amount of total carbohydrate followed by variety Rasthali (12.9mg), Hill banana (12.3mg), Nendran (11 mg) and Red banana (9.4mg).

Monroe (1995) conducted a study on carbohydrate content of banana pulp at different stage of ripeness and found that carbohydrate content was high

in the yellow stage (22.12 per cent) and it gradually change to 16 per cent when the banana was over ripe i.e., when the peel change to brown.

A study done by Khawas *et al* (2014) also reported an increase in starch content from 12.36 to 22.66g/100g during the maturity of banana. According to Sakyi *et al*. (2008), total carbohydrate content increased from stage I (21.32g/100g) to stage III (32.15g/100g) and decreased at stage V (27.63g/100g). The changes in carbohydrate contents during growth could be due to degradation of starch.

5.1.4 Protein

Proteins are essential component of diet needed for survival of animals and human beings (Pugalanthal *et al*., 2004). Deficiency of protein causes growth retardation, muscle wasting, oedema and swelling of the belly (Perkins *et al*., 2005). Oguntona (2007) stated that banana is good for malnourished children, because it contains proteins and fibres.

In the present study, highest protein content was observed in variety Poovan (1.37g/100g) and was significantly different from other types. Variety Rasakadali (0.9g/100g) showed lowest protein content. The results are in accordance with the findings of Aurore *et al*. (2009) who had also reported protein content of 1.1 per cent in *Musa* AAA Cavendish. Jyothirmayi and Rao (2015) reported that banana contained 1.09 g of protein/ 100g.

Tamil and Mukunthan (2012) in their study found that total protein content was high in variety Hill banana (malai vazhai) (16mg) followed by Moris (8mg), Rasthali (4.4 mg), Red banana (4.0mg) and Nendran (4.0 mg). Similar findings were also reported by Lohi (2010) who had found protein content of 12.8mg/g in the pulp of the banana cv. Nendran.

5.1.5 Total minerals

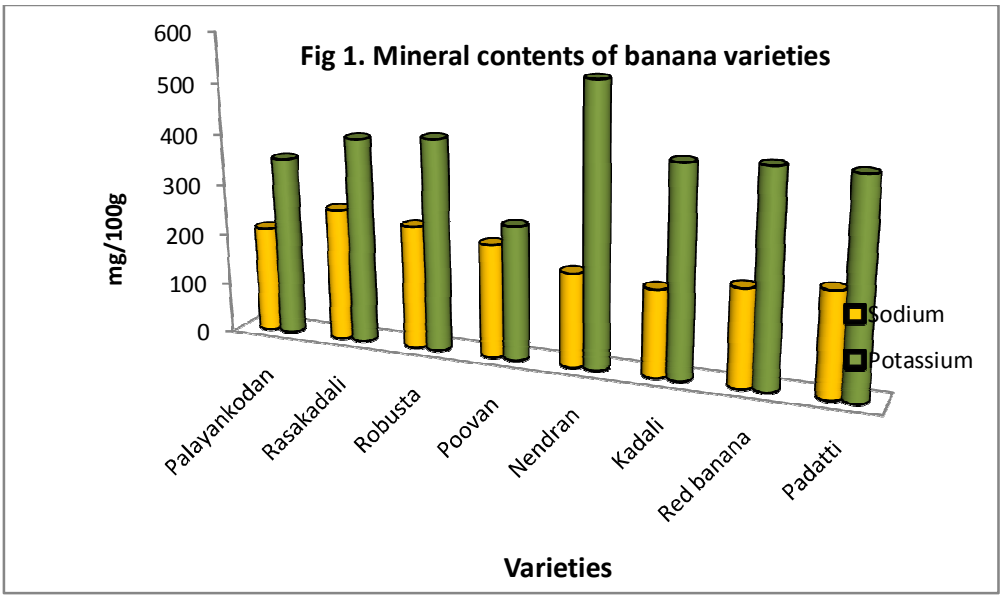
Total minerals or ash content is a measure of the total amount of minerals present within a food, whereas the mineral content is a measure of the amount of specific inorganic components present within a food, such as Ca, Na, K, Cl etc.

Ash is the inorganic residue left after the removal of water and organic matter by heat (Mcclements, 2003).

Ash is a non organic compound containing mineral content of food and nutritionally aids in the metabolism of other organic compounds such as fat and carbohydrate. Ash content is an indication of mineral content; hence samples with higher ash content are expected to have a relatively higher mineral content.

Minerals play an important role in maintaining proper function and good health in the human body. Inadequate intake of minerals in the diet weakens the immune system in human body and hence increases the susceptibility to infectious diseases. The source of essential elements in human body is through diet (Chaturvedi *et al*., 2004). An average adult requires an intake of more than 100 mg per day of macronutrients (calcium, phosphorus, sodium, potassium, magnesium and sulphur) and trace elements (selenium, zinc, copper, cobalt, manganese, molybdenum and iron) for the functioning of the body (Hendricks, 1998).

The highest total mineral content was found in variety Red banana (0.70g/100g). Sreedevi (2013) reported that mineral content was higher in organically cultivated variety Nendran (T1-0.83 and T2-0.59), Palayankodan *(*T1-0.72, and T2 0.51) and Rasakadali (T1 - 0.74 and T2 - 0.59) samples.



5.1.5.1 *Sodium*

Sodium is seen mostly as an extracellular constituent and maintains the osmotic pressure of the body.

Fruits and vegetables are low in sodium generally valued from the health point of view. An assessment of sodium profile would thus be helpful. The excessive intake of sodium can lead to hypertension (Belitz *et al*., 2009).

The study revealed a significant difference among the varieties with respect to sodium content. Variety Rasakadali (260mg/100g) exhibited highest sodium content followed by variety Robusta (241.66mg/100g). Sodium content was found to be minimum for variety Kadali (170.00 mg/100g) (Fig 1).

Sodium being the most abundant mineral found in the fruits. Low sodium diet has been reported to be beneficial in the prevention of high blood pressure.

Sreedevi (2013) conducted a study on organically and conventially cultivated banana varieties and found that organic variety Nendran showed

higher amount of sodium (32.46mg/100g) followed by Palayankodan (28.68mg/100g) and Rasakadali (27.91mg/100g).

In a study by Smitha *et al*. (2015) using nine varieties of banana showed sodium content of 4.73 to 6.02 mg 100g fresh weight. Highest sodium content was found in Galhi variety and lowest in Kadali variety.

5.1.5.2 *Potassium*

Among fruits, banana is valued for potassium content, because of its role in maintaining the body's blood pressure. A single banana provides 23 per cent of the potassium needed on a daily basis. It also reduces the risk of stroke (Sampath, 2012).

The present study revealed that potassium content was found to be highest in variety Nendran (546.66 mg/100g) and lowest in variety Poovan (261.66 mg/100g). The results are in close agreement with the findings of Jyothirmayi and Rao (2015) and Sampath (2012) who had also reported potassium content of 358mg and 467 mg respectively /100g of banana studied. Hang *et al.* (2008) found that organic fertilizer application had increased potassium and phosphorus in soil and makes it more available (Fig 1).

Contrary to the present findings, Sreedevi (2013) found that the potassium content of organically cultivated samples of Nendran, Palayankodan and Rasakadali was 86.5 mg, 80.76mg and 79.4mg respectively. Average potassium content of Hawaii's banana (Dwarf Brazilian and Williams) was 330.6 mg/ 100g. (Marisa, 2006). Similar results were also reported by Leterme *et al*. (2006). Bernstein *et al*. (2011) found that potassium increases protein, starch and soluble solid content in plants and improves colour and taste.

Smitha *et al.* (2015) conducted a study on "A comparative study of mineral contents in variety of bananas grown in coastal belt of Karnataka" using nine varieties, showed potassium content in the range of 285.34 to 397.01 mg

per 100g of fresh sample. Among the varieties high content of potassium was found in variety Cavendish (397.01 mg/100g).

5.1.5.3 *Calcium*

Calcium is an essential macronutrient for humans, which represents approximately 2% of body weight in an adult person (Petrovich *et al*., 2007). It is necessary for building strong bones, cell adhesiveness, mitosis, blood coagulation, muscle contraction and glandular secretion. Bone stores of calcium can be used to maintain adequate blood calcium levels for short term.

It is undisputable that, natural food sources of calcium are anytime healthier than synthetic supplements. With the increasing number of population suffering from bone defects, the awareness of calcium levels is felt needed.

The findings of present study revealed that calcium content of variety Palayankodan was found to be highest (1.35mg/100g). The lowest calcium content was observed in variety Red banana (0.35mg/100g). The results are in tune with the findings of Lohi (2010) who had reported calcium content of 0.118mg/100g in the fruit pulp of variety the Nendran. Similar results were also observed by Jyothirmayi and Rao (2015). The results of the study conducted by Marisa (2006) on banana fruits grown in different locations in Hawaii ranged between 3.8-9.7 mg/100g.

Smitha *et al*. (2015) opined that calcium content of banana varieties in Karnataka, ranged from 17.15 to 47.19 mg per 100 g fresh weight. The banana having local name Galhi balhe showed higher calcium content (47.19 mg/100g), where as Kadalhi and Boodi balhe showed calcium content of 37.44mg and 35.77mg respectively. Composition of fruits and vegetables vary according to variety, cultivation practices, weather, type of soil, degree of maturity and the condition of ripeness (Smitha *et al*., 2015).

5.2 PHYTOCHEMICAL ANALYSIS

Phytochemicals may help to prevent the formation of potential carcinogens or block the action of carcinogens on their target organs or tissue, or act on cells that suppress cancer development (Premier, 2010).

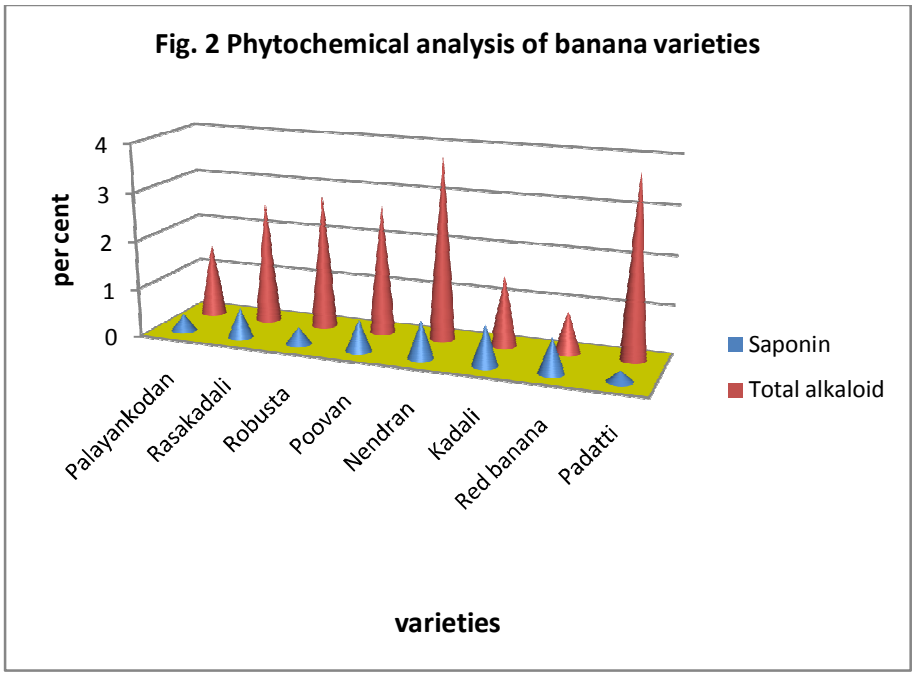
Duijinhoven *et al*. (2009) reported that increased intake of fruits and vegetables can decrease the risk of colon cancer and pancreatic cancer (Chan *et al*., 2005)

5.2.1 Total alkaloids

Alkaloids are toxic due to their stimulatory effects, leading to excitation of cells and neurological dysfunction (Ekam and Ebong, 2007). From the beginning of civilization, alkaloids have been of great interest to human because of their pronounced physiological and medicinal properties.

Alkaloids have many pharmacological activities including antihypertensive effects, antiarrhythmic effect, antimalarial activity and anti cancer actions (Wink *et al*., 1998). Some alkaloids have stimulant property (Dubois and Wagner, 2000).

In the present study, significant differences were found to exist between the varieties with respect to alkaloid content and the highest alkaloid content was observed for the variety Nendran (3.76 per cent) and lowest for Red banana (0.84 per cent) (Fig 2).



5.2.2 Flavonoids

Fruits and vegetables are rich source of flavonoids, which reduces the risk of diseases, such as cancer, stroke and diabetes (Liu, 2004). More than 5000 individual flavonoids have been isolated and identified.

Flavonoids have antioxidant, anti-allergic, anti- inflammatory, antimicrobial and anticancer activity (Blach and Balch., 2000; Jisika *et al*., 2000). Flavonoids posess wide range of substances which protects the body against oxidative damage (Atmani *et al*., 2009; Cao *et al*., 1997).

Significant difference was observed in the total flavonoid content of banana varieties studied. The variety Rasakadali (9.49mg/100g) was found to be having maximum flavonoid content and variety Red banana (3.58mg/100g) showed less amount of flavonoid. (Fig 3). The study is in close agreement with the findings of Merlene *et al*. (2012).

A study conducted by Fatemeh *et al*. (2012) also reported significant differences among samples with respect to flavonoid content. The total flavonoid

content was found highest in Cavendish banana samples when compared to Dream banana samples. The variation in total flavonoid content among banana varieties might be due to factors such as natural and chemical composition, maturity and type of soil (Huang *et al*., 2005).

5.2.3 Saponin

Saponins are natural detergents found in plants which can also act as dietary supplements and neutraceuticals in traditional medicinal preparations (Elekofehinti *et al*., 2012).

Saponins are considered as part of plant's defense systems and known as phyto anticipins or phyto protectants (Dubois and Wagner, 2000).

Topping *et al*. (1995) reported that saponins can lower plasma cholesterol concentrations.

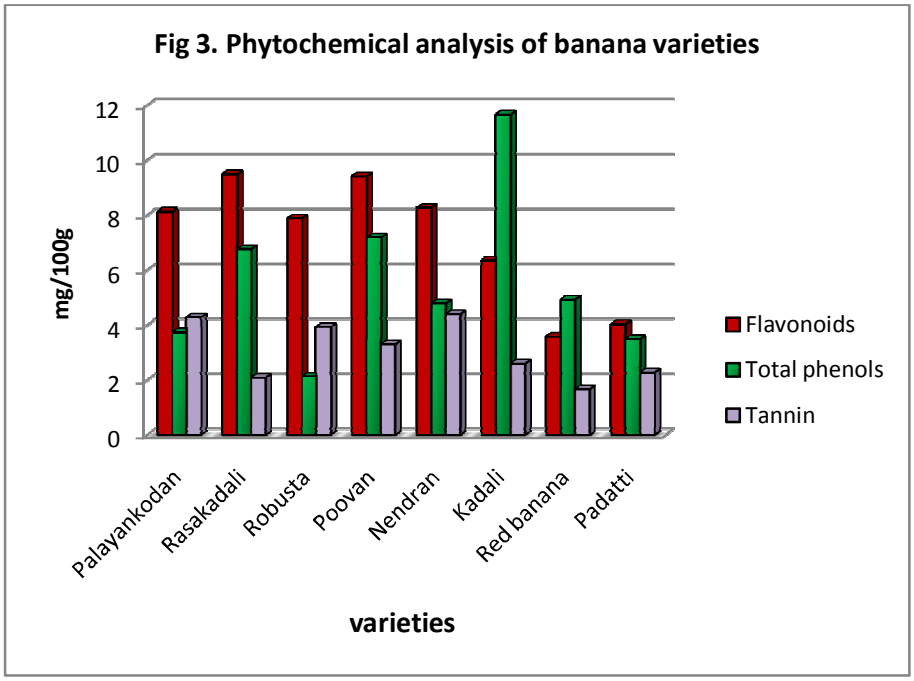
Findings of the present study revealed that highest saponin content was observed in variety Kadali (0.82 per cent) and lowest in variety Padatti (0.22 per cent) (Fig 2). Adeniji *et al*. (2007) conducted a study on anti- nutrients in banana flour and found that PITA 17 lowest (1.66%) in saponin, while PITA 24 (4.97%) is highest in saponin content.

5.2.4 Total phenols

Phenols, the secondary metabolites of plants play a vital role in the reproduction, growth and defense mechanisms (Rui, 2013). The plant phenolics comprise simple phenols, coumarins, lignans, condensed and hydrolysable tannins, phenolic acids and flavonoids (Slivova *et al*., 2005).

In the present study, highest phenol content was observed for the variety Kadali (11.6mg/100g) and the lowest for Palayankodan (Fig 3).

Total phenol content of variety Pinang Awak was found to be 5.9mg/GAE and also the content of phenolics in Pisang Awak was higher than that of *Musa sapient* (Darsini *et al*., 2012).



Variations in total phenolic content have been observed in several studies (Kondo *et al*., 2005). Total polyphenol was found higher at stage I compared to other stages (Khawas *et al*., 2014). A decrease in phenolic content with ripening was noted in *Hon Thong* banana where as in *Khai* banana, phenol content was decreased with increase in ripening (Fernando *et al*., 2014). Similar observations were also reported by Newilah *et al*. (2010) Sulaiman *et al*. (2011) in hybrid and Malaysian banana respectively.

A study conducted by Merlene *et al*. (2012) using 4 varieties of locally available bananas such as Rasthaly, Karpooravalli, Manjal vazhapazham and Pachai vazhapazham in Tamil Nadu revealed that Green banana contained total phenolic content of around 180µm GAE/mg followed by Yellow variety (154µg GAE/mg).

The variation of phenol content in different plant materials might be attributed to factors such as natural, chemical composition, harvest maturity and type of soil state and conditions of post harvest storage (Huang *et al*., 2015)

5.2.5 Tannins

Tannins are polymeric phenol substances having antimicrobial and anti oxidant activities (Sumathy *et al*., 2011). Agnieszha and Borowska (2008) revealed that tannins play an essential role in shaping the sensory properties of fruits and fruit products. They are responsible for the tart taste and changes in the colour of fruit and fruit juices.

The results of present study revealed that variety Nendran (4.40 mg/100g) showed highest tannin content and were significantly different from the other varieties. The lowest tannin content was noticed in variety Red banana (1.66mg/100g). (Fig 3). Similar results were also observed by Mendoza *et al* (1992). The variation in tannin could be due to difference in cultivar, condition of growth and environmental factors.

A study conducted by Khawas *et al*. (2014) reported that tannin content of banana samples differed significantly with stages of development.

The present study indicated banana is the potent source of noval bioactive compounds like total alkaloids, flavonoids, total phenol and tannis with wide range of medicinal properties. Other phytochemicals such as anthocyanins, delphinidil, cyaniding have been also identified in ripe banana pulp (Kanazawa and Sakakibara, 2000).

5.3. Antioxidant activity

Frequent consumption of fruits and vegetables are associated with low risk of chronic diseases such as diabetes, cardiovascular disease and cancers (Safaa *et al*, 2010). Banana is a tropical fruit has a strong ability to protect itself from the oxidative stress caused by intense sunshine and high temperature by increasing its antioxidant levels (Kanazawa and Sakakibara, 2000; Mokbel and

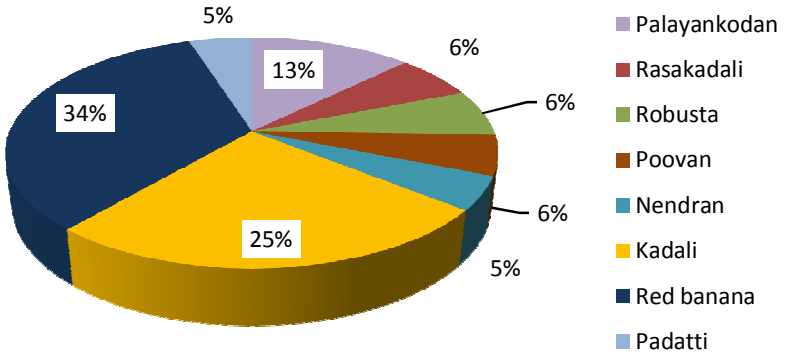
Hashinaga, 2005). Studies revealed that banana pulp contain antioxidants like vitamins (A, C and E), beta carotene and phenolic compounds such as catechin, epicatechin, lignin, tannins and anthocyanins (Someya *et al*., 2002).

5.3.1 Beta carotene

Among the various plant pigments, carotenoids comprise a large family of more than 700 structures (Britton *et al*., 2004). β carotene is a natural antioxidant present in plants protect against many diseases (Muzandu *et al*., 2005; Olson, 1999).

In the present study, highest beta carotene was found in variety Red banana (21.19 µg/100g) and was significantly different from other varieties. The lowest beta carotene content was noticed in variety Nendran (2.19 µg/100g) (Fig 4). The results of the present study showed a wide variation in β carotene levels among the bananas studied. The findings are in close agreement with other studies (Arora *et al*., 2008; Amorim *et al*., 2009) who had reported wide variability in β carotene content in bananas.

Fig. 4 Beta carotene of banana varieties



A study conducted by Fungo and Pillay (2011) found that β carotene levels in sweet bananas ranged from 50.6µg/100g in Sukali Ndizi (AAB) to 1138.7µg/100g

in Pisang mas (AA). Pisang mas had almost twice the β carotene content of the Cavendish varieties.

Report for other AAB cultivars that are used as dessert bananas showed that Poovan(AAB) and Rasthali (AAB) had 300 and 29.61 µg/100g respectively (Arora et al.,2008) while the dwarf Brazilian banana had 96.9 µg/100g β carotene (Wall,2006). Previous studies have reported different values for β carotene levels in dessert bananas. This ranges from 21 µg/100g to 55.7 µg/100g (Wall, 2006). The present study also showed a higher value for β carotene. This may be due to a number of factors like differences in methodology and separation of beta carotene (Wall (2006).

5.3.2 Ascorbic acid

Ascorbic acid, a water soluble vitamin protects the body from ill effects of free radicals (Elekofehinti and Kade, 2012). Fresh fruits, vegetables and synthetic tablets supplement the ascorbic acid requirement of the body (Frei and Traber, 2004). However, stress, smoking, infections and burns deplete the ascorbic acid reserves in the body

The ascorbic acid content of the banana varieties was observed to range between 1.52 - 5.35 mg/100g. The highest ascorbic acid was observed in variety Red banana (5.35 mg) and the lowest for variety Robusta (1.52 mg).

A study conducted by Poongodi (2012) on locally available banana in Tamil Nadu revealed that vitamin C content varied from 0.71-4.69 mg g^{-1} fresh tissues. The highest vitamin C content was present in Poovan and on the other hand, least content was found in Robusta.

Sreedevi (2013) conducted a study on organically cultivated banana varieties like Nendran, Palayankodan and Rasakadali and found that vitamin C level was high in Rasakadali (6.46mg) followed by Nendran (6.4mg) and Palayankodan (3.33 mg).

Study by Oyeleke and Odedeji (2011) using three waxing materials in banana such as PKB (Banana treated with palm kernel wax), HWB (Banana treated with honey wax), CWB (Banana treated with chemical) and CB (Untreated banana sample). Vitamin C contents in PKB, HWB and CWB are respectively 20.70±0.05, 18.40±0.04 and 16.70±0.04 mg/100g while that of CB was 21.40±0.05 mg/100g.

Fernando *et al*. (2014) reported that ascorbic acid content of 'Khai' bananas was higher than that of 'Hon Thong' banana. Sies and Stahl (1995) opined that ascorbic acid is one of the most important vitamins that are supplied by fruits and vegetables.

The content of vitamin C in fruits and vegetables is affected by various factors such as genotype difference, pre harvest climatic condition and cultural practices, maturity level, harvesting methods and post harvest processing (Lee and Kader, 2000).

5.4.3 Total antioxidant activity

The antioxidant property of banana can be determined based on its capacity to inhibit lipids, peroxides, to scavenge free radicals, to reduce a transition metal or to chelate a ferrous iron.

A study conducted by Shian *et al*. (2012) on "Antioxidant properties of three banana cultivars" (*Musa accuminata* 'Berangan', 'Mas' and ' Raja') revealed that the type of solvent used for extraction had a significant effect on the antioxidant compounds in banana.

A study conducted by Fatemeh *et al*. (2012) reported that Cavendish variety had higher antioxidative compounds.

The antioxidant activity of eight varieties of banana in Malaysia was studied by Shaida *et al*. (2011) and reported significant differences among cultivars of banana.

A study by Shian *et al.* (2012) reported that acetone (70 per cent) had the strongest antioxidant extraction power when compared to other solvents.

Poongodi *et al.* (2012) conducted a study on the antioxidant activity of the pulp extracts of nine varieties of banana. According to the results, the ethanol extracts of variety Rasathali banana showed highest antioxidant activity in the range of 6.60 µmol g^{-1}, whereas poovan banana showed minimum activity in the range of 3.80 µmol g^{-1} in ethanolic extract. Antioxidant activity differed with ripening stage due to differences in concentrations of antioxidant compounds (Raffo *et al.*, 2002). The variations in the antioxidant potential might be due to differences in cultivars, extraction procedures, soil, temperature, sunlight, horticulture practices and so on (Kim *et al.*, 2001).

Pinelo *et al.* (2004) opined that carotenoids, vitamin C, phenolic compounds and their interactions contribute to the overall antioxidant activity.

5.4.4 DPPH radical scavenging activity

DPPH radicals react with suitable reducing agents and the electrons become paired off (Subhasree *et al.*, 2009).

The DPPH radical scavenging activity expressed as IC_{50} value which is inversely proportional to the antioxidant activity (Onder *et al.*, 2009).

Fruits having an IC_{50} value less than 1 mg/ ml is categorized as fruits with high antioxidant potential (Safaa *et al.*, 2010).

The results of present study revealed that antioxidant activity ranged from IC_{50} values of 41.2 µg/ml to 54.8 µg/ml in the banana varieties studied. Maximum antioxidant capacity was observed in variety Padatti (41.2 µg/ml) and minimum antioxidant capacity observed in variety Kadali (54.8 µg/ml).

A study conducted by Pongoodi *et al.* (2012) reported that Karpooravalli banana showed least DPPH radical scavenging activity. Similar findings were also reported by Rungnapa *et al.* (2007) on Thai bananas.

A study conducted by Rungnapa *et al*. (2007) on three Thai banana showed antioxidant activity and the IC_{50} value was found to be 90, 73 and 81µg/ml respectively.

Fidrianny *et al*. (2015) reported IC_{50} values of 0.39 to 121.67 µg/ml of banana varieties studied.

According to Khawas *et al*. (2014) highest DPPH activity was seen in stage 1 and lowest in stage V. A decrease in scavenging activity was also reported by Zubair *et al*. (2013) during ripening in papaya fruit.

Darsini *et al*. (2012) found that methanolic fruit extract of Awak banana had an IC_{50} value of 65µg/ml.

Qusti *et al*. (2010_a) and Miller *et al*. (2000) conducted a study on antioxidant activity of fresh fruits using DPPH assay and found that plant variety, growing condition, maturity, season, geographic location, fertilizer application, soil type, storage conditions and amount of sunlight received are some of the factors which affect the DPPH assay.

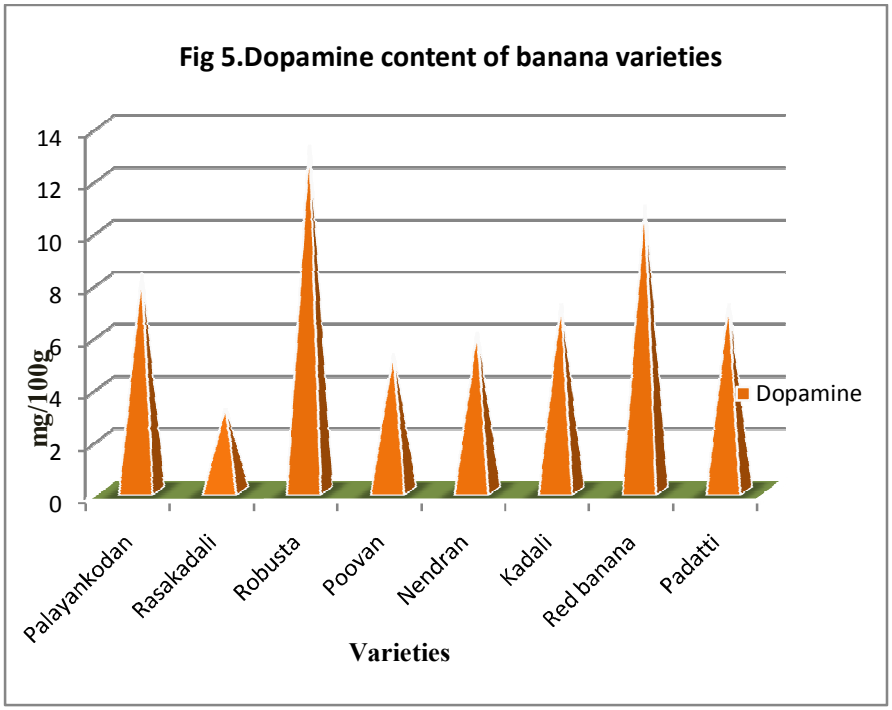
Qusti *et al*. (2010_b) categorized banana has moderate antioxidant activity with an IC_{50} value of 10.93 ± 0.77 on wet extracts where as in the case of dry extracts it categorized as high antioxidant activity with a value of 0.54 ± 0.17.

5.4.5 Dopamine

Dopamine, 4-(2-aminoethyl) - benzene-1, 2-diol control movement, emotional response, and ability to experience pleasure and pain (Liu *et al*, 2004) and also important for cardiovascular, hormonal, renal and central nervous system functions in the body (Hussain and Lokhandwala, 2003; Zare *et al*., 2006).

Variations in the yield of extracts, extracting compounds, type of soil and agro- climatic condition also affect dopamine content of banana (Hsu *et al*., 2006).

The dopamine content of the different banana varieties was observed to range between 3.2- 13.3 mg/100g. The highest dopamine content was observed in variety Robusta (13.3 mg) and the lowest for variety the Rasakadali (3.2g) (Fig 5).



According to Pereira and Marcelo (2015), the dopamine content in the banana pulp at 4-6 stages is 9.1±3.1 mg/100g.

5.4 Sensory evaluation

Sensory quality is a composite of products characteristics that impart value to the buyer and consumer. Consumers prefer fruits that look good, firm and offer good flavour and nutritive value. Producers and handlers are first concerned with appearance and textural quality along with long post harvest life (Kader, 2012).

5.4.1 Appearance

Glaring colours formed in artificially ripened fruits, is a cause of concern among consumers in the recent years. Hence, appearance of the fruit was evaluated by a sensory panel.

It was evident from the results that highest rank score for appearance was achieved for Rasakadali (58.7) followed by Nendran (51.6) and Red banana (49.3). Various studies have revealed the influence of fertilizers on the colour of fruits. Increased use of nitrogen fertilizers led to quality of fruits in terms of colour and keeping quality (Murthy *et al*., 2011).

5.4.2 Flavour

During ripening, components that cause flavour development are accumulated in fruits. Early harvesting leads to loss of flavour. Kader (2008) has observed that the influence of cultural practice on precursors of esters that determine the ultimate level of volatile esters in fresh fruits which in turn affect flavour.

The judges preferred variety Rasakadali (54.3) followed by Red banana (46.9) and Nendran (41.3).

Flavour is the combined impression perceived via the chemical stimuli from a product in to the mouth. The consumer acceptance of fruits most often relies up on the inherent flavour and textural quality of the product.

The flavour of fruits improves during ripening and the different volatile compounds which contributes flavour in banana are Isomyl acetate, 2-pentanol acetate, 2-methyl-1-propanol, 3- methyl-1-butanol banana (Jordan *et al*., 2001).

5.4.3 Texture

Texture means the sensory manifestation of the structure or inner make up of a food product. Fruit texture is influenced by environmental, cultural, physiological and genetic factors (Sams, 1999). In the present study, high score

of textural quality was obtained for variety Rasakadali (60.9) followed by variety Red banana (47.5) and Padatti (47.4).

Decrease in flesh texture has been reported due to excessive fertilization in many fruit crops (Blampied *et al.*, 1998). High fertilization levels impaired the early solubilization of polyuronides resulting in the accumulation of low molecular weight water soluble polyuronides, which ultimately causes inferior texture of fruits (Jia *et al.*, 2006).

5.4.4 Taste

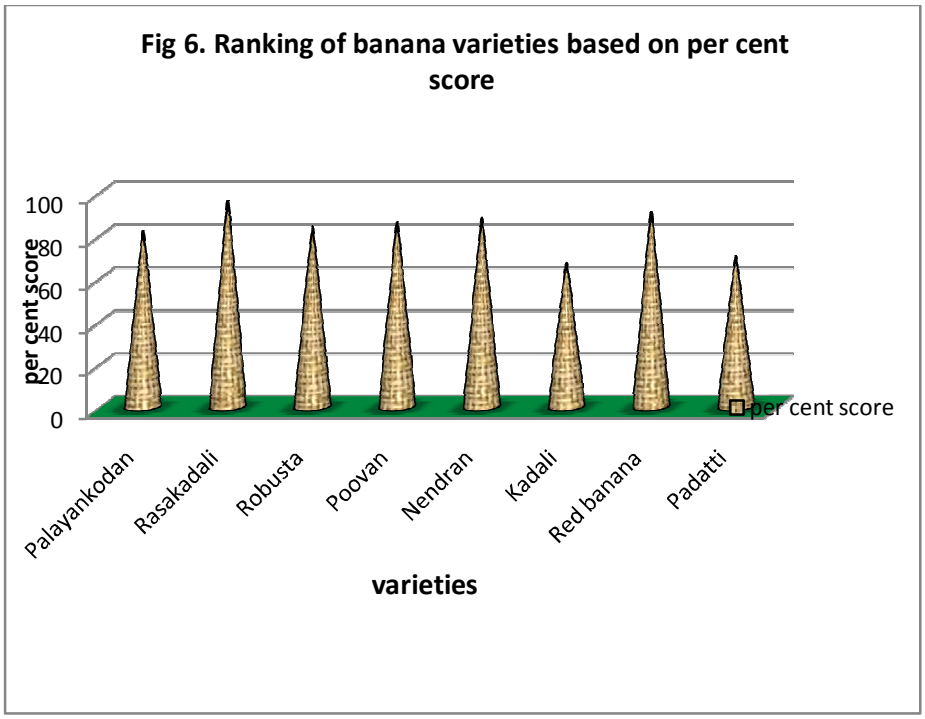
Taste is a balance between sugar and acid contents in banana (Dadzie and Orchard, 1996). Malic, citric, tartaric and citric acids are the major acids in banana. The decrease in acidity reduction improves taste. Bananas having multifarious varieties in different regions of the world are also identified with characteristic tastes.

Taste of banana varieties revealed that variety Rasakadali (63.4) showed high score for taste followed by variety Red banana (46.9).

Sreedevi (2013) reported that organically cultivated banana varieties had significantly higher value for taste as compared to conventionally cultivated banana varieties.

5.4.5 Overall acceptability

Overall acceptability can be considered as a summary of sensory evaluation. The analyzed results for all the attributes were in higher preference level for variety Rasakadali (Fig 6).



It can be concluded that the panelists preferred the external appearance rather than internal quality of the banana varieties. This effect has previously been found by Karamura and Karamura (1995).

The increase in moisture content during ripening will improve the taste and aroma of the fruits (Appiah, *et al*., 2011). During ripening, carbohydrates are hydrolyzed into sugars (Kays, 1991).

A study on "A comparative quality analysis of banana (var. Palayankodan) "by Sreedevi and Suma (2015) found that, sensory parameters were found to be better in organically cultivated varieties.

5.5 Therapeutic value

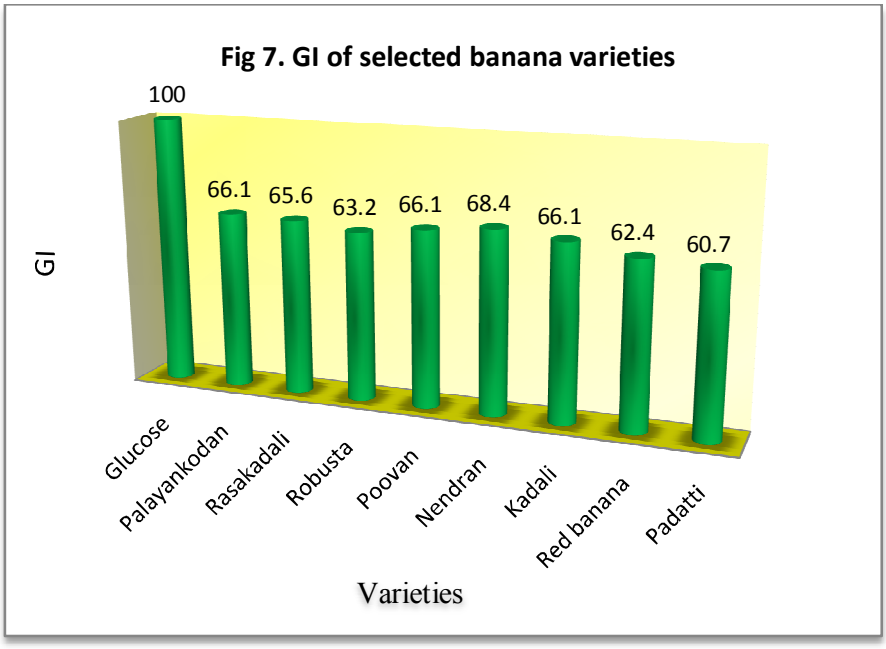
Glycemic index (GI) of a food is defined as the incremental area under the two hour blood glucose response curve (AUC) following a 12hr fasting and ingestion of a food with a certain quantity of available carbohydrate (usually

50g) (Jenkins, 2004). Glucose has a glycemic index of 100 and other foods have a lower glycemic index.

Glycemic index is a ranking of food based on their potential to raise blood glucose.

According to Wolever *et al*. (1990), the area under the glycemic index curve for each food taken by the same subjects and the resulting values were arranged to obtain the glycemic index value of the food.

In the present study, the glycemic index of the banana varieties were determined and compared with reference food (glucose). The lowest glycemic index was observed in the variety Padatti (60.70) followed by variety Poovan (61.00) (Fig 7).



The blood glucose levels depend on many other factors such as ripeness, the total amount of carbohydrate. fibre content, time of day, blood insulin levels and activity (Alison *et al*., 2014). Thus glycemic index is a useful tool to measure the blood glucose level (Brandmiller, 1995).

Summary

6. SUMMARY

The present study entitled "Phytochemical analysis and antioxidant potential of banana (*Musa* spp.)" was under taken with the objective to study the phytochemical, nutrient, chemical composition and antioxidant potential of the selected banana varieties and to assess its therapeutic value.

Eight varieties of banana viz., Palayankodan, Rasakadali, Poovan, Robusta, Red banana, Nendran, Kadali and Padatti were selected for the study. The banana varieties were procured (when the characteristic fruit colour develops) from Instructional Farm, Vellayani or from local markets of Trivandrum. The chemical and nutrient composition, phytochemical and antioxidant activity, sensory evaluation and therapeutic value of selected banana varieties were determined.

The chemical and nutrient composition of the banana varieties were ascertained with respect to TSS, acidity, total carbohydrate, protein, total minerals and minerals such as sodium, potassium and calcium. Results of the chemical and nutrient analysis revealed that the TSS content of banana varieties was ranged between 17.83^0 Brix to 23.90^0 Brix. The highest TSS content was observed for variety Kadali (23.90^0 Brix) and the lowest for variety Padatti (17.83^0 Brix). It was found that significant difference was found to exist between the varieties. Significant differences were also observed in the acidity of banana varieties studied. The varieties Kadali (0.46%) and Robusta (0.47%) were found to be less acidic.

The carbohydrate content of banana varieties studied ranged between 21.70- 41.33g/100g. Highest carbohydrate content was observed in variety Nendran (41.33g/100g). The protein content of banana varieties ranged between 0.91- 1.37g/ 100g and was found to be higher in variety Poovan (1.37g/100g) and Kadali (1.37g/100g) followed by variety Red banana (1.34g/100g. The total mineral contents of banana varieties ranged between 0.17g- 0.70g/100g. Highest

mineral contents were noticed in varieties Red banana (0.70g/100g) followed by Nendran (0.68 g/100g) and Rasakadali (0.58 g/100g) whereas, it was found to be less in varieties Robusta (0.17g/100g) and Palayankodan (0.18 g/100g). Varieties such as Rasakadali (260 mg/100g) and Nendran (546.66 mg/100g) exhibited highest content of sodium and potassium respectively. The calcium content of banana ranged from 0.35-1.35 mg/100g. The Ca content of Palayankodan was found to be highest (1.35 mg/100g) and lowest Ca content was observed in variety Red banana (0.35mg/100g).

Estimation of phytochemicals revealed that the total alkaloid content of the banana varieties was ranged between 0.84 – 3.76 per cent. Varieties Nendran (3.76%) and Padatti (3.72 %) were found to be having maximum alkaloid content and variety Rasakadali (9.49mg/100g) and Poovan (9.41mg/100g) were having maximum flavonoid content. The saponin content of banana varieties was ranged between 0.22 -0.82 per cent and significant differences were noticed with respect to saponin content. The saponin content of varieties Kadali, Nendran, Red banana and Poovan was found to be 0.82%, 0.77%, 0.73% and 0.65% respectively. The highest saponin content was observed in the variety Kadali (0.82 per cent) and lowest in variety Padatti (0.22 per cent).

The phenol content was found to be highest for variety Kadali (11.6mg/100g) and lowest for variety Palayankodan (3.73 mg/ 100g). The total phenol content of the banana varieties ranged between 3.73 – 11.66 mg/100g.The results of tannin content revealed that variety Nendran (4.40 mg/100g) and variety Palayankodan (4.28mg/100g) showed highest tannin content and was significantly different from the other varieties.

The results of antioxidant study revealed that highest beta carotene content was found in variety Red banana (8.53 mg/100g) and was significantly different from all the other varieties. The lowest beta carotene content was

found in variety Nendran (1.19 mg/100g).The ascorbic acid content of the banana varieties was observed to be ranged between 1.52 - 5.35 mg/100g. The highest ascorbic acid content was observed in the variety Red banana (5.35 mg) and the lowest in variety Robusta (1.52 mg). Free radical scavenging activity of the banana varieties were studied using DPPH assay and total antioxidant activity using different solvents such as petroleum ether, methanol and water. The results revealed that the variety Robusta had the highest DPPH activity with an IC_{50} value of 43.6 µg/ ml in petroleum ether solvent.

With regard to total antioxidant activity, variety Padatti exhibited highest activity with an IC_{50} value of 41.2 µg/ ml in petroleum ether. The dopamine content of the different banana varieties was observed to be ranged between 3.2- 13.3 mg/100g. The highest dopamine content was noticed in the variety Robusta (13.3 mg/ 100g) and the lowest for the variety Rasakadali (3.2mg/ 100 g).

The organoleptic evaluation of banana varieties showed that mean ranks for appearance pertaining to the eight banana varieties ranged from 23.5 – 58.7. The highest mean rank (58.7) was obtained for the variety *Rasakadali* and lowest mean rank for the variety *Kadali* (23.5). In the case of flavour evaluation, the flavour of the banana varieties differ in mean ranks, which ranged from 33.2- 54.3. The highest mean rank was recorded for the variety Rasakadali (54.3) followed by the variety Red banana (46.9) and lowest for the variety Robusta (33.2). The mean ranks for texture of the banana varieties ranged between 24.4- 60.9. The highest mean rank (60.9) for texture was obtained for the variety Rasakadali and the lowest mean rank for the variety Kadali (24.4).The mean ranks for taste parameter in the eight banana varieties ranged between 21.3- 63.4. Maximum mean rank for taste was obtained for the variety Rasakadali (63.4) followed by the variety Red banana (46.9) and least mean score was secured by the variety Kadali (21.3). In the case of overall

acceptability, variety Rasakadali and Red banana were relished by the panel members.

The therapeutic value of selected banana varieties was assessed by determining glycemic index. The glycemic index of the banana varieties revealed that the variety Padatti (60.70) was found to be having lesser glycemic index when compared to other bananas. The highest glycemic index was noticed in variety Nendran(68.40).

From the present research work, it can be concluded that banana, “Poor man’s Apple” serves as a natural store of various health beneficial phytochemicals and antioxidants which possesses therapeutic properties.

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Appendices

APPENDIX-I

Score card for Bananas

(Kindly indicate a tick mark in the appropriate columns)

Sl .no	particulars	scores	T1	T2	T3	T4
1)	**Colour/ Apperance**					
	Excellent	5				
	Very good	4				
	Good	3				
	Satisfactory	2				
	Fair	1				
2)	**Aroma**					
	Highly aromatic	5				
	Aromatic	4				
	Moderately aromatic	3				
	Bland	2				
	Off odour	1				
3)	**Texture**					
	Very soft	5				
	Soft	4				
	Moderately soft	3				
	Less soft	2				
	Firm	1				
4)	**Taste**					
	Excellent	5				
	Very good	4				
	Good	3				
	Fair	2				
	Poor	1				
5)	**Overall acceptability**					
	Like Extremely	5				
	Like Very Much	4				
	Like Moderately	3				
	Like Slightly	2				
	Dislike	1				

Date: Name:

APPENDIX-II

Sensory Evaluation

Particulars	Scores	Appearance				Colour				Flavour				Taste				Texture				Overall Acceptability			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Like Extremely	9																								
Like Very Much	8																								
Like Moderately	7																								
Like Slightly	6																								
Neither Like nor Dislike	5																								
Dislike Slightly	4																								
Dislike moderately	3																								
Dislike Very Much	2																								
Dislike Extremely	1																								

Date:

Name :

Signature:

Abstract

PHYTOCHEMICAL ANALYSIS AND ANTIOXIDANT POTENTIAL OF BANANA (*Musa* spp)

SIJI .S

(2014-16-103)

Abstract of the

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COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2016

ABSTRACT

The research project entitled "Phytochemical analysis and antioxidant potential of banana (*Musa* spp.)" was conducted at College of Agriculture, Vellayani, Trivandrum during 2014-2016 with objectives to study the phytochemical, nutrient, chemical composition and antioxidant potential of the selected banana varieties and to assess its therapeutic value.

Eight varieties of banana viz., Palayankodan, Rasakadali, Poovan, Robusta, Red banana, Nendran, Kadali and Padatti were selected for the study. The banana varieties were procured (when the characteristic fruit colour develops) from Instructional Farm, Vellayani or from local markets of Trivandrum. The chemical and nutrient composition, phytochemical and antioxidant activity, sensory evaluation and therapeutic value of the selected banana varieties were ascertained.

Results of chemical and nutrient composition revealed that TSS of banana varieties was ranged between 17.83^0 Brix to 23.90^0 Brix. TSS was found to be more in Kadali (23.90^0 Brix) followed by Rasakadali (23.83^0 Brix) and Nendran (22^0 Brix). Significant differences were noticed in the acidity of banana varieties studied. The varieties Kadali (0.46%) and Robusta (0.47%) were found to be less acidic. Maximum Acidity was noticed in Poovan (1.28%). The varieties Kadali (0.46%) and Robusta (0.47%) were found to be less acidic. The variety Nendran exhibited highest carbohydrate content (41.33g/100g) where as protein content was found to be higher in variety Poovan (1.37g/100g). Total mineral content of banana varieties ranged between 0.17g- 0.70g/100g and varieties such as Rasakadali (260 mg/100g) and Nendran (546.66 mg/100g) exhibited highest content of Na and K respectively. The calcium content of the selected banana varieties ranged between 0.35-1.35 mg/ 100g.

Quantitative estimation of phytochemicals revealed that total alkaloid content of the banana varieties was observed to range between 0.84 – 3.76 per cent. The varieties Nendran (3.76%) and Padatti (3.72 %) were found to be having maximum alkaloid content. Whereas variety Rasakadali exhibited highest flavonoid content (9.49 mg/100). Saponin content of banana varieties was found to be ranged between 0.22 -0.82 per cent. The saponin content was found to be maximum in variety Kadali (0.82 per cent) and minimum in variety Padatti (0.22 per cent). Total phenol content was found to be more in varieties Kadali (11.6 mg/ 100g), Poovan (7.19 mg /100g), and Rasakadali (6.76 mg/100 g). The variety Palayankodan (4.28mg/100g) showed maximum tannin content and was significantly different from the other varieties.

Antioxidant activity in the present study revealed that variety Red banana showed highest β carotene and (8.53 µg/100g). Ascorbic acid content of banana varieties ranged between 1.52 - 5.35 mg/100g. Highest ascorbic acid content was noticed in Red banana (5.35 mg). Highest dopamine content was exhibited in variety Robusta (13.3 mg/100g) and lowest was found in variety Rasakadali (3.2mg/100g).

Free radical scavenging activity of banana varieties were studied by DPPH radical assay and total antioxidant activity using different solvents such as petroleum ether, methanol and water. The results revealed that variety Robusta had the highest DPPH activity with an IC_{50} value of 43.6 µg/ ml in petroleum ether solvent. With regard to total antioxidant activity, variety Padatti exhibited highest activity with an IC_{50} value of 41.2 µg/ ml in petroleum ether while variety Rasakadali (48.4) and Poovan (48.4) showed maximum activity in methanol followed by variety Red banana with an IC_{50} value of 44.4 µg/ ml in methanol.

Sensory evaluation of eight banana varieties was done using a 5 point score card and 9 point hedonic rating scale. The results revealed that

varieties Rasakadali and Red banana were most consumer acceptable varieties compared to other varieties.

The therapeutic value of the banana varieties were studied by determining glycemic index. The lowest glycemic index was noticed in variety Padatti (60.70) followed by Poovan (61.00).

Findings of the present study revealed that banana is rich in various health beneficial chemical components and nutrients, bioactive compounds such as ascorbic acid, beta carotene, dopamine, tannins, saponins, alkaloids and flavonoids having potent antioxidant activities and/ or free radical scavenging activity.

സംഗ്രഹം

തിരുവനന്തപുരം വെള്ളായണി കാർഷികകോളേജിലെ ഹോംസയൻസ് വിഭാഗത്തിൽ ''ഫൈറ്റോ കെമിക്കൽ അനാലിസിസ് ആന്റ് ആന്റി ഓക്സിഡന്റ് പൊട്ടൻഷ്യൽ ഓഫ് ബനാന'' എന്ന പേരിലുള്ള ഗവേഷണം 2014-16 കാലയളവിൽ നടത്തപ്പെട്ടു. തെരഞ്ഞെടുത്ത ചില ഇനങ്ങളിലൂടെ വാഴപ്പഴങ്ങളുടെ രാസഘടന, പോഷകമൂല്യം, രോഗ പ്രതിരോധശേഷി ഘകങ്ങൾ, പഞ്ചേന്ദ്രിയങ്ങൾ ഉപയോഗിച്ചുള്ള വിലയിരുത്തൽ എന്നിവയായിരുന്നു ഈ ഗവേഷണത്തിന്റെ ഉദ്ദേശലക്ഷ്യങ്ങൾ.

പാളയംതോടൻ, രസകദളി, പൂവൻ, റോബസ്റ്റ, കപ്പ, നേന്ത്രൻ, കദളി, പടത്തി ഉൾപ്പെടെ 8 തരം പഴങ്ങൾ പഠനത്തിനുവേണ്ടി തെരഞ്ഞെടുത്തു. മുകളിൽ പറഞ്ഞിരിക്കുന്ന ഇനങ്ങളുടെ പഴുക്കാനാരംഭിക്കുന്ന ഘട്ടത്തിലെ വിവിധ സാമ്പിളുകൾ കാർഷികകോളേജിലെ ഫാമിൽ നിന്നും, തിരുവനന്തപുരത്തെ മറ്റ് പ്രാദേശിക മാർക്കറ്റുകളിൽ നിന്നും ശേഖരിച്ചു. ഇതിലെ പോഷകാംശങ്ങളുടെ അളവ്, സ്വാദ്, രുചി, രോഗപ്രതിരോധ ഘടകങ്ങൾ തുടങ്ങിയവ വിലയിരുത്തുകയുണ്ടായി.

മുകളിൽ സൂചിപ്പിച്ച ഇനങ്ങളുടെ റ്റി.എസ്.എസ് 17.83° ബ്രിക്സ് മുതൽ 23.90° ബ്രിക്സ് വരെ ആണെന്ന് കണ്ടു. എന്നാൽ രസകദളിയിൽ 23.83° ബ്രിക്സും നേന്ത്രനിൽ ഇത് 22° ബ്രിക്സുമാണ്. അസിഡിറ്റിയുടെ കാര്യത്തിലും ശ്രദ്ധേയമായ വ്യത്യാസങ്ങൾ കാണുവാൻ കഴിഞ്ഞു. ഏറ്റവും കുറവ് കദളിയിലും (0.46%) റോബസ്റ്റയിലുമാണ് (0.47%). ഏറ്റവും കൂടുതൽ അസിഡിറ്റി (പുളിപ്പ്) ശ്രദ്ധിക്കപ്പെട്ടത് പൂവനിലാണ് (1.28%). നേന്ത്രനിലാണ് അന്നജം കൂടുതലായി അടങ്ങിയിരിക്കുന്നത് (41.33ഗ്രാം/100 ഗ്രാം) അതേ സമയം മാസ്യം അംശം കൂടുതലായി കാണപ്പെട്ടത് പൂവനിലാണ് (1.37 ഗ്രാം/100 ഗ്രാം). ധാതുലവണത്തിന്റെ അംശം വിവിധയിനങ്ങളിൽ 0.17 ഗ്രാം മുതൽ 0.70 ഗ്രാം വരെ (100 ഗ്രാമിൽ) എന്ന അളവിലാണ്. സോഡിയവും പൊട്ടാസ്യവും രസകദളിയിൽ (260 മി:ഗ്രാം/100ഗ്രാം), നേത്രനിൽ (546.66 മി:ഗ്രാം/100 ഗ്രാം) ആയും കണ്ടു.

കാൽസ്യത്തിന്റെ അംശം തെരഞ്ഞെടുത്ത ഇനങ്ങളിൽ 0.35 മുതൽ 1.35 മി:ഗ്രാം/100 ഗ്രാം ആണെന്ന് രേഖപ്പെടുത്തി.

സസ്യരാസഘടകങ്ങളായ ആൽക്കലോയിഡിന്റെ അംശം വിവിധയിനം പഴങ്ങളിൽ 0.84 മുതൽ 3.76% വരെയാണെന്ന് രേഖപ്പെടുത്തി. നേന്ത്രനിൽ 3.76% വും പടത്തിയിൽ 3.72 % വും കാണപ്പെട്ടു. എന്നാൽ രസകദളിയിൽ ഫ്ളവനോയിഡിന്റെ അംശം 9.49 മില്ലിഗ്രാം/100 ഗ്രാം ആണെന്ന് കണ്ടു. സപ്പോനിന്റെ അംശം പഴങ്ങളിൽ 0.22 മുതൽ 0.82 % വരെയാണ്. കദളിയിൽ സപ്പോനിന്റെ അളവ് പരമാവധി 0.82% ആയും കുറഞ്ഞ അളവ് പടത്തിയിൽ 0.22% ആയും വെളിപ്പെട്ടു. ആകെയുള്ള ഫീനോൾ അളവ് കദളിയിൽ (11.6 മി:ഗ്രാം/100 ഗ്രാം), പൂവൻ (7.19മി.ഗ്രാം/100 ഗ്രാം), രസകദളിയിൽ (6.76 മി.ഗ്രാം/ 100 ഗ്രാം) ആയും കണ്ടു.

മറ്റിനങ്ങളിൽ നിന്നും വ്യത്യസ്തമായി പാളയംതോടൻ പഴങ്ങളുടെ വിവിധ യിനങ്ങളിൽ റ്റാനിന്റെ അംശം പരമാവധി 100 ഗ്രാമിൽ 4.28 മി: ഗ്രാം ആയിരുന്നു.

ഇപ്പോഴത്തെ പഠനത്തിൽ നിന്നും ഓക്സീകരണ പ്രവർത്തനങ്ങളെക്കുറിച്ച് വെളിപ്പെടുന്നത് കപ്പ പഴത്തിൽ പരമാവധി വിറ്റാമിൻ എ ധാരാളാമായി ലഭിക്കാൻ സഹായിക്കുന്ന മൂലകമായ ബി-കരോട്ടിൻ 100 ഗ്രാമിൽ 8.53 മൈക്രോഗ്രാം ഉള്ളതായിട്ടാണ്. വിറ്റാമിൻ സി-ലഭിക്കുന്ന അസ്കോർബിക് അമ്ലം ഏറ്റവും കൂടുതൽ കാണപ്പെടുന്നത് കപ്പപ്പഴത്തിലാണ് (5.35 മി:ഗ്രാം/100 ഗ്രാം). ഡോപമിൻ കൂടുതലായി കാണപ്പെടുന്നത് റോബസ്റ്റയിലും (13.3 മി:ഗ്രാം/100ഗ്രാം) കുറഞ്ഞ അളവിൽ കണ്ടത് രസകദളിയിലുമായിന്നു (3.2മി:ഗ്രാം/100 ഗ്രാം)

DPPH റാഡിക്കൽ അസ്സേ രീതി ഉപയോഗിച്ച് ശരീരമാലിന്യങ്ങളെ ശുദ്ധീകരിക്കാനുള്ള കഴിവിനെക്കുറിച്ച് വിവിധ തരം ലായനികളിലൂടെ അതായത് പെട്രോളിയം, ഈഥർ, മെഥനോൾ, വെള്ളം ഇതിനായി ഉപയോഗപ്പെടുത്തി. റോബസ്റ്റ ഇനങ്ങളിൽ പരമാവധി DPPH പ്രവർത്തനം വെളിപ്പെട്ടു. പെട്രോളിയം ഈഥർ ലായനിയിൽ IC_{50} മൂല്യം 43.6 മൈക്രോഗ്രാം/മി: ഗ്രാം ആയി കണ്ടു. പടത്തിയിൽ ഇത് 41.2 മൈക്രോഗ്രാം/മി: ഗ്രാം. കപ്പയിൽ 44.4 മൈക്രോഗ്രാം/മി: ഗ്രാം. രസകദളിയിലും പൂവനിലും 48.4 മൈക്രോഗ്രാം/മി: ഗ്രാം (ഏറ്റവും കൂടുതൽ) എന്നീ ക്രമത്തിൽ കാണപ്പെട്ടു.

മുകളിൽ വിവരിച്ച 8 തരം പഴങ്ങളുടെ പഞ്ചേന്ദ്രിയങ്ങൾ ഉപയോഗിച്ചുള്ള വിലയിരുത്തൽ 5 പോയിന്റ് സ്കോർ കാർഡ് വഴിയും 9

പോയിന്റ ഹെഡോണിക് റേറ്റിംഗ് വഴിയും നടത്തി. ഇതിന്റെ ഫലം വെളിപ്പെടുത്തുന്നത് മറ്റിനങ്ങളെ അപേക്ഷിച്ച് രസകദളിയും കപ്പപ്പഴവും ഉപഭോക്താവിന് കൂടുതൽ സ്വീകാര്യമാണെന്നാണ്.

വിവിധ ഇനങ്ങളുടെ രോഗ പ്രതിരോധ മൂല്യത്തെക്കുറിച്ച് പഠിച്ചത് ഗ്ലൈസീമിക് ഇൻഡക്സ് വഴിയാണ്. ഏറ്റവും കുറഞ്ഞ ഗ്ലൈസീമിക് ഇൻഡക്സ് ശ്രദ്ധയിൽപ്പെട്ടത് പടത്തിയിലും (60.70) പൂവനിലുമാണ് (61.00).

ഇപ്പോഴത്തെ പഠനത്തിൽ നിന്നും കണ്ടെത്തിയ കാര്യങ്ങളിലൂടെ മനസ്സിലായത് വാഴപ്പഴത്തിൽ ആരോഗ്യദായകവും പോക്ഷകഗുണവുമുള്ള രാസപദാർത്ഥങ്ങൾക്കുപുറമേ ശരീരത്തിൽ അടിഞ്ഞുകൂടുന്ന പല മാലിന്യങ്ങളെയും ശുദ്ധീകരിച്ച് രോഗപ്രതിരോധ ശക്തി കൂട്ടുവാൻ സഹായിക്കുന്ന പദാർത്ഥങ്ങളായ ഡോപമിൻ, ബീറ്റ കരോട്ടിൻ, അസ്കോർബിക് അമ്ലം, റ്റാനിൻ, സപ്പോനിൻ, ഫ്ളവനോയിഡ്സ്, ആൽക്കലോയിഡ്സ് എന്നിവ അടങ്ങിയിട്ടുണ്ടെന്നാണ്.