QUALITY EVALUATION OF BAMBOO SEED AND ITS PRODUCTS

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Quality evaluation of bamboo seed and its products"** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me 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 **"Quality evaluation of bamboo seed and its products"** is a bonafide record of research work done independently by **Miss. Shabna Kunhimon** 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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ABBREVIATIONS

Ca	-	Calcium
cfu	-	Colony fungal unit
con.	-	Concentrated
$CuSO_4$	-	Copper sulphate
EDTA	-	Etylene diamino tetra acetate
g	-	Gram
HCl	-	Hydrochloric acid
hr	-	Hour
H_2SO_4	-	Sulphuric acid
Kcal	-	Kilo calories
Kg	-	Kilo gram
Km^2	-	Kilo meter square
KOH	-	Pottasium hydroxide
K_2SO_4	-	Pottasium bisulphate
M	-	Molar
Mg	-	Magnesium
mg	-	Milli gram
µg	-	Micro gram
min	-	Minutes

ml	-	Milli litre
mm	-	Milli meter
N	-	Normal
NaOH	-	Sodium hydroxide
NIN	-	National Institute of Nutrition
nm	-	Nano meter
nos	-	numbers
OD	-	Optical density
SWBC	-	Seventh World Bamboo Congress
tbsp	-	Table spoon
UNDP	-	United Nations Development Programme
WAI	-	Water absorption index
WSI	-	Water solubility index
^0C	-	Degree celcius
>	-	Greater than
<	-	Less than
%	-	Percent

Introduction

1. INTRODUCTION

Bamboo is one of the precious plant resources of the earth. It has played a significant role in human civilization since ancient times and is still contributing to the subsistence of over two billion people living in tropical and sub- tropical belts in Asia, Latin America and Africa. Traditional use of bamboo differs from region to region and from people to people. Since time immemorial, bamboo is being used for fuel, food, housing and shelter by indigenous communities and is considered as a natural gift for human livelihood.

Bamboo is the common term for members of the taxonomic group of large woody grasses with family *Poaceae* and sub family *Bambusoideae*. Asia accounts for about 1000 species of bamboo, covering an area of over 180, 000 Km^2 (Scurlock *et al.*, 2000). Bamboo grows rapidly, has a wide range of uses and plays an important role in the rural economy of many tropical and subtropical regions (Guangchu, 2002).

Bamboo has a peculiarity of flowering and seeding only after a long vegetative phase and it varies from species to species. This is followed by the death of the flowered culms, has intrigued mankind and it still remains a mystery. Bamboo flowering is like an epidemic and the entire belt of the forest will flower at once and shed bamboo seeds. Bamboo seeds are highly nutritious and mostly relished by rats, squirrels and gerbils (Raju, 1997).

When the bamboo trees shed its paddy like seeds, the tribal families collect it and are dried, winnowed and husked to obtain the milled bamboo rice. The grains of bamboo are locally known as '*Mulayari*' that means 'bamboo rice'. Bamboo seed, which is a rich source of nutrients, is not yet commercially exploited as a food crop. In overall nutritive value it is better than rice and wheat (Mitra and Nayak, 1972). Bamboo seed can be used as a good dietary supplement to both humans and animals. The tribal cuisine has several delicacies made of bamboo rice and it is also included in the list of forest produce procured and sold along with other items like wild honey, gooseberry, herbs and medicinal plants. There is a great demand for bamboo seeds in pharmaceutical industry due to its medicinal values.

Bamboo seed, which is a rich source of nutrients, is not yet commercially exploited as a food source. Easily available source of nutrients from forest needs to be popularised for increasing the nutrition as well as safeguarding against possible deficiencies (Bhargava *et al.*, 1996). As bamboo seeds are nutrient rich indigenous food, it can be used as a substitute for rice and wheat during availability by the city dwellers also. If the tribals are encouraged by way of remunerating them for the procurement, it can be collected in massive scales and even sold in the market which will fetch a good supplementary income for the tribal families.

Thousands of people sustained themselves on bamboo seed in the time of food scarcity in the past. Normally it is only consumed by the hill and forest tribes. Even though it is available in plenty in tribal areas of Kerala, no studies have been conducted regarding its quality aspects and acceptability of the products prepared with bamboo seed. Hence the study entitled **"Quality evaluation of bamboo seed and its products"** was under taken with the following objectives:

1. To evaluate the biochemical, nutritional, cooking and organoleptic qualities of bamboo seed.

2. To assess the physical and keeping qualities of bamboo seed flour and to assess the acceptability of products made with the flour.

2. REVIEW OF LITERATURE

Bamboos are versatile group of plants with multiple utility. They usually form a rich belt of vegetation in moist deciduous, semi evergreen, tropical and temperate forests. Bamboos are fairly well represented in all the continents except Europe. Almost all the 75 genera and 1250 species of bamboo are woody and fast growing. The genus widely distributed in India is *Bambusa*. One-third of the human race uses bamboos for several purposes such as building, plywood and particle board manufacture, scaffolding, constructions, agricultural implements, fishing rods, pulp and paper industry, handicraft and furniture. Various parts of bamboo like leaves, seeds, rhizome and even the young bamboo shoots are useful to mankind and are used in several ways. This chapter contains the review of work done on bamboo, bamboo seed, nutritional and biochemical constituents of bamboo seed, health benefits of bamboo and bamboo based products and its quality evaluation.

2.1. Bamboo - A versatile crop

From being termed as 'Poor Man's Timber' to being called 'Green Gold', the perception of bamboo, a versatile grass found mainly in Asia and Africa, has undergone a drastic change. Recognition of the usefulness of bamboo existed even in the ancient times. Only in recent years it is being increasingly realised what a valuable resource bamboo is; not only for the traditional subsistence economy but also for modern industry (Der, 2005).

Bamboo is a giant, fast-growing, wood like grass and one of the earth's oldest and most precious plant material. It has benefited human societies since times before recorded history. Today, it helps more than two billion people to meet their basic needs, and as a widespread, renewable, productive, versatile, low or no-cost, easily accessed environment enhancing resource. It has great potential to improve life even more in the years ahead, especially in the villages and countryside of the developing world (Sastry, 2008).

India accounts for about half the total bamboo area of the world and about 100 species are indigenous belonging to 20 genera (Sharma, 1980). Vermah and Bahadur (1980) indicated bamboo as a valuable gift to India and reported that bamboo occur throughout the country except in Kashmir, extending an area of about 10 million hectares and about 72.8 percent of the total forest area of the world.

According to SWBC (2004), in India there are about 136 bamboo species distributed in 75 genera, 25 species among these are considered as edible types and are consumed by tribal communities. The study estimated that 10.3 million hectares or 12.8 percent of the country's total forest cover is under bamboo plantations. According to Dutt (2007) India has the largest bamboo forest in world, and two-third was reported to be in North Eastern states. The author also indicated that bamboo occupies 8.96 million hectares forest areas in India which accounted 12.8 percent of the total forest area and observed a huge potential of bamboo for the welfare of the country. Pandey (2008) reported that India is home to more than 125 species of bamboo, which spread across 18 genera. Bamboo resource base extends over 11.36 million hectares under forests and private land, with a total productivity of around 13.50 million tonnes. In homesteads of Kerala *Bambusa bambos* (*Bambusa arundinacea*), *Bambusa vulgaris* and *Dendrocalamus strictus* are the most common species (Chandrashekara *et al.*, 2008). Different species of bamboos grow in areas which receive an annual rainfall of 700 to 4000 mm and where mean annual temperature ranges from 8 to 36 ^{0}C (Seethalakshmi *et al.*, 2008).

Bamboo produces a woody stem matching properties of the strongest wood. Being a fast growing plant, it is relatively available at low cost and if harvested scientifically, on a sustainable basis. Being a low cost material, it is mostly used in rural and tribal areas for making handicrafts and as a source of livelihood. Despite its versatile and favorable characteristics, its use in high end structures is very limited in India (Kumar, 2008).

There is an immense potential to increase the productivity of bamboo resources, enhance the quality of extracted bamboo and utilize the resource for new generation value added products based on bamboo in segments like wood substitutes and composites, utility and craft products, charcoal, activated carbon and gasification for rural and decentralised energy needs, edible bamboo shoot for dietary requirements, other industrial products, and earthquake resistant bamboo based structures for cost effective, rural and disaster response requirements (Pandey, 2008).

Bamboo is traditionally used as a structural or decorative material, such as to create rugs and flooring. Bamboo is also used for making flutes, xylophones, drums and fishing rods. Bamboo can also be used for making paper (Work, 2008). Bamboo is used in making clothing that is beautiful and long lasting. It is also being used to make high quality furniture and flooring, and it is also becoming popular in gardening and as a cuisine item (Tustle, 2010).

Durability of bamboo has been of great concern since its recognition as a useful material especially in structures. Its vulnerability to insect attack has also been well known to the early users. Absence of any toxic components and presence of high amounts of sugar and starch make it an attractive food source for a variety of organisms (Kumar, 2008). Incense sticks are also made from bamboo. All available species of bamboo are used for charcoal production (Pandey, 2008).

The decline in timber availability and the emergence of new technologies and product options has spurred interest in bamboo based composites and wood substitutes. The highest priority, because of the employment intensity, and the linkages between industrial scale units and the cottage sector, needs to be accorded to mat based composites, including flattened bamboo boards, bamboo-jute composites, corrugated roofing, shuttering material and mat-glass fibre composites (Pandey, 2008).

Janssen (1988) reported that in South East Asia, bamboo is a main thing used for housing and scaffolding. Mishra (1988) reported that bamboo have great potential for making house components such as trusses, purlins, roof grids and walling. A scientific use of bamboo can ensure a long trouble free life to it. The author also reported that as compared to some constructional timbers, bamboo possess better strength and can thus be used for structural purposes.

Uses of bamboo depend upon the characteristics of individual species such as culm strength, flexibility and size. Their contribution to the ecology of an area derives from their ability to recycle nutrients efficiently, their ability to protect against soil erosion, and the high nutritive value of its parts (Stapleton, 1996). Parsai (2007) reported that the demand for bamboo has increased within the country and abroad as a raw material for furniture making, as panel boards substituting wood, as agricultural implements, house construction related uses and as a vegetable.

Tender shoots of bamboo are soaked in water, boiled and used in curries and for making pickles. The sap of shoot contains hydrocyanic acid and possesses antiseptic and larvicidal properties. If eaten raw, shoots often prove poisonous (Chandy, 1996). Singh (2008) reported that young shoots of bamboos have been in high esteem for edible delicacy. A wide range of fresh and fermented products are prepared from bamboo shoot for domestic consumption.

The bamboo shoots are consumed in the form of fermented-slice, crushed-fermented moist, crushed-fermented dry, fermented whole shoot, roasted whole shoot and boiled whole shoot in different states of the region (Bhatt et al., 2005). Bamboo shoots are crunchy and nutritious vegetable. Young shoot contain 90 percent of water, and are rich in vitamins, fibre, cellulose and amino acids and low in fat (Brias and Hunde, 2009).

Bamboo has a peculiar phenomenon of flowering (Plate 1). Some species flower after a long period of time and gregariously, some flower sporadically while others flower annually. Flowering gregariously is the most dominant behavior in bamboo (Panwar, 2008). Flowering and seedling are necessary for reproduction and new generation (Brias and Hunde, 2009).

Plate 1: Flowered bamboo

Typical examples of gregariously flowering species which also show sporadic flowering are *Dendrocalamus strictus* and *Bambusa bambos* (Chandy, 1996). Raju (1997) reported that bamboo flowering is like an epidemic and the entire belt of the forest will flower at once and shed bamboo seeds. The author also indicated that the bamboo seeds are highly nutritious and mostly relished by rats, squirrels and gerbils (Plate 2). Sometimes sporadic flowering is seen in bamboo forests in some years. After seeding bamboo will die and dries up gradually. According to (Singha *et al.*, 2003) some members of the family *Poaceae* have the suicidal habit, where the parent plants die after flowering.

Ahamed and Das (1986) reported sporadic flowering in Bangladesh and stated no seeds were set due to the sterility of pollen or failure of the pollen in producing pollen tube. Koshy and Pushpangadan (1997) reported flowering of *Bambusa vulgaris* in Alappuzha and Pathanamthitta districts of Kerala in 1996. *Bambusa vulgaris* flowered in different places of coastal districts of Orissa in March, 2005 (Bhola, 2006). Takahashi *et al* (2007) observed that total soil nitrogen, available nitrogen and exchangeable Ca and Mg content were low in sites where bamboo had flowered and died.

The peculiar behavior of many woody bamboos is flowering and seeding only at very long intervals followed by the death of the flowered clumps and the reason behind it still remains a mystery even after long years (John and Nadgauda, 1997). John and Nadgauda (2002) showed that the famine is related to the fact that seed of bamboo contain high protein. Due to plentiful availability of bamboo seeds, the reproductive rate of rats increases. This increased rat population move towards agricultural fields and destroy all the crops leading to famine. The absence of new culms in the previous year is generally held to be a sign of prospective flowering in the following season. Flower buds are visible about September to October and flowering takes place in December or January. During blooms the branches become mostly leafless (Alam, 2008).

Plate 2: Squirrel consuming bamboo seed

2.2. Bamboo seed- A novel food

Bamboo seed popularly known as "bamboo rice" is a reputed famine food. Thousands of people sustained themselves on these seeds in time of scarcity in the past. Normally it is consumed only by the hill and forest tribes. The bamboo flowers towards the end of its life span of 15-20 years. Very large quantities of seeds are available during the season (Rao *et al.*, 1955). One medium sized full grown clump usually produces 5-7 kg seeds in one flush and 25-40 kg within whole flowering period before dying. Seed production is optimum during May to June and poor from later part of September to November (Alam, 2008).

The embryo of bamboo seed is minute, embedded at one end of the endosperm. The seed dries up during maturation and the moisture content varies according to species at the time of shedding. The seeds are tolerant to desiccation and can be dried up to 5 percent moisture content, which is considered safe for storage. The seeds are non dormant and germinate readily. There are 20,000- 30,000 seeds per Kg, depending upon the species and the moisture content present in seeds. A considerable proportion of seed is empty, which can be separated by winnowing or with the help of seed blowers (Bahar and Singh, 2008).

The husked seeds grossly resembled rice but closer examinations showed, it was more like wheat. As compared with rice, the grain had a thicker and tougher bran-coat which was difficult to polish completely. The fully or partially polished grains cooked like rice but were slightly more glutinous. Unpolished grains required a longer time for cooking (Rao *et al.*, 1955).

When the bamboo seeds matured, the tribal's cleaned the ground around the plant and patch the floor by using cow dung. They collect the seeds that fall from the plants on this clean floor (Gadgil and Prasad, 1984). Seeds collected are sold to the forest department. It helps to empower and improve the economy of the tribal women (Bhatt *et al.*, 2003). Singh (2008) reported that bamboo add sustainability to farmer's income by producing various valuable products like seeds and shoots.

Bamboo seeds need to be collected immediately before the rain sets in, as seeds lose viability rapidly on exposure to excess moisture. Storage of wet seeds also poses problems. Moisture content of seeds could be reduced to as low as 1.90 percent for effective storage. Rapid loss in viability of the seeds stored under ambient conditions occurred within 6 months, while in other storage conditions deterioration was gradual, reaching 6 percent germination after 18 months (Warrier *et al.*, 2004). The seeds of all bamboo species investigated exhibited enhanced longevity after reduction of moisture content and storage at low temperature in sealed containers (Bahar and Singh, 2008).

Banik (2002) reported that reducing seed moisture content and storage at reduced temperatures extend viability. It is expected that if techniques were standardized and implemented quickly after seed harvesting, many practical problems of seed handling will be solved. Rawat (2005) reported that ideal condition for germination of bamboo seeds were at incubation temperature of 30°C, in the presence of light with top of paper as sowing medium. Bamboo seeds germinate better under shade than in direct sunlight. Hence, bamboo seeds can be considered as negatively photoblastic.

2.3. Nutritional and biochemical constituents of bamboo seed

Rao *et al* (1955) investigated the nutritive value of bamboo seed as a part of a work on little known foods and reported that bamboo seeds are nutrient rich; the overall nutritive quality is slightly greater than rice and wheat. Mitra and Nayak (1972) analysed bamboo seed and revealed that bamboo seeds are similar to wheat in protein content and similar to rice in protein quality.

Bhargava *et al* (1996) analysed the nutritional constituents in bamboo seed and observed a total carbohydrate content of 38 percent in *Bambusa arundinacea,* 36 percent in *Bambusa nutans* and 26 percent in *Dendrocalamus strictus*. They also reported that the protein content in bamboo seed varies among varieties and it ranged from 4.48- 13.54 percent. A protein content of 7.52 g in *Bambusa arundinacea*, 4.48 g in *Bambusa nutans* and 13.54 g in *Dendrocalamus strictus* per 100 g were also noted by the authors.

According to Gopalan *et al.* (2007) bamboo seed contained moisture 7.8 g, protein 13.1 g, fat 1.2 g, fiber 0.9 g, carbohydrate 75.9 g, energy 367 kcal, calcium 37 mg, phosphorus 162 mg, iron 6.4 mg, thiamine 0.17 mg, riboflavin 0.12 mg and niacin 1.1 mg per 100g.

Rao *et al.* (1955) reported that the major protein in bamboo seed is glutelins. The amino acid make up of the protein as determined by the two dimensional paper chromatographic procedure developed in the laboratory showed that bamboo seeds were well provided with all the essential amino acids. Karunakaran (1999) reported that bamboo seeds are rich in all essential amino acids and reported a protein efficiency ratio of 2.92 in bamboo seeds.

Major amino acids present in bamboo seed protein includes Arginine 8.9 g, Histidine 2.0 g, Lysine 4.6 g, Tryptophan 0.8 g, Phenyl alanine 4.4 g, Tyrosine 3.2 g, Methionine 1.7 g, Leusine 7.7 g, Threonine 3.6 g, Isoleusine 5.0 g and Valine 5.9 g per 16 g nitrogen (Karunakaran, 1999). Gopalan *et al* (2007) reported that their values are 560, 130, 290, 50, 270, 200, 110, 130, 480, 230, 310 and 370 mg respectively per g of nitrogen.

According to Karunakaran (1999) proteins present in bamboo seed includes albumin 0.96 percent, globulin 0.64 percent, prolamine 0.64 percent and glutelin 7.22 percent. The percentage composition of the husked bamboo seeds as given by Kiruba *et al* (2007) was moisture 10 g, carbohydrate 73.4 g, protein 12 g, fat 0.9 g, fibre 2.6 g, calcium 25 mg, phosphorus 218 mg, iron 9.2 mg, vitamin B_1 0.1 mg, nicotinic acid 2.03 mg, riboflavin 36.3 μg and carotene 12.0 μg per 100 g.

Swaminathan (1996) reported that riboflavin content of bamboo seed is 0.47 mg 100 g^{-1} which is higher than that of legumes. Bamboo seed contained considerable amounts of thiamine, riboflavin and niacin (Karunakaran, 1999). Kumbhare and Bhargava (2008) reported that seeds of *Dendrocalamus strictus* contain good amount of pyridoxine, nicotinic acid, riboflavin and ascorbic acid. Pyridoxine content is 0.44 mg 100 g^{-1} and nicotinic acid content is 0.48 mg 100 g^{-1}. But they reported a low thiamine content of 0.0074 mg 100 g^{-1} in *Dendrocalamus strictus.*

Vitamin C content of bamboo seed ranged from 28- 50 mg in different varieties. Sodium is 0.18 percent in *Bambusa arundinacea* and *Bambusa nutans* and 0.095 percent in *Dendrocalamus strictus*. Potassium content is high in *Bambusa nutans* (0.32 %). High magnesium of 0.14 percent is seen in *Bambusa arundinacea* (Bhargava *et al.*, 1996). A reduction in total content of food reserves such as sugars, proteins and lipids were seen in *Bambusa bambos* seeds due to aging (Ravikumar *et al.*, 1998).

Tewari (1992) compared various nutrients in bamboo seed to IR 8 rice variety and reported that the protein content in bamboo seed is 12.77 percent compared to 7.035 percent in IR 8 rice. Starch is 72.91 percent compared to 74.65 percent in IR 8 rice. Bamboo seed also contained fibre 1.27 percent, calcium 86.88 mg 100 g^{-1} and potassium 162.90 mg 100 g^{-1} which are completely absent in IR 8 rice variety.

Biological value of bamboo seed protein is as high as that of rice proteins and higher than that of wheat proteins. In the matter of protein content, the seeds are comparable with wheat but superior to rice (Kiruba *et al.*, 2007). The moisture content of bamboo seed varies according to species at the time of shedding. The seeds are tolerant to desiccation and can be dried up to 5 percent moisture content, which is considered safe for storage (Bahar and Singh, 2008).

The effect of complete substitution of rice by the bamboo seed in a conventional poor rice diet on its overall nutritive value was ascertained by rat growth experiments. In overall nutritive value it excels both rice and wheat (Rao *et al.*, 1955). Due to accelerated ageing, seed lost its viability and changed its biochemical constituents. Reduction in content of sugars, starch, protein and lipids were found. Decrease in the activity of peroxidase, as well as acid and alkaline phosphatase was also observed. Increase in total free amino acid content and the activity of amylase confirmed the degradation of seeds (Ravikumar et al., 2002).

2.4. Health benefits of bamboo

Nag (1999) reported that the bamboo seeds appeared to be a delicious food item for jungle rats, which emerged in massive numbers to devour them, and the consumption of bamboo seeds resulted in a vast increase in the rodent population. Jaksic and Lima (2003) reported an increase in rodent population associated with bamboo flowering and subsequent seeding.

Nag (2001) reported that with the flowering of bamboo in the Mizo district rat population has phenomenally increased. Lalnunmawia *et al* (2005) reported that seeds of bamboo eaten by rodents enhance their reproductive ability which leads to increased rodent population. This destroys the paddy fields and thus causes famine.

John and Nadgauda (2002) reported that the presence of high protein content of bamboo seed increases the reproductive capacity of rats. The *Kani* tribes of Kanyakumari believed that the bamboo seeds increases the fertility and reproductive capacity of the tribes (Kiruba *et al.*, 2007). UNDP (2008) also reported similar findings.

According to Raju (1997), highly nutritious bamboo seeds are relished by rats, squirrels and gerbils. The reproductive capacity of rodents increases due to adequate supply of bamboo seeds. As the *Kani* tribe of Kanyakumari believes that the seeds of *Bambusa bambos* enhance fertility, there is a great demand of seeds of this species in pharmaceutical industry to manufacture drugs to improve fertility (Kiruba *et al.*, 2007).

Hmar (2007) reported that, in Mizoram people believe that nutrient rich bamboo seed increases fertility and reproductive capacity of Mizos. The author also reported various cases of success in this field. The bamboo grains are nutritious and cure *doshas* (faults) of our body, discards toxic substances from our body and cures the disease in which the vital humors of the body are excreted through urine (Love, 2009). Anon (2010) reported that Mizos used bamboo seed as viagra and it acts as a sex stimulant for rats.

Zhang (2007) reported that bamboo leaf extracts help reduce acrylamide, a carcinogen created when foods are baked or toasted or fried. An antioxidant-rich extract from bamboo leaf helps to reduce the formation of acrylamide in an asparagines - glucose model system heated by microwave (Daniells, 2008). Seki *et al* (2008) reported that bamboo leaf extract induces activation of human natural killer cells, macrophages and potent induction of IL-2, IL-12 and IFN-gamma in tumor bearing mice.

Bamboo leaves are used to treat febrile disease with interior heat and dryness, irritability and insomnia (Bensky and Barolet, 1990 and Bingshan and Yuxia, 1993). Flavonoids made from bamboo leaves are used to make medicines (Fu, 2001). The extract solution of bamboo leaves can obviously inhibit damage of free radical and prevent lipid peroxidation (Hua, 2004). Bamboo leaves have been used in traditional Chinese medicine for treating fever and detoxification (Lu et al., 2005).

Balkrishna (2010) reported that fresh bamboo leaves are beneficial in reducing the burning sensation and pain in the bladder. Thus it is beneficial to cure urinary problems. Bamboo leaves are also extremely beneficial to cure gonorrhea. Bamboo leaf also helps to reduce the effect of poison. Bamboo leaves are used in treating fever, fidgeting and urinary retention with blood in the urine and lung inflammation.

Kuboyama *et al* (1981) reported the antitumor activity of bamboo leaf against various transplantable tumor strains. The author also reported that bamboo leaf has a direct action on tumor cells. Flavonoid - rich bamboo leaf extract has multiple biological effects, such as anti-free radical, anti-oxidation, anti-aging, anti-fatigue, anti-bacteria, anti-virus, and prevention of cardiovascular diseases (Xu *et al.*, 2001 and Fu *et al.*, 2004).

As medicine, bamboo can be used for a variety of ailments, such as intestinal disorders like diarrhoea. It is also thought to promote healthy body functions, like the female menstrual cycle and while the bamboo leaves are known as an anti-spasmodic and blood secretion. Boiling the leaves and mixing it with palms jaggery can induce labour in pregnant women or cause a spontaneous abortion of a foetus earlier in the pregnancy (Fitzgerald, 2000).

Bamboo is utilised in Chinese medicine for treating infections and healing, and bamboo is said to be a tonic for the respiratory diseases. Bamboo is also a low-calorie source of potassium, and it truly is identified for its sweet taste and an excellent source of nutrients and protein (Michaels, 2002). Roots and leaves of bamboo have also been used to treat venereal diseases and cancer (Love, 2009).

Bamboo shoots itself aids in digestion of proteins and can promote stomach functions (Fitzgerald, 2000). Offshoots of bamboo are spicy, sour, pungent, bitter and slightly cold and are beneficial in bleeding piles, burning sensation and gonorrhea (Love, 2009). Roy (2009) reported that ingredients from the black bamboo shoot help to treat kidney diseases. Water from the culm of bamboo is used to treat diseases of bone effectively. The juice of tender shoots of bamboo helps to kill worms and heal the wound quickly (Balkrishna, 2010).

Bamboo manna is healthy for the different humors of our body. It is beneficial in thirst, cough, fever and respiratory disorders. Bile disorder due to tuberculosis, blood impurities, leprosy with jaundice, wounds, ulcers, and painful flow of urine can be cured with consumption of manna. It also increases the sperm count and uses in the case of post delivery problems and abortion (Love, 2009).

Bamboo skin and roots are used to cure baldness and hair loss. Eye problems can be cured with bamboo pulp boiled in water (Love, 2009). The author also reported that powdered bamboo pulp cures dry cough, respiratory disorders, bleeding from the mouth, burning sensation in the hands and feet, pain of ribs, fever caused due to indigestion and humors, weakness in young children, burning sensation of the eyes and throat.

Dried bamboo sap is effective for dislodging phlegm, cooling the heart, and controlling convulsions. It is often used in children when there is high fever, irritability, convulsions, and night crying caused by disturbance of the heart and liver by phlegm-heat. It can also be used to treat fever, shortness of breath, and cough and thick sputum in conditions of phlegm-heat in the lung. In clinical practice, it is used for convulsions in infectious diseases, and for pneumonia, acute bronchitis, and influenza (Yifang, 2002).

Liquid sap of bamboo is used to treat epilepsy, hemiplegia, facial paralysis, and numbness and tingling or cramp of the limbs. It is able to open the heart orifice also, and is used when phlegm-heat covers the heart. In this situation, patients lose consciousness, and have gurgling sounds in the throat, such as occurs with epilepsy, stroke, and heart attack (Yifang, 2002).

Bamboo vinegar has been used for multiple reasons, including medicinal purposes. Bamboo vinegar has been used to treat various stomach disorders (Fitzgerald, 2000). Bamboo vinegar is used medicinally to treat eczema, atopic dermatitis, and other skin diseases. Bamboo vinegar is recognized as an anti-inflammatory and anti-fungal (Yuki et al., 2004). Sulaiman *et al* (2005) reported that bamboo vinegar has the ability to inhibit the growth of micro-organisms.

Bamboo beer showed multiple health benefits such as lowering blood lipids and preventing heart diseases (Fu, 2001). Bamboo shaving is very effective in reducing heat in the chest and eliminating irritability. It is often used to treat febrile diseases when there is heat in the heart, lung, or chest (Yifang, 2002).

2.5. Bamboo based products and its quality evaluation

Bamboo is rich in minerals and high in fibre, which can be a great addition to any nutritious, well balanced diet. Bamboo offers a variety of different amino acids, including eight types of amino acids that humans must receive from a food source, since the body does not manufacture these certain amino acids within the body (Fitzgerald, 2000).

In India, the seeds of *Bambusa arundinacea, Cephalostachyum pergracile* and *Dentrocalamus strictus* are extensively eaten by poor during famine. The seeds are pickled and candied and used for making beer. (Raizada and Chatterjee, 1956). Edible bamboo parts are good dietary supplement to both human and animals (Bhargava *et al.*, 1996). Raju (1997) indicated that the bamboo seeds are highly nutritious and mostly relished by rats, squirrels and gerbils.

Kiruba *et al.* (2007) indicated that the indigenous people consumed dried bamboo seeds like rice after boiling and consumed with fish curry and vegetables and used as a substitute of rice.

Bamboo seed has a nutrient quality slightly higher than rice and wheat. There is no evidence that bamboo seed contains the toxic secondary compounds normally found in tropical tree seeds (Janzen, 1974). In India, tribal people in some area collect and store bamboo seeds for use in time of scarcity. Seeds can be baked in to flakes which tastes very much like corn flakes and can be brewed to bamboo beer and sake. They can also be used like wheat as a cereal (Kumbhare and Bhargava, 2008).

The grains could be consumed either in the cooked form or as various culinary preparations like chapaties made out of the flour (Rao *et al.*, 1955). Raju (1997) reported that bamboo seeds are highly nutritious and eaten by forest tribals along with honey. In Mizoram, pickles are made from bamboo seed and have been making profits. A traditional Mizo stew called *Bai* is prepared from bamboo seed (Kumbhare and Bhargava, 2008).

The husked seeds grossly resembled rice but closer examinations reported were more like wheat. As compared with rice, the grain had a thicker and tougher bran-coat which was difficult to polish completely. The fully or partially polished grains cooked like rice but were slightly more glutinous. Unpolished grains required a longer time for cooking (Rao *et al.*, 1955).

Saxena (1996) reported that *Abhujmarias*, a group of tribal people in Madhya Pradesh used to consume bamboo seeds. He also reported that the staple cereal of Kadar tribe of Nilgiris and Annamalai hills is rice but they subsisted entirely on bamboo seeds during lean months.

Luzzi (1980) reported that during "*navagraha*" ceremony practiced by high castes during ear piercing and wedding bamboo seed is one of the important grain offered in nine grains along with paddy, wheat, peas, sesame, bengal gram, green gram, horse gram and black gram.

The bamboo beer was prepared by adding the juice of green dried bamboo leaves to the original beer and mixed filtered and bottled. Bamboo beer showed various health benefits (Fu, 2001).

Yuki et al (2004) reported that when bamboo is heated at very high temperature in an airless vessel, it becomes charcoal, which is used like other charcoal products, as a fuel component, a deodorizer, or an absorbent. The vapour that comes off the heated bamboo can be condensed to produce a liquid known as bamboo vinegar. It contains high content of acetic acid accompanied by many other compounds, especially phenols, such as guaiacol and cresol.

Raju (1997) reported that young shoots are pickled with mixing with lime juice and chillies. Soups are prepared from tender bamboo shoots in modern restaurants. Most food choices center on the shoots of the bamboo, which are tender and delicious vegetables. Shoots are used in different recipes, such as bamboo candy, beer, chutney and even soup (Fitzgerald, 2000).

Joshi *et al* (1994) indicated the usefulness of bamboo shoots in the preparation of chutney, curry and pickle. The authors also indicated that bamboo shoots were preserved by steaming, pickling and drying for future consumption which added a distinct flavour to many dishes.

Soibum is an indigenous fermented food exclusively produced from succulent bamboo shoots and is consumed as an indispensable constituent of the diets. It can be processed from the material of single species or from an intermixed material of more than one species. It is consumed after cooking with colocasia corms, green peas, pumpkins, potatoes etc in different recipies. It is also consumed by frying with fishes (Giri and Janmejay, 2000).

Giri and Janmejay (1994) reported that unskilled preservation of shoots without aeration allows fungal growth leading to spoilage, where in compact and airtight storage conditions its shelf life exceeds two years.

Bamboo leaves can be used as a pharmaceutical intermediate, dietary supplement, cosmetic ingredient, and food additive (Xu *et al.*, 2001 and Fu *et al.*, 2004). Lu *et al* (2006) reported that the antioxidant of bamboo leaves has been certificated as a natural antioxidant by the Ministry of Health of the People's Republic of China in 2003, which has a warrant for use in edible oil, meat product, aquatic product and puffed food as a novel food additive.

The antioxidant of bamboo leaves is a kind of polyphenol-rich extract from bamboo leaves and intended for use in edible oil, meat product, aquatic product and puffed food with maximum dosage of 0.5 g/kg, which was approved by the Food Additive Standardisation Committee of People's Republic of China on December 28, 2003 as a novel kind of natural antioxidant (Lu *et al.*, 2006).

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled **"Quality evaluation of bamboo seed and its products"** was attempted to evaluate the cooking, biochemical, nutritional and organoleptic qualities of bamboo seed. The study also aimed to assess the physical and keeping qualities of bamboo seed flour and the acceptability of the products made with the flour.

Dried bamboo seeds were used for the study. Bamboo seeds collected during March - April 2008 were procured from a reliable source of Wayanad district (Plate 3). The study was divided into two experiments and the methods followed in the study are presented in this chapter.

Experiment no: 1

3.1. Quality evaluation of bamboo seed

Cooking qualities, Nutritional and Biochemical and Organoleptic qualities of bamboo seed were evaluated. All the analysis was carried out in five replicate samples.

3.1.1. Cooking qualities of bamboo seed

Bamboo seed was analysed for various cooking qualities as detailed below.

3.1.1.1. Cooking time

Optimum cooking time was estimated by the method outlined by Juliano and Bechtel (1985). In a 250 ml beaker, about 100 ml distilled water was boiled (98 ± 1^0C) and 5 g of sample was dropped into it. Measurement of cooking duration was started immediately. After 10 min and every min thereafter, grains were removed and pressed between two clean glass plates.

Plate 3: Bamboo seed

Cooking time was recorded when at least 90 percent of grains no longer had opaque core or uncooked centres. The grains were then allowed to simmer for about 2 min to ensure that the core of all grains has been gelatinised. Optimum cooking time included the additional 2 min used for simmering.

3.1.1.2. Water uptake

Water uptake was estimated by the method outlined by Zhou *et al* (2007). A known weight of grain (10 g) was cooked with excess cooking water (100 ml) in a beaker. The excess residual cooking water was withdrawn using a pipette after the cooking process and the volume was measured. Water uptake capacity of the cooked grain was calculated from the difference between the total cooking water and residual cooking water after the cooking process and expressed as ml per g of grain.

3.1.1.3. Volume expansion

Volume expansion was estimated by the method suggested by Pillaiyar and Mohandoss (1981). It was determined from the ratio between the cooked volume of grain to that of uncooked grain. The volumes of ten bamboo grains were noted initially and after cooking. The volume expansion was calculated from the ratio between cooked volume to uncooked volume.

3.1.1.4. Grain elongation

The method suggested by Azeez and Shafi (1966) was followed for evaluating the degree of elongation of cooked grains. The elongation test consists of measuring 25 whole kernels in a beaker and was soaked in 20 ml of distilled water for 30 min. The samples were placed in a water bath and the temperature is maintained at 98 °C for 10 min. The cooked grains were transferred to a petridish lined with filter paper. Ten cooked whole grains were selected and measured by placing it linearly on a graph paper. The proportionate elongation is the ratio of the average length of cooked grains to the average length of raw grains.

3.1.1.5. Amylose content

Amylose content was determined by the method suggested by Sadasivam and Manickam (1992). To 100 mg of powdered sample, 1 ml of distilled ethanol and 10 ml of 1 N NaOH were added and kept it overnight and the volume was made upto 100 ml. 2.5 ml of the extract was taken and added about 20 ml of distilled water and three drops of phenolphthalein. Then 0.1 N HCl was added drop by drop until the pink colour just disappears. To this, 1 ml of iodine reagent was added and the volume was made upto 50 ml. The intensity of the colour developed was read at 590 nm. The amylose present in the sample was estimated from standard graph prepared using serial dilution of standard amylose solution and expressed in percentage.

3.1.1.6. Gelatinisation temperature index

An estimate of gelatinisation temperature was indexed by the alkali digestion test suggested by Little *et al.* (1958). It was measured by observing the degree of spreading of individual milled kernels in a weak alkali solution. Six whole-milled kernels without cracks were selected and placed in a petridish. Ten ml of 1.7 percent potassium hydroxide (KOH) solution was added. The samples were arranged to provide enough space between kernels to allow for spreading. The petridish was covered and incubated for 23 hours in a 30°C oven. Starchy endosperm was rated visually to index the degree of spreading in alkali.

3.1.1.7. Gel consistency

All the samples were stored in the same room temperature for at least two days so that the moisture content was similar. Whole-milled grains were ground to give fine flour (100 mesh). Hundred mg of powder was weighed into the culture tubes. Ethyl alcohol (0.2 ml of 95%) and 2.0 ml of 0.2 M KOH were added with a pipette. The contents were mixed well. The test tubes were covered with glass marbles (to prevent steam loss and to reflux the samples). The samples were cooked in a vigorously boiling water bath for 8 min, making sure that the tube contents reached 2/3 the height of the tube. The test tubes were removed from the water bath and left to stand at room temperature for 5 min. The tubes were cooled in an ice-water bath for 20 min and laid horizontally on a laboratory table, lined with a graph paper. The total length of the gel is measured in mm from the bottom of the tube to the gel front (Cagampang *et al.*, 1973).

3.1.2. Nutritional and biochemical qualities of bamboo seed

Nutritional and biochemical qualities of bamboo seed were assessed using standard procedures. Analysis was carried out for the following constituents.

3.1.2.1. Moisture

Moisture content of the bamboo seed was estimated by the method of AOAC (1980). To determine the moisture content, 5 g of the bamboo seed was taken in a petridish and dried in a hot air oven at 60 - 70 °C, cooled in a dessicator and weighed. The process of heating and cooling was repeated until a constant weight was achieved. The moisture content was calculated from the loss in weight during drying and expressed in percentage.

3.1.2.2. Protein

The protein content was estimated by the method of A.O.A.C (1980). Bamboo seed flour was digested with 6 ml con. H_2SO_4 after adding 0.4 g of $CuSO_4$ and 3.5 g K_2SO_4 in a digestion flask until the colour of the sample was converted to green. After digestion it was diluted with water and 25 ml of 40 percent NaOH was pumped. The distillate was collected in 2 percent boric acid containing mixed indicator and then titrated with 0.2 N HCl. The nitrogen content obtained was multiplied with a factor of 6.25 to get the protein content and expressed in percentage.

3.1.2.3. Fat

The fat content of bamboo seed was estimated by the method of A. O. A. C (1955). Five gram of flour was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for 6 hours without interruption by gentle heating in a Soxhlet apparatus. Extraction flask was then cooled, and ether was removed by heating and weight was taken. The fat content was expressed in g per 100 g of the sample.

3.1.2.4. Starch

The starch content was estimated colorimetrically using anthrone reagent (A. O. A. C, 1980). The sample (0.5 g) was extracted repeatedly with 80 percent ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml of water and 6.5 ml 52 percent perchloric acid were added and extracted at 0°C for 20 min. The supernatant was pooled and made up to 100 ml. Pipette out 0.2 ml of the supernatant and made up to 1 ml with water and 4 ml of anthrone reagent was added, heated for 8 min, cooled and read the OD at 630 nm.

A standard graph was prepared using serial dilution of standard glucose solution. From the graph glucose content of the sample was obtained and multiplied by a factor of 0.9 to arrive at the starch content.

3.1.2.5. Reducing sugar

Reducing sugar was estimated by the method given by Lane and Eyon (Ranganna, 1986). To 10 g of powdered sample, 100 ml of distilled water was added and then clarified with neutral lead acetate. Excess lead was removed by adding potassium oxalate. The volume was then made up to 250 ml. An aliquot of this solution was titrated against a mixture of Fehling's solution A and B using methylene blue as indicator. The reducing sugar was expressed as percentage.

3.1.2.6. Total sugar

The total sugar was determined using the method given by Lane and Eyon (Ranganna, 1986). From the clarified solution used for the estimation of reducing sugar, 50 ml was taken and boiled gently after adding citric acid and water. It was later neutralized with NaOH and the volume was made up to 250 ml. An aliquot of this solution was titrated against Fehling's A and B. The total sugar content was expressed as percentage.

3.1.2.7. Fibre

The fibre content was estimated by acid alkali digestion method as suggested by Chopra and Kanwar (1978). Two gram of dried and powdered sample was boiled with 200 ml of 1.25 percent sulphuric acid for thirty min. It was filtered through a muslin cloth and washed with boiling water and again boiled with 200 ml of 1.25 percent sodium hydroxide for thirty min. Repeated the filtration through muslin cloth and washed with sulphuric acid, water and alcohol. The residue was transferred to a pre weighed ashing dish, dried, cooled and weighed and ignited for 30 min in a muffle furnace at 600 °C, cooled in a dessicator and reweighed. The fibre content of the sample was calculated from the loss in weight on ignition and expressed in percentage.

3.1.2.8. Calcium

The calcium content was estimated using titration method with EDTA as suggested by Page (1982). Two gram of dried and powdered sample was predigested with 10 ml of 9:4 mixtures of nitric acid and perchloric acid and volume was made up to 100 ml. To five ml of diacid extract, 10 ml water, 10 drops of hydroxylamine hydrochloride, 10 drops of triethanolamine, 2.5 ml sodium hydroxide and 10 drops of calcone were added. Then, it was titrated with 0.02 N EDTA till the appearance of permanent blue colour. Calcium content was expressed in mg 100 g^{-1} of the sample.

3.1.2.9. Iron

The iron content was analysed colorimetrically by Wong's method as suggested by Raghuramulu *et al* (2003). To an aliquot of 6.5 ml diacid solution, one ml of 30 percent sulphuric acid, 1 ml of 7 percent potassium persulphate solution and 1 ml of 40 percent potassium thiocyanate solution were added. The intensity of the red color was measured within twenty min at 540 nm. The content of iron present in the sample was estimated from standard graph prepared using serial dilution of standard iron solution and expressed in mg 100 g^{-1}

3.1.2.10. Phosphorus

The phosphorus content was estimated colorimetrically as suggested by Jackson (1973). Five ml of diacid extract was taken in a volumetric flask and five ml of nitric acid vandate molybdate reagent was added and made up to 50 ml with distilled water. After 10 minutes the OD was read at 420 nm. The content of phosphorus present in the sample was estimated from standard graph prepared using serial dilution of the standard phosphorus solution and expressed in mg 100 g^{-1}.

3.1.2.11. *In vitro* digestibility of starch

Starch digestibility was estimated as suggested by Satterlee *et al* (1979). One gram of the powdered sample in 100 ml water was gelatinised and boiled for one hour and filtered. One ml of gelatinised solution was taken and one ml of the enzyme solution (saliva diluted with equal quantity of water) was added. The mixture was incubated at 37 °C for 1-2 hours. The reaction was stopped by adding 1 ml of NaOH. Later, glucose was estimated by the method of Somoygi (1952).

3.1.2.12. *In vitro* availability of calcium, iron and phosphorus

HCl extractability of minerals in foods is an index of their bioavailability from foods. Thus, the solubility of minerals in foods subjected to *in vitro* gastric intestinal digestion is a useful indicator of mineral bioavailability.

For HCl extractability of minerals, the sample was extracted with 0.03 N hydrochloric acid by shaking the contents at 37 °C for 3 hours. The clear extract obtained after filtration with Whatman No: 42 filter paper was oven dried at 100 °C and wet acid digested. The amount of HCl extractable calcium, iron and phosphorus in the digested samples were determined by the method as described above for the estimation of total mineral. HCl extractability of each mineral was derived by using the following formula (Duhan *et al.*, 2001).

$$\text{Mineral Extractability, percent} = \frac{\text{Mineral Extractability in 0.03 N HCl}}{\text{Total mineral}} \times 100$$

3.1.3. Organoleptic evaluation of bamboo seed

Three products namely cooked bamboo rice (by straining method), *kanji* and *payasam* were prepared from bamboo seed by following standard procedures and organoleptic evaluation was carried out.

3.1.3.1. Selection of judges

A series of organoleptic trials were carried out using simple triangle test at laboratory level to select a panel of ten judges between the age group of 18 to 35 years as suggested by Jellanick (1985).

3.1.3.2. Preparation of score card

Score card containing the six quality attributes like appearance, colour, flavour, texture, taste and overall acceptability were prepared for the assessment of bamboo seed products. Each of the above mentioned qualities were assessed by a nine point hedonic scale. The score card used for the evaluation of bamboo seed products is given in the Appendix 1

3.1.3.3. Organoleptic evaluation of bamboo seed

Organoleptic evaluation of bamboo seed was carried out by preparing cooked rice, *kanji* and *payasam* by standard procedures. The products prepared from bamboo seed were compared with similar products prepared from parboiled rice. The procedures are given in Appendix 2-4. The evaluation was carried out in the morning time using the score card by a panel of ten selected judges.

Experiment no: 2

3.2. Preparation of bamboo seed flour

Roasted and unroasted bamboo seed flour was prepared from bamboo seed in five different lots. The flour was packed in 200 gauge polythene covers and stored for three months under ambient condition (Plate 4).

3.3. Quality evaluation of bamboo seed flour

Roasted and unroasted flour prepared from bamboo seed were evaluated for the following aspects initially and after three months of storage of the flour.

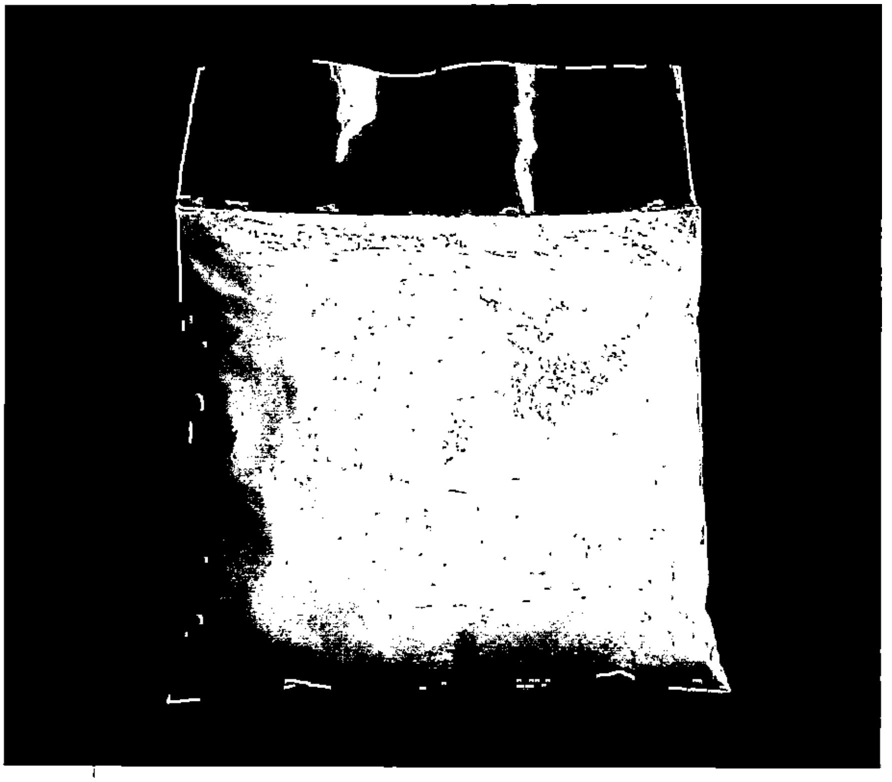

Plate 4: Bamboo seed flour kept for storage

3.3.1. Physical qualities of bamboo seed flour

Physical qualities of roasted and unroasted bamboo seed flour were assessed using standard techniques. The following physical qualities were evaluated.

3.3.1.1. Bulk density

The bulk density was determined by the method described by Okaka and Potter (1977). Fifty gram sample was put into a 100 ml graduated cylinder. The cylinder was tapped 50 times and the bulk density was calculated as weight per unit volume of sample.

3.3.1.2. Water absorption index (WAI) and water solubility index (WSI)

WAI and WSI of flours were determined by the method of Anderson *et al* (1969). The ground flour samples were mixed with 30 ml distilled water using a glass rod and cooked at 90 ^{0}C for 15 min in water bath. The cooked paste was cooled to room temperature and transferred to centrifuge tubes and centrifuged for 10 min. WAI and WSI are calculated by the expressions

$$WAI = \frac{\text{Weight of the sediment}}{\text{Weight of the dry solids}}$$

$$WSI = \frac{\text{Weight of the dissolved solids in supernatant}}{\text{Weight of the dry solids}}$$

3.3.1.3. Starch

The starch content was estimated colorimetrically using anthrone reagent (A. O. A. C, 1980) and the procedure is described in 3.1.2.4.

3.3.1.4. Gluten content

The gluten content was analysed by the method given by Kerkkonen *et al* (1975). To 50 g of flour sufficient water was added so as to make a stiff dough. Allowed to stand in a beaker of water and gently kneaded under a stream of running water until the starch washed away and the water squeezed out becomes clear. The residue was squeezed and dried.

3.3.1.5. Retrogradation property

Retrogradation index of bamboo seed flour was worked out as described by Singh *et al* (2005b). Flour pastes (9%) were heated to 90 ^{0}C for 20 min and held for 20 min at 90 ^{0}C and then cooled to 50 ^{0}C. The cooked flour pastes were stored for 3, 6, 9 and 12 days at 4 ^{0}C. Syneresis was measured as percentage amount of water released after centrifugation for 15 min.

3.3.2. Acceptability of bamboo seed flour based products

The following traditional products were prepared using roasted and unroasted bamboo seed flour by standard procedures initially and after three months of storage of flour.

Roasted flour - *puttu, idiyappam* and *ada* (Standard procedures given in Appendix 5-7)

Unroasted flour - *appam, unniyappam* and *murukku* (Standard procedures given in Appendix 8-10)

The products were compared with the traditional concerned rice products. Organoleptic evaluation of the products prepared from roasted and unroasted bamboo seed flour was carried out in morning time using the score card by a panel of ten selected judges initially and after three months of storage of the flour.

3.3.3. Shelf life of bamboo seed flour

3.3.3.1. Microbial enumeration of bamboo seed flour

The total microbial count of roasted and unroasted bamboo seed flour was enumerated using serial dilution and plate count method as described by Agarawal and Hasija (1986) initially and at the end of three months of storage of the flour. One gram of sample was added to 9 ml sterile water and agitated for 20 min. One ml of this solution was transferred to a test tube containing 9 ml of sterile water to get 10^{-2} dilution and similarly 10^{-3}, 10^{-4} and 10^{-5} dilutions were also prepared.

Enumeration of total microbial count was carried out using nutrient agar media for bacteria, potato dextrose agar media for fungus and sabouraud's dextrose agar media for yeast, which was obtained from Himedia Lab, Mumbai. The dilution used for bacteria was 10^{-5} and for fungi and yeast 10^{-3} dilution was used.

3.3.3.2. Insect infestation in bamboo seed flour

By examining the roasted and unroasted bamboo seed flour under the microscope, the presences of storage insects were assessed at the end of three months of storage of the flour.

3.4. Statistical Analysis

The observations recorded were tabulated and the data was analysed statistically as Completely Randomised Design (CRD). The scores of organoleptic evaluation were assessed by Kendall's coefficient of concordance and Mann Whitney 'U' value. The comparison of bamboo seed with rice and wheat was statistically analysed by paired 't' test.

Results

4. RESULTS

The results pertaining to the study entitled **"Quality evaluation of bamboo seed and its products"** are presented in this chapter.

4.1. Quality evaluation of bamboo seed

Bamboo seed was analysed for various quality attributes like cooking qualities, nutritional and biochemical qualities and organoleptic qualities.

4.1.1. Cooking qualities of bamboo seed

Cooking qualities of bamboo seed like cooking time, water uptake, volume expansion, grain elongation, amylose content, gelatinisation temperature index and gel consistency were analysed. The results are presented in Table 1.

Table 1: Cooking qualities of bamboo seed

Quality parameters	Values
Cooking time (min)	70
Water uptake (ml/ g)	6.90
Volume expansion ratio	2.16
Grain elongation ratio	0.89
Amylose content (%)	34.4
Gelatinisation temperature index	High
Gel consistency (mm)	48.20

Mean of five replications

Cooking time of 70 min was taken for obtaining optimum cooked bamboo seed. Since prolonged cooking was noted for bamboo seed in ordinary cooking, pressure cooking was tried. Cooking time of 18 min was taken for bamboo seed in pressure cooking.

The water uptake by bamboo seed while cooking was measured and it was found to be 6.90 ml/g of bamboo seed with a volume expansion ratio of 2.16. Grain elongation ratio in bamboo seed was recorded as 0.89.

The amylose content in bamboo seed was 34.4 percent. Gelatinisation temperature index was found to be high in bamboo seed. A gel consistency of 48.20 mm was observed in bamboo seed.

4.1.2. Nutritional and biochemical qualities of bamboo seed

Bamboo seed was analysed for nutritional and biochemical qualities like moisture, protein, fat, starch, reducing sugar, total sugar, fibre, calcium, phosphorus and iron. *In vitro* digestibility of starch, *in vitro* availability of calcium, iron and phosphorus were also analysed by standard techniques. The results for nutritional and biochemical qualities are presented in Table 2.

The moisture content in dried and milled bamboo seed was found to be 6.70 percent. The analysis of protein content in bamboo seed revealed that it contains 13.78 percent protein. The fat content in bamboo seed was observed as one percent.

Starch content of 62.56 percent was noted in bamboo seed. Reducing sugar and total sugar in bamboo seed was 0.41 and 0.99 percent respectively. Fibre content in bamboo seed was recorded as 0.92 percent.

The calcium content in bamboo seed was 30.60 mg $100g^{-1}$. Bamboo seed contains good amount of phosphorus and it was found to be 158.60 mg $100g^{-1}$. The iron content in bamboo seed was 5.94 mg $100g^{-1}$.

Table 2: Nutritional and biochemical qualities of bamboo seed (per 100 g)

Quality parameters	Values
Moisture (g)	6.70
Protein (g)	13.78
Fat (g)	1.00
Starch (g)	62.56
Reducing sugar (g)	0.41
Total sugars (g)	0.99
Fibre (g)	0.92
Calcium (mg)	30.60
Phosphorus (mg)	158.60
Iron (mg)	5.94
In vitro starch digestibility (%)	50.16
In vitro calcium availability (%)	20.20
In vitro iron availability (%)	10.72
In vitro phosphorus availability (%)	20.72

Mean of five replications

In vitro starch digestibility of bamboo seed was estimated and it was found to be 50.16 percent. *In vitro* availability of calcium, iron and phosphorus of bamboo seed was found to be 20.20, 10.72 and 20.72 percent respectively.

4.1.2.1. Comparison of nutritional components of bamboo seed with rice and wheat

The major nutritional and biochemical constituents like moisture, protein, fat, fibre, calcium, phosphorus and iron of bamboo seed were compared with the values for these components in rice and wheat as given by National Institute of Nutrition (NIN), Hyderabad (Gopalan *et al.* 2007). The comparison is given in Table 3.

The moisture content in bamboo seed was found to be significantly lower than rice and wheat. The moisture content in rice and wheat was 13.7 percent and 12.8 percent respectively, whereas in bamboo seed it was only 6.70 percent.

In bamboo seed the protein content (13.78 %) was found to be significantly higher than rice (6.8 %) and wheat (11.8 %). The fat content in bamboo seed varied significantly from rice and wheat. The fat content in bamboo seed (1 %) was slightly higher than rice (0.5 %) and lower than wheat (1.5 %).

The fibre content in bamboo seed differed significantly from rice and wheat. In bamboo seed the fibre content was 0.92 percent and it was found to be slightly lower than wheat (1.2%) and higher than rice (0.2%)..

In bamboo seed the calcium content was found to be significantly lower than wheat (41 mg $100g^{-1}$). But compared to rice (10 mg $100g^{-1}$), it was found that bamboo seed contain more calcium (30.60 mg $100g^{-1}$).

The phosphorus content in bamboo seed was found to be significantly lower than rice and wheat. In bamboo seed the phosphorus content was 158.60 mg $100g^{-1}$ where as in rice and wheat it was 160 mg $100g^{-1}$ and 306 mg $100g^{-1}$ respectively.

Significantly higher amount of iron was observed in bamboo seed (5.94 mg $100g^{-1}$) compared to rice (0.7 mg $100g^{-1}$) and wheat (5.3 mg $100g^{-1}$) (Fig 1-3).

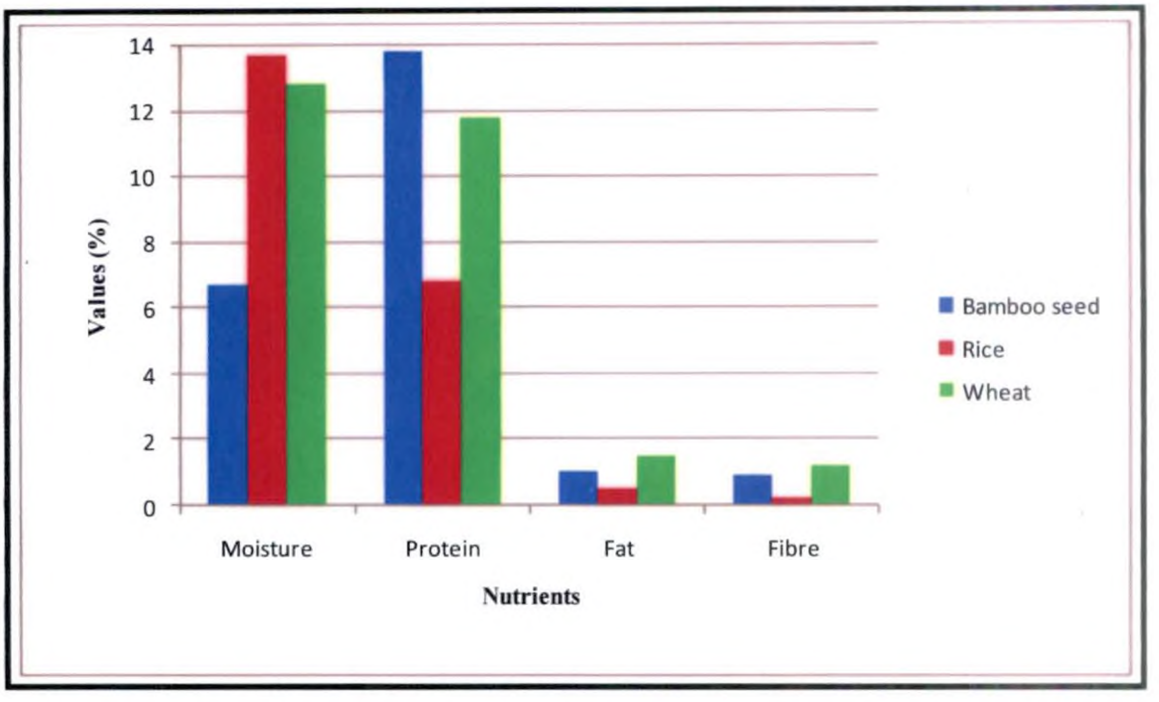

Fig 1: Comparison of nutritional constituents in bamboo seed with rice and wheat

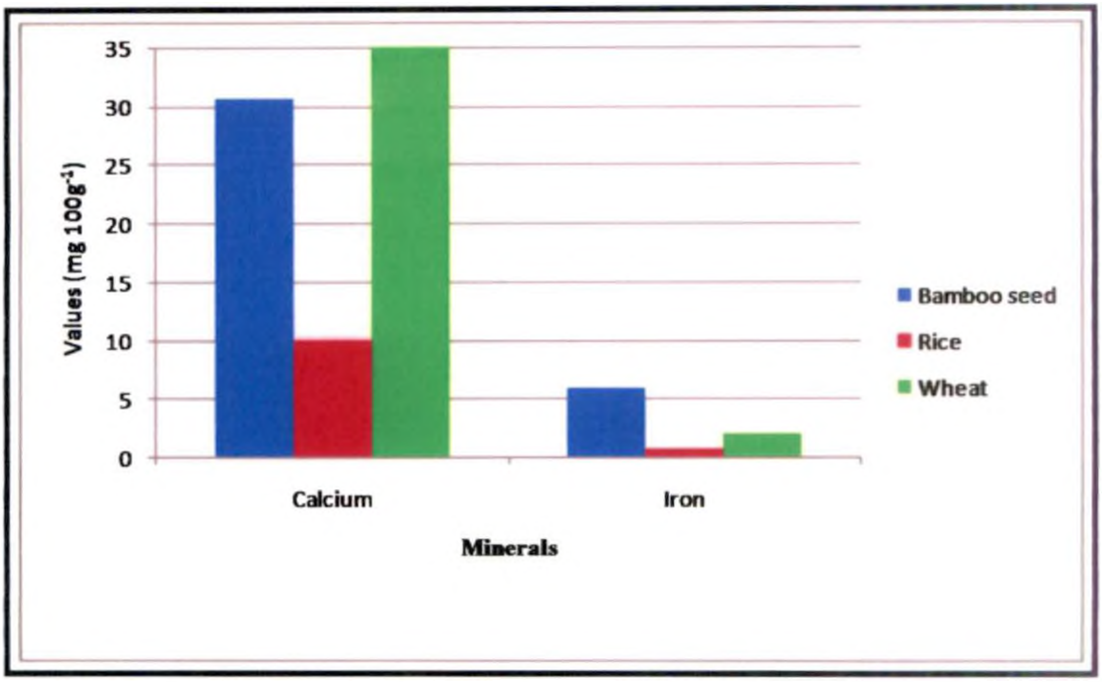

Fig 2: Comparison of calcium and iron in bamboo seed with rice and wheat

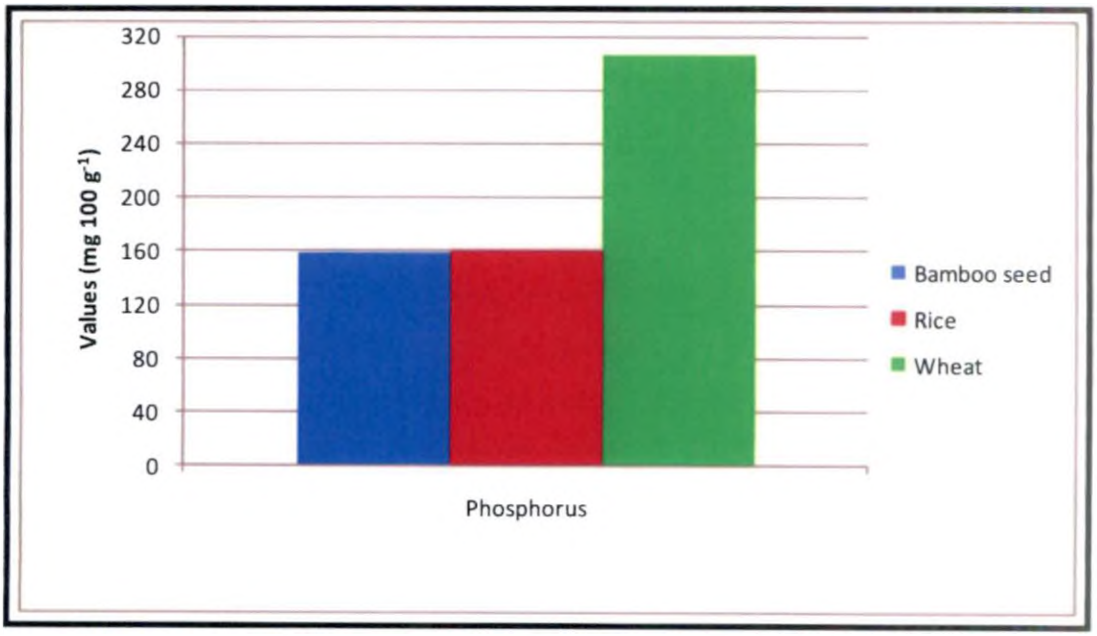

Fig 3: Comparison of phosphorus in bamboo seed with rice and wheat

Table 3: Nutritional components of bamboo seed in comparison with rice and wheat (per 100 g)

Nutrients	Bamboo seed	Rice	Wheat	t value†	t value††
Moisture (g)	6.70	13.7	12.8	57.16**	49.81**
Protein (g)	13.78	6.8	11.8	13.17**	3.74*
Fat (g)	1.00	0.5	1.5	2.80*	2.80*
Fibre (g)	0.92	0.2	1.2	6.00**	2.33*
Calcium(mg)	30.60	10.00	41.00	15.11**	7.63**
Phosphorus(mg)	158.60	160	306	0.59*	61.96**
Iron (mg)	5.94	0.70	5.30	18.46**	2.25*

† Rice, †† Wheat, *Significant at 5% level, **Significant at 1% level

4.1.3. Organoleptic evaluation of bamboo seed

For evaluating the organoleptic qualities, three products namely cooked bamboo rice (by straining method), *kanji* and *payasam* were prepared and the products were compared with similar products prepared from parboiled rice. The products were evaluated for different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability (Fig 4). The products were ranked for different quality attributes based on mean scores using Kendall's (W) test. The results of the organoleptic evaluation of the bamboo seed products are presented in Table 4. The mean rank scores obtained on the basis of Kendall's coefficient of concordance are also given in the same table.

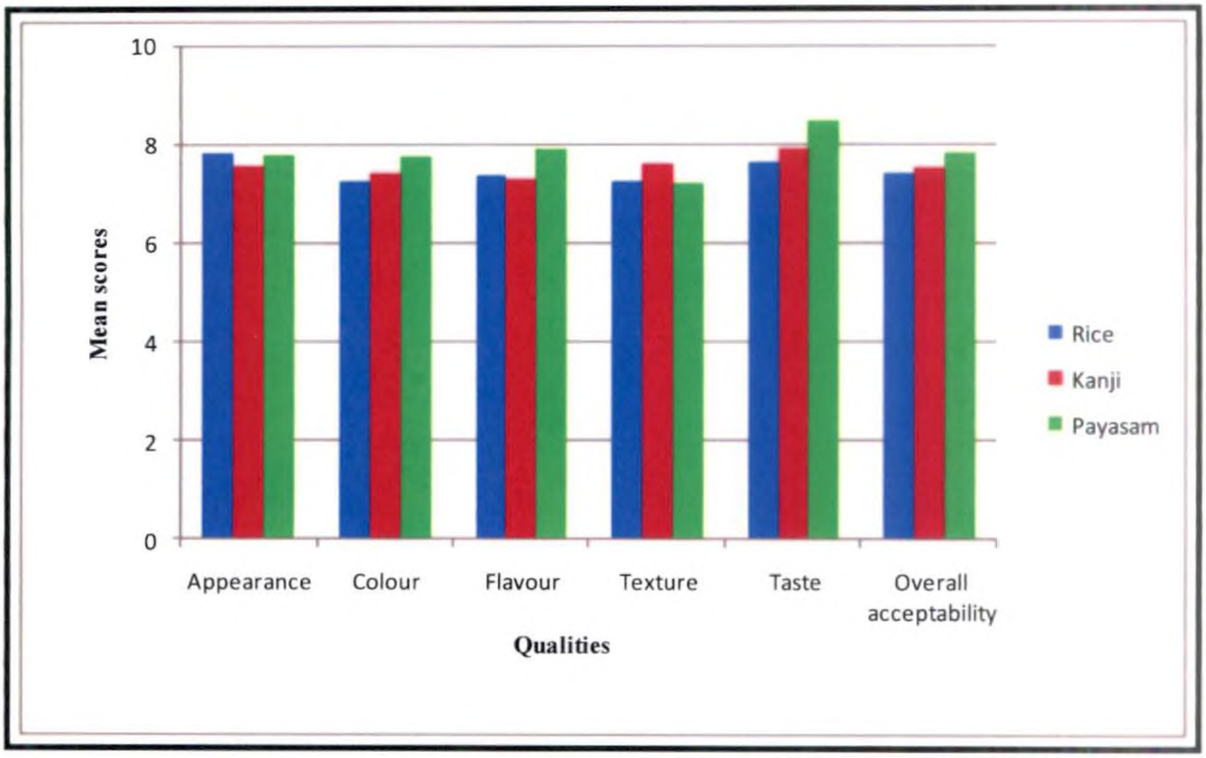

Fig 4: Mean scores for organoleptic evaluation of bamboo seed

Table 4: Mean scores for organoleptic evaluation of bamboo seed and rice products

Products	Item	Characters					
		Appearance	**Colour**	**Flavour**	**Texture**	**Taste**	**Overall acceptability**
Cooked Rice	BS	7.48 (1.80)	7.26 (1.45)	7.38 (1.70)	7.24 (1.80)	7.64 (1.40)	7.40 (1.20)
	R	7.74 (1.60)	8.00 (2.25)	7.22 (1.50)	7.88 (1.90)	7.70 (1.55)	7.57 (1.50)
Kanji	BS	7.56 (1.60)	7.40 (1.75)	7.28 (1.30)	7.58 (2.70)	7.90 (1.75)	7.53 (1.85)
	R	7.74 (1.55)	8.00 (2.15)	7.26 (1.50)	7.88 (2.00)	7.70 (1.45)	7.57 (1.50)
Payasam	BS	7.78 (2.60)	7.74 (2.80)	7.92 (3.00)	7.20 (1.50)	8.46 (2.85)	7.81 (2.95)
	R	8.02 (2.85)	7.88 (1.60)	7.90 (3.00)	7.95 (2.10)	8.52 (3.00)	8.06 (3.00)
Kendalls (W) value	BS	0.303*	0.543**	0.832**	0.433*	0.603**	0.803**
	R	0.620**	0.196*	0.833**	0.120*	0.814**	0.789**

Figures in parenthesis are mean rank scores, BS-Bamboo seed, R- Parboiled rice
*Significance at 5% level, **Significance at 1% level

In the case of cooked rice from bamboo seed (Plate 5), a mean score of 7.48 was recorded for appearance with mean rank score of 1.80. For the colour of cooked bamboo seed rice a mean score of 7.26 was obtained and the mean rank score was 1.45. The mean scores for flavour and texture of cooked bamboo seed rice were 7.38 and 7.24 with mean rank scores of 1.70 and 1.80 respectively. Mean score for taste of bamboo seed rice was 7.64 with a mean rank score of 1.40. The overall acceptability score for cooked bamboo seed rice was 7.40 with a mean

Plate 6: Bamboo seed *kanji*

Plate 5: Cooked bamboo rice

Plate 6: Bamboo seed *kanji*

Plate 7: Bamboo seed *payasam*

rank score of 1.20. Cooked rice prepared from bamboo seed had higher score only for flavour compared to cooked rice prepared from parboiled rice.

Bamboo seed *kanji* (Plate 6) got a mean score of 7.56 for appearance with a mean rank score of 1.60. Mean score for colour of bamboo seed *kanji* was 7.40 and mean rank score was 1.75. Mean scores for flavour and texture of bamboo seed *kanji* were 7.28 and 7.58 with rank scores 1.30 and 2.70 respectively. Mean score for taste of bamboo seed *kanji* was 7.90 and the rank score was 1.75. Bamboo seed *kanji* got an overall acceptability score of 7.53 with a mean rank score of 1.85. Compared to rice *kanji* bamboo seed *kanji* had higher mean score for taste and flavour.

The mean score for appearance of bamboo seed *payasam* (Plate 7) was 7.78 with a mean rank score of 2.60. The mean score for colour, texture and flavour of bamboo seed *payasam* was 7.74, 7.20 and 7.92 respectively with a mean rank score of 2.80, 1.50 and 3.0 respectively. A mean score of 8.46 was obtained for the taste of bamboo seed *payasam* with a mean rank score of 2.85. Mean score for overall acceptability of bamboo seed *payasam* was 7.81 with a mean rank score of 2.95. Rice *payasam* had higher mean scores for all attributes except for flavour, compared to bamboo seed *payasam.*

From the table it is clear that the judges had significant agreement in differentiation of all the parameters. Cooked rice, *kanji* and *payasam* from bamboo seed had mean score above 7.0 for all the parameters. Among the three products, bamboo seed *payasam* was found to be the most acceptable product with higher mean score for all the parameters except for texture. For texture, bamboo seed *kanji* obtained the maximum score.

Shelf life of the products under ambient storage condition was recorded. Cooked rice, *kanji* and *payasam* prepared from bamboo seed and parboiled rice did not show much difference in shelf life. The flavour and taste of the products remained unchanged upto 15 hours in both bamboo seed and rice products.

4.2. Physical qualities of bamboo seed flour

Roasted and unroasted flour prepared from bamboo seed was evaluated for various physical qualities initially and after three months of storage. Physical qualities like bulk density, water absorption index, water solubility, starch, gluten content and retrogradation property were analysed. The results are given in Table 5.

The bulk density of roasted bamboo seed flour was found to be 0.90 g/ml initially and it decreased to 0.87 g/ml after three months of storage. In unroasted flour the bulk density was recorded as 0.80 g/ml initially and after three months of storage.

Table 5: Physical qualities of bamboo seed flour during storage

Physical qualities	Roasted flour		Unroasted flour	
	I	F	I	F
Bulk density (g/ml)	0.90	0.87	0.80	0.80
WAI (ratio)	14.56	14.52	12.92	12.82
WSI (ratio)	0.068	0.067	0.06	0.05
Starch (%)	60.96	60.60	62.30	61.32
Gluten content (g)	-	-	-	-

Means of five replication   I-initial, F-final

Water absorption index (WAI) in roasted bamboo seed flour was 14.56 initially, which showed slight decrease (14.52) after three months of storage. In unroasted flour, water absorption index was 12.92 initially and 12.82 after three months of storage.

Water solubility index (WSI) of roasted bamboo seed flour was 0.068 initially and 0.067 after three months of storage. In the case of unroasted flour it was 0.06 and 0.05 respectively.

In roasted bamboo seed flour, initial starch content was obtained as 60.96 percent. After three months of storage, it decreased slightly to 60.60 percent. In the case of unroasted flour, initial starch content was 62.30 percent and it decreased to 61.32 percent after three months of storage. Gluten content was also analysed in roasted and unroasted bamboo seed flour. No gluten was found in both flours initially and after three months of storage.

Table 6: Retrogradation property of bamboo seed flour during storage

Days of syneresis	Syneresis (%)			
	Roasted flour		Unroasted flour	
	I	F	I	F
3rd day	17.78	16.67	16.67	16.67
6th day	25.56	24.44	23.33	22.22
9th day	37.78	35.56	35.36	34.44
12th day	47.78	46.67	45.56	44.44

Means of five replication, I-initial, F-final

Retrogradation property of roasted and unroasted bamboo seed flour was evaluated initially and after three months of storage. The results are presented in Table 6. Before storage, in roasted flour, there was a gradual increase in syneresis percentage with advancement in days of storage of the starch paste. Syneresis was minimum during the third day (17.78 %) which increased to 25.56 percent on the 6^{th} day, 37.78 percent on the 9^{th} day and a maximum of 47.78 percent on the 12^{th} day. Slight decrease in the syneresis percentage was noted in the starch paste prepared from roasted flour after third month of storage and the percentage syneresis was 16.67, 24.44, 35.56 and 46.67 on 3^{rd}, 6^{th}, 9^{th}, and 12^{th} day respectively. Similar results were observed in the case of unroasted flour too. The syneresis percentage of starch paste prepared from unroasted bamboo seed flour before storage was 16.67, 23.33, 35.56, and 45.56 on 3rd, 6th, 9th, and 12th day respectively. Slight decrease in the syneresis percentage was noted in the starch paste prepared from unroasted flour after third month of storage and the syneresis percentage was noted as 16.78, 22.22, 34.44 and 44.44 on 3rd, 6th, 9th and 12th day respectively.

4.3. Acceptability of products from bamboo seed flour

Various products were prepared from roasted and unroasted bamboo seed flour initially from freshly prepared flour and after three months of storage of the flour. The organoleptic evaluation of the products were carried out. The prepared products were compared with the concerned traditional rice products.

The organoleptic evaluation was carried out using score card for different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability. All the products were ranked for different quality attributes based on mean rank scores using Kendall's (W) test. Mann Whitney 'U' statistic was used for comparing the products with the concerned traditional rice products by assigning Mann Whitney mean scores for each quality attribute. The results of the organoleptic evaluation are as follows.

4.3.1. Organoleptic evaluation of products from roasted bamboo seed flour

. Products namely *puttu*, *idiyappam* and *ada* were prepared using roasted bamboo seed flour and compared with similar products prepared using rice flour.

4.3.1.1. Bamboo seed *puttu*

The mean scores for different quality attributes of bamboo seed *puttu* (Fig 5) and rice *puttu* in initial and final evaluation are given in Table 7.

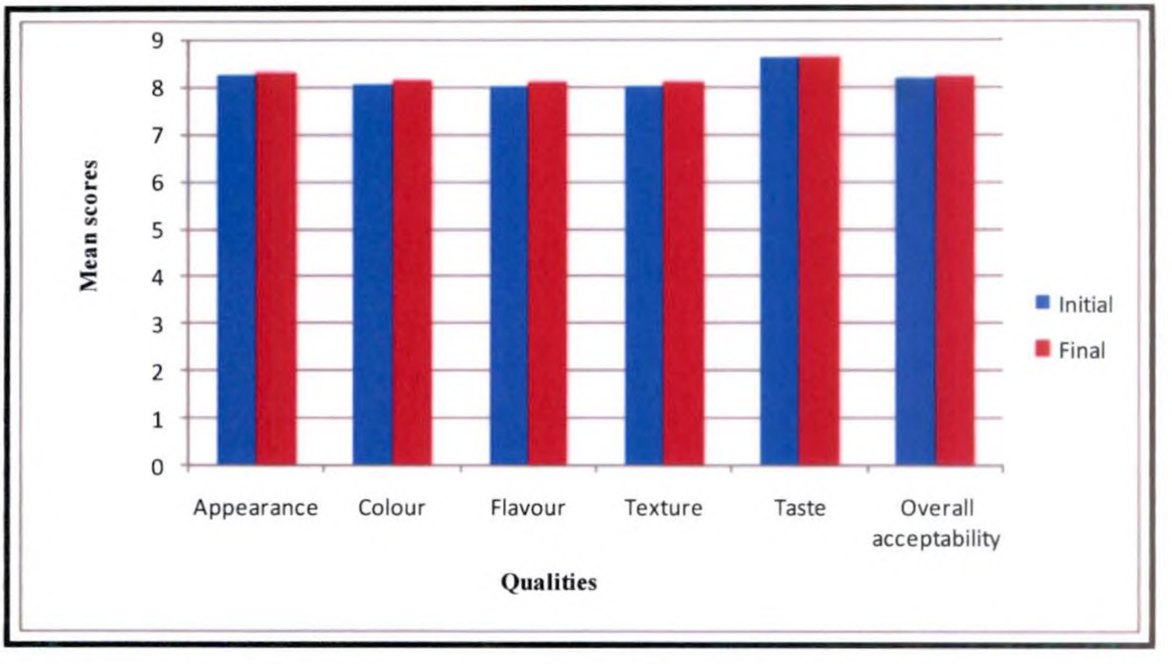

Fig 5: Comparison of organoleptic qualities of bamboo seed *puttu*

The mean scores for appearance of bamboo seed *puttu* (Plate 8) was 8.26 initially and a slight increase in mean score was noticed during final evaluation (8.28). Compared to rice *puttu* (Plate 9) a better mean score was observed for appearance of bamboo seed *puttu* in initial and final evaluation.

Table 7: Mean scores for different quality attributes of bamboo seed *puttu* and rice *puttu*

Puttu	Quality attributes											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Bamboo seed flour	8.26	8.28	8.06	8.14	8.00	8.10	8.00	8.10	8.60	8.62	8.19	8.20
Rice flour	7.86	8.02	7.86	8.16	7.74	8.14	7.80	8.00	8.28	8.48	7.96	8.24

I-initial, F-final

The mean scores for colour of bamboo seed *puttu* increased from 8.06 (initial) to 8.14 (final). Initially, the mean score for the colour of bamboo seed *puttu* was higher than rice *puttu*, but in final evaluation rice *puttu* obtained a better score of 8.16.

Initially, the mean score for flavour and texture of bamboo seed *puttu* was 8.00. An increase in mean score (8.10) was noticed for flavour and texture of bamboo seed *puttu* in final evaluation. When the mean scores for flavour and texture were compared with rice *puttu*, it was observed that rice *puttu* faired better with highest score for flavour during final evaluation.

Bamboo seed *puttu* had a mean score of 8.60 and 8.62 for taste in initial and final evaluation respectively. The mean score for taste of bamboo seed *puttu* was found to be better than rice *puttu* in both initial and final evaluation.

Plate 8: Bamboo seed *puttu*

1 – Rice, 2 - Bamboo seed

Plate 9: Comparison of bamboo seed *puttu* and rice *puttu*

Table 8: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *puttu* in comparison with rice *puttu*

Quality attributes	Initial †		Mann Whitney 'U' value	Final †		Mann Whitney 'U' value
	BSF	RF		BSF	RF	
Appearance	14.40	6.60	11.00**	13.65	7.35	18.50*
Colour	12.70	8.30	28.00^{NS}	9.95	11.05	44.50^{NS}
Flavour	13.25	7.75	22.50*	9.85	11.15	43.50^{NS}
Texture	12.65	8.35	28.50^{NS}	12.20	8.80	33.00^{NS}
Taste	13.85	7.15	16.50**	12.25	8.75	32.50^{NS}
Overall acceptability	14.40	6.60	11.00**	9.30	11.70	38.00^{NS}

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BSF- bamboo seed flour, RF- rice flour

The overall acceptability scores for bamboo seed *puttu* was found to be 8.16 initially, which increased to 8.20 in final evaluation. Initially the mean score for overall acceptability of bamboo seed *puttu* was found to be higher than rice *puttu*. But in final evaluation maximum score for overall acceptability was noted in rice *puttu*.

Comparison of different quality attributes of *puttu* prepared using bamboo seed flour and rice flour is given in Table 8. From the table it is clear that, initially, bamboo seed *puttu* was significantly better than rice *puttu* in all parameters except for colour and texture. In final evaluation bamboo seed *puttu* was found to be significantly better than rice *puttu* only in appearance and the difference observed for all other parameters were found to be statistically non significant.

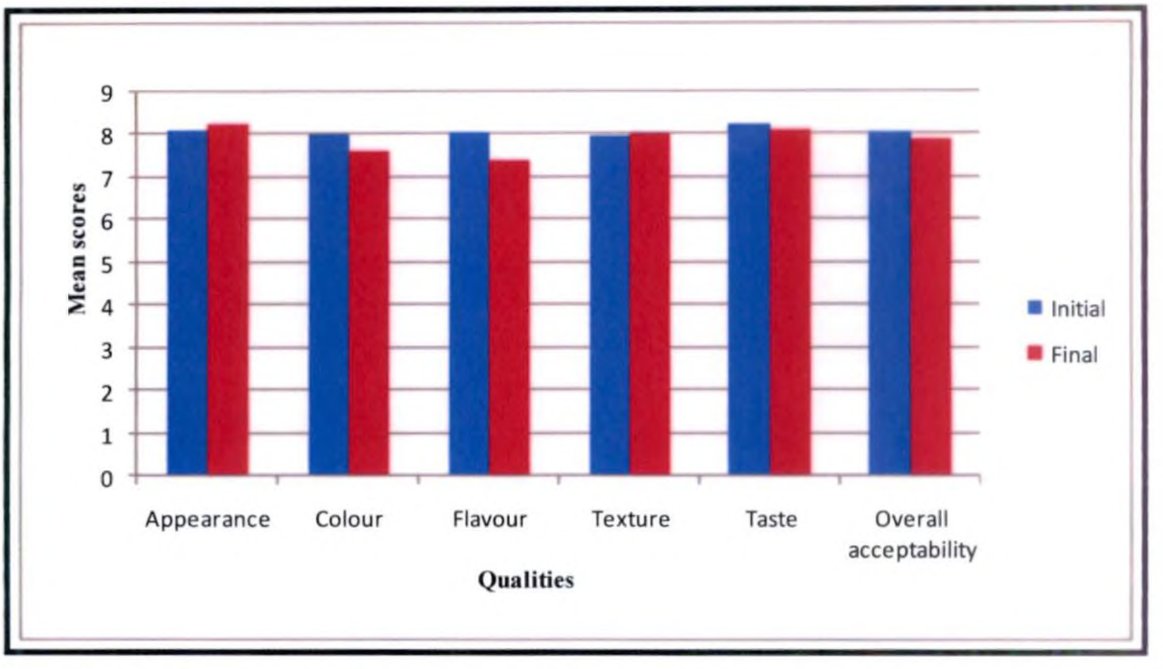

Fig 6: Comparison of organoleptic qualities of bamboo seed *idiyappam*

4.3.1.2. Bamboo seed *idiyappam*

The mean scores obtained for different quality attributes of bamboo seed *idiyappam* (Fig 6) and rice *idiyappam* in initial and final evaluation are presented in Table 9.

Table 9: Mean scores for different quality attributes of bamboo seed *idiyappam* and rice *idiyappam*

Idiyappam	**Quality attributes**											
	Appearance		**Colour**		**Flavour**		**Texture**		**Taste**		**Overall acceptability**	
	I	**F**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**F**	**I**	**F**
Bamboo seed flour	8.12	8.22	8.00	7.62	8.06	7.40	7.96	8.00	8.22	8.12	8.06	7.89
Rice flour	7.76	7.96	7.82	7.74	7.80	7.64	7.74	7.98	8.00	8.04	7.81	7.88

I-initial, F-final

The mean score for appearance of bamboo seed *idiyappam* (Plate 10) was higher than rice *idiyappam* (Plate 11) in initial and final evaluation. Initially the mean score for appearance of bamboo seed *idiyappam* was 8.12 which increased to 8.22 during final evaluation.

The mean score for colour and flavour of bamboo seed *idiyappam* decreased in final evaluation and the decrease in mean scores were from 8.00 to 7.62 and 8.06 to 7.40 respectively. Compared to rice *idiyappam* the bamboo seed *idiyappam* had a better mean score for colour and flavour. But in final evaluation maximum mean score for colour and flavour was noted in rice *idiyappam*.

Plate 10: Bamboo seed *idiyappam*

1 – Rice, 2 - Bamboo seed

Plate 11: Comparison of bamboo seed *idiyappam* and rice *idiyappam*

Table 10: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *idiyappam* in comparison with rice *idiyappam*

Quality attributes	Initial †		Mann Whitney U value	Final †		Mann Whitney U value
	BSF	RF		BSF	RF	
Appearance	13.75	7.25	17.50*	13.60	7.40	19.00*
Colour	13.00	8.00	25.00*	8.60	12.40	31.00^{NS}
Flavour	13.85	7.15	16.50**	7.60	13.40	21.00*
Texture	13.15	7.85	23.50*	10.55	10.45	49.50^{NS}
Taste	12.85	8.15	26.50^{NS}	11.80	9.20	37.00^{NS}
Overall acceptability	14.90	6.10	6.00**	10.70	10.30	48.00^{NS}

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BSF- bamboo seed flour, RF- rice flour

The mean score for texture and taste of bamboo seed *idiyappam* was initially 7.96 and 8.22 respectively. The mean score for texture increased to 8.00 during final evaluation. Whereas the mean score for taste decreased to 8.12. Compared to rice *idiyappam*, bamboo seed *idiyappam* had better mean scores for texture and taste in both initial and final evaluation.

A decrease in mean score from 8.06 to 7.89 was noted in bamboo seed *idiyappam* during final evaluation for overall acceptability. Compared to rice *idiyappam*, a better mean score for overall acceptability was noted in bamboo seed *idiyappam* in the two evaluations.

Comparison of different quality attributes of *idiyappam* prepared using bamboo seed flour and rice flour is given in Table 10. On the basis of Mann Whitney 'U' value, the mean scores for the quality attributes of bamboo seed *idiyappam* namely appearance, colour, flavour, texture and overall acceptability differed significantly from rice *idiyappam*. But the difference observed in mean scores of taste among bamboo seed *idiyappam* and rice *idiyappam* was non significant. In final evaluation bamboo seed *idiyappam* had significantly better mean score only for appearance and flavour than rice *idiyappam*. For all other parameters the difference observed among mean scores were found to be non significant.

4.3.1.3. Bamboo seed *Ada*

The mean scores obtained for different quality attributes of bamboo seed *ada* (Fig 7) and rice *ada* are given in Table 11.

Table 11: Mean scores for different quality attributes of bamboo seed *ada* and rice *ada*

Ada	Quality attributes											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Bamboo seed flour	8.20	8.06	7.92	7.50	8.32	8.16	7.84	7.86	8.34	8.46	8.12	7.96
Rice flour	7.86	7.94	7.86	7.60	8.02	8.22	7.78	7.94	8.14	8.24	7.94	7.99

I-initial, F-final

The mean score for appearance of bamboo seed *ada* (Plate 12) was 8.20 initially which decreased to 8.06 during final evaluation. A better mean score was noted for appearance of bamboo seed *ada* compared to rice *ada* (Plate 13) in both initial and final evaluation.

A decrease in mean score for colour (7.92 to 7.50) and texture (8.32 to 8.16) of bamboo seed *ada* was observed in final evaluation. Compared to rice *ada*, bamboo seed *ada* had better mean scores for colour and flavour initially. During final evaluation, higher mean score for colour (7.60) and flavor (8.22) was observed in rice *ada*.

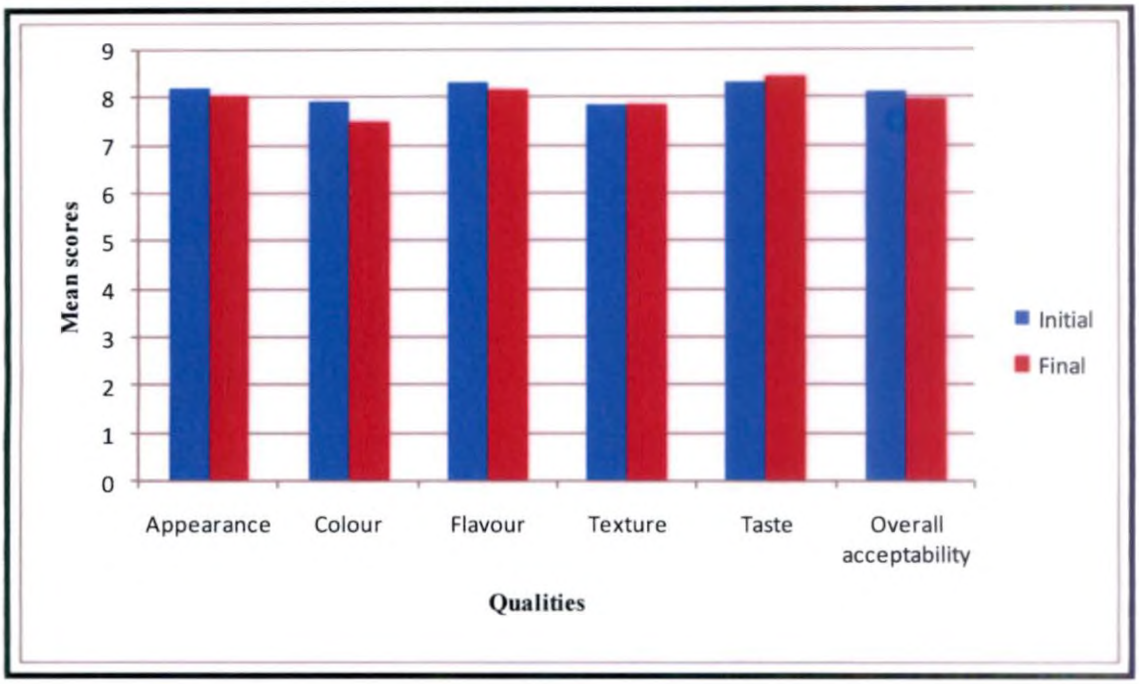

Fig 7: Comparison of organoleptic qualities of bamboo seed *ada*

Plate 12: Bamboo seed *ada*

1 – Rice, 2 - Bamboo seed

Plate 13: Comparison of bamboo seed *ada* and rice *ada*

Mean score for texture of bamboo seed *ada* increased from 7.84 to 7.86 in final evaluation. Initially, bamboo seed *ada* had better mean score for texture than rice *ada*. But a higher score for texture (7.99) was noted in rice *ada* during final evaluation. Bamboo seed *ada* had a mean score of 8.34 and 8.46 for taste in initial and final evaluation respectively. In both evaluations, bamboo seed *ada* had better mean score for taste compared to rice *ada*.

Table 12: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *ada* in comparison with rice *ada*

Quality attributes	Initial †		Mann Whitney 'U' value	Final †		Mann Whitney 'U' value
	BSF	RF		BSF	RF	
Appearance	13.55	7.45	19.50*	12.55	8.45	29.50^{NS}
Colour	11.45	9.55	40.50^{NS}	9.40	11.60	39.00^{NS}
Flavour	14.50	6.50	10.00**	9.30	11.70	38.00^{NS}
Texture	11.00	10.00	45.00^{NS}	8.50	12.50	30.00^{NS}
Taste	12.75	8.25	27.50^{NS}	13.05	7.95	24.50*
Overall acceptability	14.90	6.10	6.00**	9.50	11.50	40.00^{NS}

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BSF- bamboo seed flour, RF- rice flour

Initially, a mean score of 8.12 was noticed for the overall acceptability of bamboo seed *ada* which decreased to 7.96 in final evaluation. Bamboo seed *ada* had higher mean score than rice *ada* initially, but during final evaluation rice *ada* obtained higher mean sore of 7.99 for overall acceptability.

Comparison of different quality attributes of *ada* prepared using bamboo seed flour and rice flour is given in Table 12. From the table it is obvious that initially bamboo seed *ada* was significantly better than rice *ada* in appearance, flavour and overall acceptability. Initially the difference observed in mean scores for colour, texture and taste of bamboo seed *ada* and rice *ada* was statistically non significant. During final evaluation, significant difference was noticed in taste of bamboo seed *ada* and rice *ada*. The difference in mean scores observed in all other parameters were statistically non significant.

4.3.1.4. Comparison of bamboo seed products prepared from roasted flour

Three products namely, *puttu idiyappam* and *ada* were prepared from roasted bamboo seed flour and the products were compared by Kendall's 'W' test and the results are presented in Table 13.

From the table it is clear that all the three products had a mean score above 7.00 for different quality attributes in initial and final evaluation. Kendall's value assigned to each quality attribute revealed that judges had significant agreement in differentiation of all the parameters. Highest mean rank scores for different quality attributes were noticed in bamboo seed *puttu* in both initial and final evaluation except for flavour. For flavour, bamboo seed *ada* had maximum mean score.

To choose the most acceptable product from roasted bamboo seed flour, in terms of the six parameters namely appearance, colour, flavour, texture, taste and overall acceptability, a relative ranking sequence of the products were worked out for each parameter based on the Kendall's mean rank scores obtained for each quality attribute.

After initial picking of the products based on overall acceptability, the corresponding rank for each parameter were picked up with a descending order of importance as taste, texture, flavour, colour and appearance. This final order was taken into consideration for selecting the acceptable products. This exercise was carried out in both initial and final stages and is presented in Table 14.

Table 13: Mean scores and mean rank scores for different quality attributes of products prepared from roasted bamboo seed flour

Products	Characters											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Puttu	8.26 (2.40)	8.28 (2.30)	8.06 (2.15)	8.14 (2.90)	8.00 (1.60)	8.1 (2.40)	8.00 (2.20)	8.14 (2.65)	8.6 (2.65)	8.62 (2.65)	8.19 (2.60)	8.2 (2.85)
Idiyappam	8.12 (1.75)	8.22 (2.25)	8.00 (2.00)	7.62 (1.60)	8.06 (1.55)	7.4 (1.00)	7.96 (2.00)	8 (2.05)	8.22 (1.30)	8.12 (1.10)	8.06 (1.45)	7.89 (1.35)
Ada	8.2 (1.85)	8.06 (1.45)	7.92 (1.85)	7.5 (1.50)	8.32 (2.85)	8.16 (2.60)	7.84 (1.80)	7.86 (1.30)	8.34 (2.05)	8.46 (2.25)	8.12 (1.95)	7.96 (1.80)
Kendall's (W) value	0.144*	0.276*	0.029*	0.642**	0.678**	0.844**	0.057*	0.495*	0.508**	0.762**	0.442*	0.624**

Figures in parenthesis are mean rank scores, I-initial, F-final

**Significant at 1% level, *Significant at 5 % level

Table 14: Ranking of products from roasted flour on the basis of mean rank scores

Products	Overall acceptability		Taste		Texture		Flavour		Colour		Appearance	
	I	F	I	F	I	F	I	F	I	F	I	F
Puttu	1	1	1	1	1	1	2	2	1	1	1	1
Idiyappam	3	3	3	3	2	2	3	3	2	2	3	2
Ada	2	2	2	2	3	3	1	1	3	3	2	3

I-initial, F-final

. From the table it is clear that among the three products prepared using roasted bamboo seed flour bamboo seed *puttu* was the most acceptable product in initial and final evaluation followed by bamboo seed *ada* and bamboo seed *idiyappam*.

4.3.2. Organoleptic evaluation of products from unroasted bamboo seed flour

Products namely *appam*, *unniyappam* and *murukku* were prepared using unroasted bamboo seed flour and compared with similar products prepared using rice flour.

4.3.2.1. Bamboo seed *Appam*

The mean scores obtained for different quality attributes of bamboo seed *appam* (Fig 8) and rice *appam* are given in Table 15.

The mean score for appearance of bamboo seed *appam* (Plate 14) was 7.54 initially and it decreased to 7.48 finally. Compared to rice *appam* (Plate 15) a better mean score was observed for appearance of bamboo seed *appam* in both initial and final evaluation.

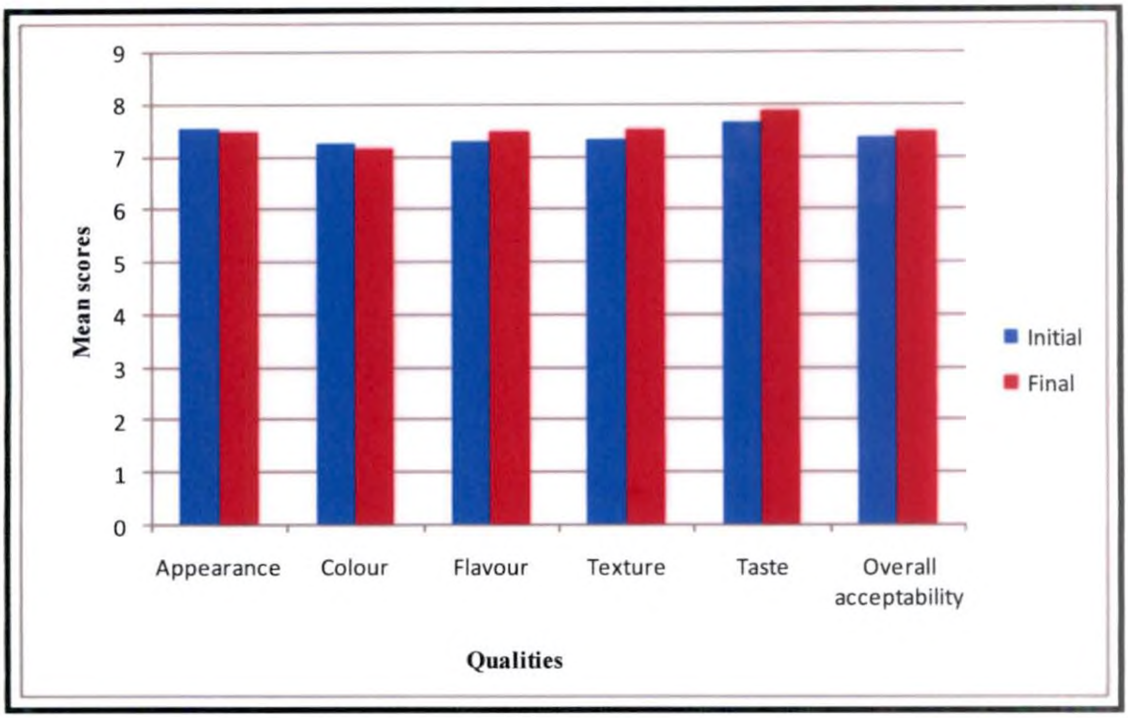

Fig 8: Comparison of organoleptic qualities of bamboo seed *appam*

Table 15: Mean scores for different quality attributes of bamboo seed *appam* and rice *appam*

Appam	Quality attributes											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Bamboo seed flour	7.54	7.48	7.26	7.14	7.28	7.48	7.32	7.52	7.64	7.88	7.37	7.47
Rice flour	7.36	7.46	7.24	7.46	7.18	7.52	7.32	7.6	7.40	7.82	7.28	7.58

I-initial, F-final

Mean score for colour of bamboo seed *appam* was 7.26 initially and a decrease in mean score (7.14) was noted in final evaluation. Initially, bamboo seed *appam* had better mean score for colour than rice *appam*. But a higher mean score for colour was observed in rice *appam* during final evaluation.

Flavour of bamboo seed *appam* got a mean score of 7.28 initially and an increase (7.48) in mean score was observed during final evaluation. Bamboo seed *appam* got a higher score than rice *appam* initially but in final evaluation rice *appam* had a higher score of 7.52.

Texture of bamboo seed *appam* got mean score of 7.32 initially and 7.52 finally. Initially, the mean score for texture of bamboo seed *appam* and rice *appam* were same. In final evaluation mean scores of both the products increased and higher mean score was noticed in rice *appam*.

The mean score for taste of bamboo seed *appam* was 7.64 (initially) and 7.52 (finally). Compared to rice *appam*, a better mean score for taste was observed in bamboo seed *appam* initially and finally.

Plate 14: Bamboo seed *appam*

1 – Rice, 2 - Bamboo seed

Plate 15: Comparison of bamboo seed *appam* and rice *appam*

The mean scores for overall acceptability of bamboo seed *appam* was 7.37 initially and 7.47 during final evaluation. Bamboo seed *appam* had a higher score than rice *appam* during initial evaluation of overall acceptability, but in final evaluation rice *appam* got a high score of 7.58.

Table 16: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *appam* in comparison with rice *appam*

Quality attributes	Initial †		Mann Whitney 'U' value	Final †		Mann Whitney 'U' value
	BSF	RF		BSF	RF	
Appearance	13.10	7.90	24.00*	10.80	10.20	47.00^{NS}
Colour	10.65	10.35	48.50^{NS}	6.45	14.55	9.50**
Flavour	11.65	9.35	38.50^{NS}	10.40	10.60	49.00^{NS}
Texture	10.45	10.55	49.50^{NS}	9.20	11.80	37.00^{NS}
Taste	12.85	8.15	26.50^{NS}	11.70	9.30	38.00^{NS}
Overall acceptability	12.90	8.10	26.00^{NS}	8.20	12.80	27.00^{NS}

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BS- bamboo seed flour, RF- rice flour

Comparison of different quality attributes of *appam* prepared from bamboo seed flour and rice flour is given in Table 16. Initially, no significant difference was observed in mean scores for different quality attributes of bamboo seed *appam* and rice *appam* except for appearance. In final comparison, significant difference among mean scores was observed only for the colour of bamboo seed *appam* and rice *appam*.

4.3.2.2. Bamboo seed *Unniyappam*

The mean scores obtained for different quality attributes of bamboo seed *unniyappam* (Fig 9) and rice *unniyappam* during initial and final evaluation are given in Table 17.

Table 17: Mean scores for different quality attributes of bamboo seed *unniyappam* and rice *unniyappam*

Unniyappam	Quality attributes											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Bamboo seed flour	7.9	8.02	8.04	7.88	8.06	8.28	8.1	8.12	8.4	8.54	8.13	8.2
Rice flour	8.00	8.00	7.92	7.92	7.98	8.36	7.9	8.2	8.28	8.6	7.91	8.26

I-initial, F-final

Mean score for appearance of bamboo seed increased from 7.9 to 8.02 initially. Rice *unniyappam* had a higher mean score for appearance than bamboo seed *unniyappam* (Plate 16) initially. But a higher score for appearance was noted in bamboo seed *unniyappam* during final evaluation.

Bamboo seed *unniyappam* had a mean score of 8.04 and 7.88 for colour in initial and final evaluation respectively. Colour of rice *unniyappam* (Plate 17) had a lower score compared to bamboo seed *unniyappam* initially and finally.

The mean score for flavour of bamboo seed *unniyappam* was 8.06 initially and it increased to 8.28 in final evaluation. Initially the mean score for flavour of rice *unniyappam* was

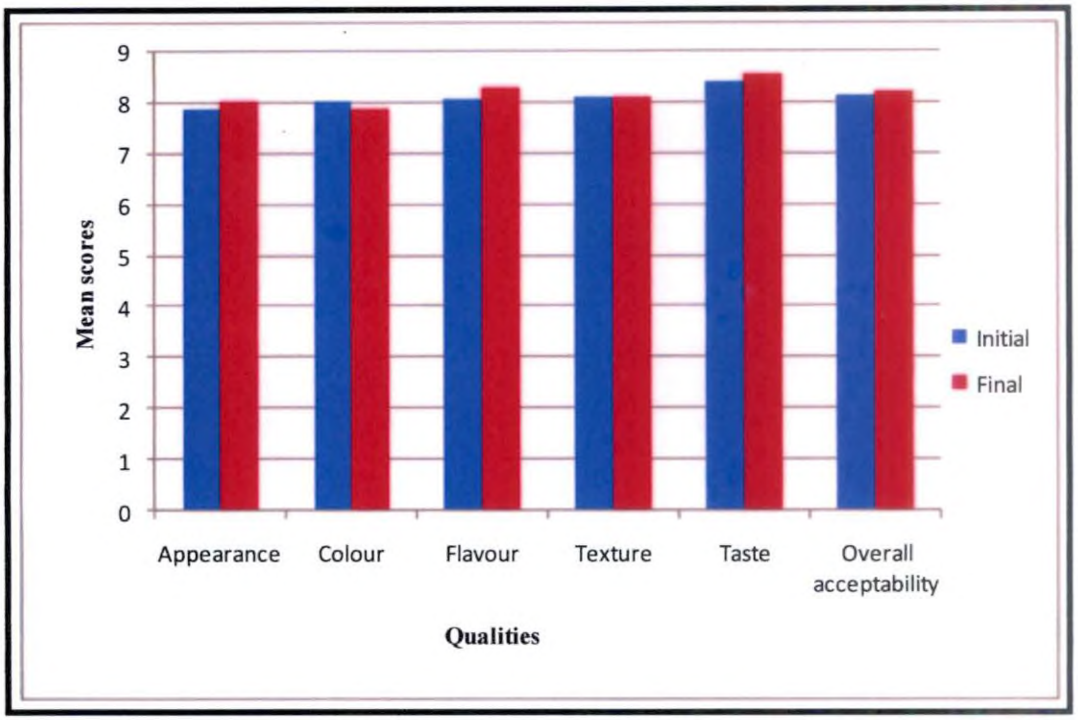

Fig 9: Comparison of organoleptic qualities of bamboo seed *unniyappam*

Plate 16: Bamboo seed *unniyappam*

1 – Rice, 2 - Bamboo seed

Plate 17: Comparison of bamboo seed *unniyappam* and rice *unniyappam*

lower than bamboo seed *unniyappam*. A higher score for flavour was observed in rice *unniyappam* during final evaluation.

The mean score for texture of bamboo seed *unniyappam* was 8.10 and it increased to 8.12 in final evaluation. Initially the mean score for texture of bamboo seed *unniyappam* was higher than rice *unniyappam*, but higher mean score for texture was observed in bamboo seed *unniyappam* during final evaluation.

The taste of bamboo seed *unniyappam* had mean scores of 8.4 and 8.54 during initial and final evaluation respectively. Initial mean score for taste of bamboo seed *unniyappam* was higher than rice *unniyappam*, but in final evaluation rice *unniyappam* got a better score of 8.60.

Table 18: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *unniyappam* in comparison with rice *unniyappam*

Quality attributes	Initial †		Mann Whitney U value	Final †		Mann Whitney U value
	BSF	RF		BSF	RF	
Appearance	9.45	11.55	39.50^{NS}	10.90	10.10	46.00^{NS}
Colour	12.05	8.95	34.50^{NS}	10.20	10.80	47.00^{NS}
Flavour	11.35	9.65	41.50^{NS}	9.55	11.45	40.50^{NS}
Texture	12.55	8.45	29.50^{NS}	9.35	11.65	38.50^{NS}
Taste	11.55	9.45	39.50^{NS}	9.75	11.25	42.50^{NS}
Overall acceptability	13.45	7.55	20.50**	9.30	11.70	38.00^{NS}

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BS- bamboo seed flour, RF- rice flour

The mean scores for overall acceptability of bamboo seed *unniyappam* was 8.13 initially and an increase in mean score was noticed during final evaluation (8.20). Bamboo seed *unniyappam* got a lower score than rice *unniyappam* during initial evaluation of overall acceptability, but in final evaluation bamboo seed *unniyappam* had a higher score of 8.26.

Comparison of different quality attributes of *unniyappam* prepared using bamboo seed flour and rice flour is given in Table 19. From the table it is clear that initially, *unniyappam* prepared from bamboo seed flour and rice flour had significant difference only in mean scores for overall acceptability. In final evaluation the difference observed among mean scores of different quality attributes of bamboo seed *unniyappam* and rice *unniyappam* was statistically non significant.

4.3.2.3. Bamboo seed *Murukku*

The mean scores obtained for different quality attributes of bamboo seed *murukku* (Fig 10) and rice *murukku* are given in Table 19.

Table 19: Mean scores for different quality attributes of bamboo seed *murukku* and rice *murukku*

Murukku	Quality attributes											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Bamboo seed flour	7.94	8.04	7.82	7.50	7.84	7.64	8.64	8.82	8.04	7.88	8.06	8.01
Rice flour	7.90	8.02	7.66	7.50	7.68	7.50	8.60	8.66	8.06	7.82	7.96	7.95

I-initial, F-final

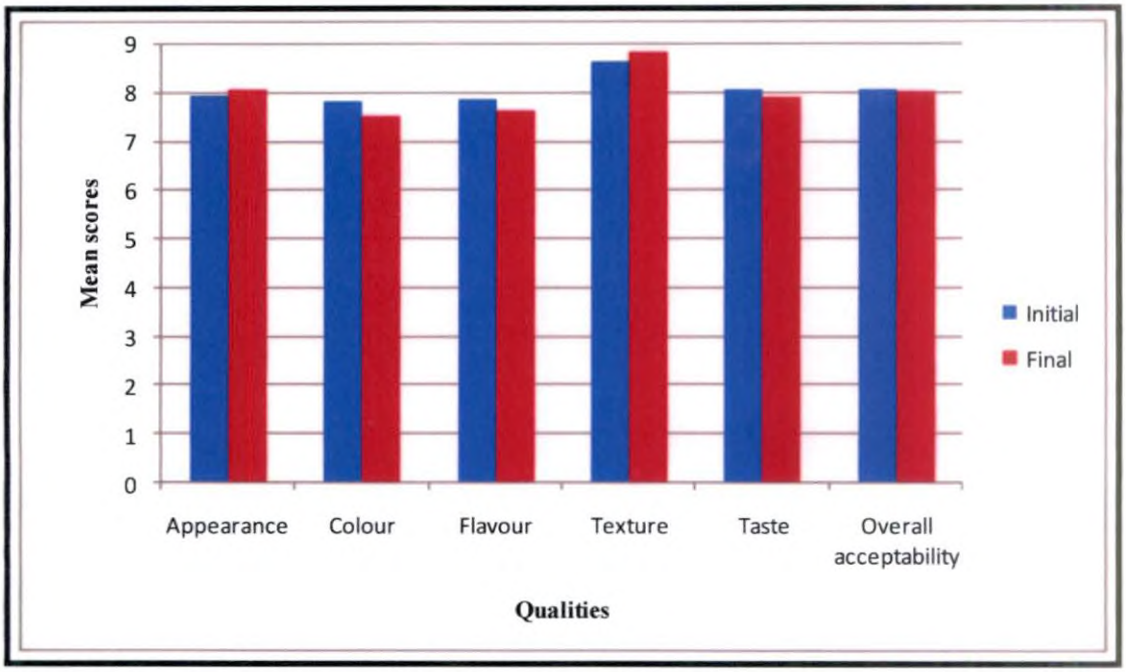

Fig 10: Comparison of organoleptic qualities of bamboo seed *murukku*

The mean score for appearance of bamboo seed *murukku* (Plate 18) was 7.94 initially and it increased to 8.04 in final evaluation. Initially and finally, appearance of bamboo seed *murukku* had higher score compared to rice *murukku* (Plate 19).

The mean scores for colour of bamboo seed *murukku* was 7.82 (initially) and 7.5 (finally). Bamboo seed *murukku* had higher mean score for colour initially. A mean score of 7.5 was observed in both products during final evaluation.

Flavour of bamboo seed *murukku* had a mean score of 7.84 initially and 7.64 finally. Compared to rice *murukku,* a better mean score for flavour was noticed in bamboo seed *murukku* in both initial and final evaluation.

The mean score for texture of bamboo seed *murukku* was 8.64 initially and it increased to 8.82 in final evaluation. Texture of bamboo seed *murukku* had higher score compared to rice murukku in both initial and final evaluation.

The mean score for taste of bamboo seed *murukku* was 8.04 and 7.88 during initial and final evaluation respectively. Initially rice *murukku* had higher mean score for taste. But in final evaluation bamboo seed *murukku* faired better with a mean score of 7.82.

The mean score for overall acceptability of bamboo seed *murukku* was 8.06 initially and a slight decrease in mean score (8.01) was observed during final evaluation. Compared to rice *murukku,* a better mean score was observed for overall acceptability of bamboo seed *murukku* during initial and final evaluation.

Comparison of different quality attributes of *murukku* prepared using bamboo seed flour and rice flour is given in Table 21. From the table it is clear that initially, the difference observed among mean scores of different quality attributes of bamboo seed *murukku* and rice *murukku* was statistically non significant. In final evaluation significant difference was

Plate 18: Bamboo seed *murukku*

1 – Rice, 2 - Bamboo seed

Plate 19: Comparison of bamboo seed *murukku* and rice *murukku*

observed only in flavour of bamboo seed *murukku* and rice *murukku.* The difference in mean scores observed among all other parameters was statistically non significant.

Table 20: Mean scores on the basis of Mann Whitney 'U' statistic for different quality attributes of bamboo seed *murukku* in comparison with rice *murukku*

Quality attributes	Initial †		Mann Whitney U value	Final †		Mann Whitney U value
	BSF	RF		BSF	RF	
Appearance	10.95	10.05	45.50 NS	10.70	10.30	48.00 NS
Colour	12.50	8.50	30.00 NS	10.60	10.40	49.00 NS
Flavour	12.15	8.85	33.50 NS	12.00	9.00	35.00 NS
Texture	11.20	9.80	43.00 NS	13.00	8.00	25.00*
Taste	10.00	11.00	45.00 NS	11.00	10.00	45.00 NS
Overall acceptability	12.40	8.60	31.00 NS	12.40	8.60	31.00 NS

† Mean scores using Mann Whitney U statistics, *Significance at 5% level, **Significance at 1% level, NS- Not Significant, BS- bamboo seed flour, RF- rice flour

4.3.2.4. Comparison of bamboo seed products prepared from unroasted flour

Three products namely *appam, unniyappam* and *murukku* were prepared initially and after three months of storage from unroasted bamboo seed flour and the products were compared by Kendall's 'W' test and the results are presented in Table 21.

From the table it is clear that all the three products had a mean score above 7.00 for different quality attributes in initial and final evaluation. Kendall's value assigned to each quality attribute revealed that judges had significant agreement in differentiation of all the parameters. Highest mean rank scores for quality attributes namely colour, flavour, taste and

Table 21: Mean scores and mean rank scores for different quality attributes of products prepared from unroasted bamboo seed flour

Products	Characters											
	Appearance		Colour		Flavour		Texture		Taste		Overall acceptability	
	I	F	I	F	I	F	I	F	I	F	I	F
Appam	7.54 (1.30)	7.48 (1.10)	7.26 (1.05)	7.14 (1.30)	7.28 (1.10)	7.48 (1.40)	7.32 (1.00)	7.52 (1.00)	7.64 (1.25)	7.88 (1.45)	7.37 (1.25)	7.47 (1.00)
Unniyappam	7.9 (2.30)	8.02 (2.40)	8.04 (2.80)	7.88 (2.75)	8.06 (2.60)	8.28 (2.95)	8.1 (2.10)	8.12 (2.10)	8.4 (2.80)	8.54 (2.95)	8.13 (2.80)	8.2 (2.85)
Murukku	7.94 (2.40)	8.04 (2.50)	7.82 (2.15)	7.5 (1.95)	7.84 (2.30)	7.64 (1.65)	8.64 (2.90)	8.82 (2.90)	8.04 (1.95)	7.88 (1.60)	8.06 (1.95)	8.01 (2.15)
Kendall's (W) value	0.435*	0.813**	0.803**	0.555**	0.663**	0.729**	0.910**	0.910**	0.634**	0.758**	0.634**	0.895**

Figures in parenthesis are mean rank scores, I-initial, F-final

**Significant at 1% level, *Significant at 5 % level overall acceptability were noticed in bamboo seed *unniyappam* in both initial and final evaluation. Bamboo seed *murukku* obtained highest mean rank scores for appearance and texture.

To choose the most acceptable product from unroasted bamboo seed flour, in terms of the six parameters namely appearance, colour, flavour, texture, taste and overall acceptability, a relative ranking sequence of the products were worked out for each parameter as done earlier. The exercise carried out in products prepared from unroasted bamboo seed flour in both initial and final stages and is presented in Table 22.

Table 22: Ranking of products from unroasted flour on the basis of mean rank scores

Products	Overall acceptability		Taste		Texture		Flavour		Colour		Appearance	
	I	F	I	F	I	F	I	F	I	F	I	F
Appam	3	3	3	2	3	3	3	3	3	3	3	3
Unniyappam	1	1	1	1	2	2	1	1	1	1	2	2
Murukku	2	2	2	2	1	1	2	2	2	2	1	1

I-initial, F-final

From the table it is clear that among the three products prepared using unroasted bamboo seed flour, bamboo seed *unniyappam* was the most acceptable product in initial and final evaluation followed by bamboo seed *murukku* and bamboo seed *appam*.

4.4. Shelf life of bamboo seed flour

The roasted and unroasted bamboo seed flour was evaluated for bacteria, fungi and yeast count initially and at the end of third month of storage and results pertaining to microbial enumeration are presented in this section. The microbial count observed in roasted and unroasted bamboo seed flour is given in Table 23 and 24 respectively.

Table 23: Microbial count in roasted bamboo seed flour during storage

Bamboo seed flour	Microbial population (cfu g^{-1})		
	Bacteria ($\times 10^5$)	Fungi ($\times 10^3$)	Yeast ($\times 10^3$)
I	1	ND	ND
F	1	ND	ND

ND – not detected, I-initial, F-final

The bacterial count in roasted bamboo seed flour was found to be 1×10^5 cfu g^{-1}, both initially and at the end of three months storage. Fungal growth and yeast growth were not detected in roasted flour initially and at the end of three months of storage.

Table 24: Microbial count in unroasted bamboo seed flour during storage

Bamboo seed flour	Microbial population (cfu g^{-1})		
	Bacteria ($\times 10^5$)	Fungi ($\times 10^3$)	Yeast ($\times 10^3$)
I	1	ND	ND
F	2	1	ND

ND – not detected, I-initial, F-final

Initially, the bacterial count in unroasted bamboo seed flour was found to be 1×10^5 cfu g^{-1}, which increased to 2×10^5 cfu g^{-1} at the end of three months of storage. Fungal growth was not detected initially. But a fungal count of 1×10^3cfu g^{-1} was observed in unroasted flour at the end of three months of storage. Yeast growth was not detected in the unroasted bamboo seed flour initially and at the end of storage.

4.4.1. Insect infestation in bamboo seed flour during storage

Insect infestations in roasted and unroasted bamboo seed flour were evaluated initially and at the end of three months of storage. Insect infestation was not detected in both roasted and unroasted bamboo seed flour during storage.

Discussion

5. DISCUSSION

The discussion of the results of the study entitled **"Quality evaluation of bamboo seed and its products"** are presented in this chapter.

5.1. Quality evaluation of bamboo seed

Bamboo seed was analysed for various quality attributes like cooking qualities, nutritional and biochemical qualities and organoleptic qualities.

5.1.1. Cooking qualities of bamboo seed

Cooking time is one of the major determinants of quality of a grain. Cooking time of 70 minutes was taken for obtaining optimum cooked bamboo seed. According to Chatterjee and Maiti (1981) rice with more protein content or a high gelatinisation temperature (74^0C or above) require more water and a longer cooking time to produce cooked rice with the same degree of doneness as rice with lower values for these properties.

Govindaswamy and Ghosh (1970) reported that the cooking time is positively correlated with the protein content. The longer cooking time observed in cooking of bamboo seed might be due to the higher protein content and higher gelatinisation temperature index noted in bamboo seed as suggested by Chatterjee and Maiti (1981) in rice. Panlasigui *et al.* (1991) reported that the cooking time of rice is 22 minutes. Singh *et al.* (2005a) reported a cooking time in the range of 13.3 to 24 minutes in rice. Compared to rice, longer cooking time was noticed in bamboo seed. Pressure cooking considerably reduced the cooking time of bamboo seed.

Water uptake by bamboo seed was found to be 6.90 ml/g which is higher than the water uptake of rice reported by Singh *et al.* (2005a). The author reported a water uptake of 2.37 to 4.45 ml/g in milled rice. A lower water uptake by milled rice was also reported by Singh *et al.* (2003) as 3.4 to 4.3 ml/g. Ortuno *et al.* (1996) indicated that water uptake had positive correlation with rapidly digestible starch and negatively with resistant starch. The water uptake by bamboo seed was found to be high when compared to rice and it might be due to the high amylase content in bamboo seed. Inatsu *et al.* (1974) reported a positive correlation between amylose content and water uptake.

Volume expansion ratio in bamboo seed was found to be 2.16. Panlasigui *et al.* (1991) evaluated volume expansion ratio of various rice varieties and it was found to be in the range of 2.0 to 2.20. Juliano (1992) reported higher volume expansion ratio of 3.1 to 4.5 in rice. The volume expansion ratio observed in the present study was almost similar to the volume expansion ratio reported by Panlasigui *et al.* (1991) and lower than the values given by Juliano (1992) in rice. According to Mohapatra and Bal (2006), amylose content had positive impact on volume expansion ratio and this seemed to be true in case of bamboo seed.

Grain elongation ratio in bamboo seed was found to be 0.89. Singh *et al.* (2005a) reported a grain elongation ratio of 1.29 to 1.74 in rice. A lower ratio for grain elongation was noticed in bamboo seed when compared to rice. Grain elongation ratio was positively related to water uptake and volume expansion ratio. (Chauhan *et al.* 1995).

Amylose content in bamboo seed was 34.4 percent. Yadav and Jindal (2007) and Wang *et al.* (2007) reported a wide variation (15.95 to 28.16%) in the amylose content of different varieties of rice. Kumar and Khush (1986) grouped rice on the basis of amylose content into waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%). Based on this grouping bamboo seed belongs to high amylose content group.

According to Jennings *et al.* (1979) rice varieties with a high gelatinisation temperature have low amylose content. Gelatinisation temperature index in bamboo seed was found to be high. A correlation between gelatinisation temperature and amylose content as indicated by Jennings *et al* (1979) is not noticed in bamboo seed. Mohammed *et al.* (2004) reported a gelatinisation temperature of 70 to 82.5^{0}C in different varieties of rice. According to Dela and Khush (2000) the gelatinisation temperature of grains are classified as low (55-69^{0}C), intermediate (70-74^{0}C) and high (> 74^{0}C) and based on this classification the gelatinisation temperature of bamboo seed falls in the higher range.

Gel consistency in bamboo seed was found to be 48.20 mm. Song *et al.* (2003) reported a gel consistency of 35 mm in rice. Wide variation in gel consistency of rice from 24 to 56 mm was reported by Wang *et al.* (2007). Graham (2002) classified the gel consistency in grains as hard (40 mm or less), medium (41-60 mm) and soft (>61 mm). According to this, bamboo seed is having a medium gel consistency. The author also suggested that the gel consistency of grains with less than 24 percent amylose content is usually soft. In bamboo seed, amylose content was found to be 34.4 percent. Medium gel consistency noted in bamboo seed is in line with the opinion of Graham (2002). Perez and Juliano (1979) opined that high protein content of grains influences the gel consistency and tends to harden the gel. In bamboo seed, the medium gel consistency might be due to the effect of higher protein and amylose content.

5.1.2. Nutritional and biochemical qualities of bamboo seed

Moisture content in bamboo seed was found to be 6.70 percent. The moisture content observed in the present study was found to be lower than the values reported by Gopalan *et al.* (2007) and Kiruba *et al.* (2007) who noticed a moisture content of 7.8 and 10 percent respectively in bamboo seed. Compared to rice and wheat, significantly lower moisture content was observed in bamboo seed. Low moisture content is likely to enhance the storage quality of bamboo seed.

Protein content in bamboo seed was 13.78 percent. Bhargava *et al.* (1996), Gopalan *et al.* (2007) and Kiruba *et al.* (2007) reported a protein content in the range of 12 - 13.1 percent in bamboo seed. The protein content of bamboo seed was found to be significantly higher than rice and wheat.

The amount of fat in bamboo seed was found to be 1 percent. Fat content recorded in the present study was found to be lower than the fat content of 1.2 percent reported by

Gopalan *et al.* (2007) and higher than the fat content (0.9 %) reported by Kiruba *et al.* (2007) in bamboo seed. The fat content in bamboo seed was found to be significantly higher than rice and lower than wheat.

Starch content of 62.56 percent was observed in bamboo seed. It was found to be lower than the starch content of bamboo seed (72.91%) reported by Tewari (1992). Starch content of bamboo seed recorded in the present study was found to be lower than the starch content of rice (72.4 – 84.1 %) reported by Hu *et al.* (2004).

Reducing sugar and total sugar in bamboo seed was found to be 0.41 percent and 0.99 percent respectively. Panlasigui *et al.* (1991) indicated higher total sugar content in the range of 3.8 to 4.6 percent in bamboo seed.

Fibre content in bamboo seed was found to be 0.92 percent. The fibre content noticed in the present study was in line with the fibre content reported by Gopalan *et al.* (2007) and lower than the fibre content given by Kiruba *et al.* (2007). Fibre content in bamboo seed was found to be significantly higher than rice and lower than wheat as given by Gopalan *et al.* (2007).

Calcium content in bamboo seed was recorded as 30.60 mg $100g^{-1}$. Tewari (1992) reported a higher calcium content of 86.88 mg 100 g^{-1} in bamboo seed. Calcium content observed in the present study was higher than the calcium content reported by Kiruba *et al.* (2007) and lower than the calcium content of 37 mg 100 g^{-1} reported by Gopalan *et al.* (2007). The calcium content of bamboo seed was significantly higher than rice and lower than wheat.

In the present study, phosphorus content of bamboo seed was noticed as 158.60 mg 100 g^{-1}. It was found to be lower than the phosphorus content of bamboo seed reported by Gopalan *et al* (2007), Kiruba *et al.* (2007) and Tewari (1992). They reported a phosphorus content of 162, 218 and 162.90 mg 100 g^{-1} respectively. Phosphorus content of bamboo seed was almost equal to the phosphorus content of rice (160 mg100 g^{-1}) and lower than the phosphorus content of wheat (306 mg 100 g^{-1}) as reported by Gopalan *et al.* (2007).

Iron content in bamboo seed was observed as 5.94 mg 100 g^{-1}. It was found to be less than the iron content reported by Kiruba *et al.* (2007) and Gopalan *et al.* (2007). They reported an iron content of 9.2 mg 100 g^{-1} and 6.4 mg 100 g^{-1} respectively. Iron content of rice and wheat as reported by Gopalan *et al.* (2007) was 0.7 mg 100 g^{-1} and 5.30 mg 100 g^{-1} respectively, which were lower than the iron content of bamboo seed noticed in the present study.

In vitro starch digestibility of bamboo seed was estimated and it was found to be 50.16 percent. It was found to be lower than the *in vitro* starch digestibility of rice (71.2 %) reported by Hu *et al.* (2004). Lower digestibility of starch noticed in bamboo seed compared to rice may be due to the presence of resistant starch formation due to high amylose content or by the higher fibre content (0.92%) compared to rice (0.2%). But it is advantageous for persons having problems with carbohydrate metabolism and utilisation.

In vitro availability of calcium, iron and phosphorus of bamboo seed was found to be 20.20, 10.72 and 20.72 percent respectively. Lower *in vitro* availability noticed in the present study might be due to the presence of phytates or other inhibitory substances which interferes with the utilisation of minerals.

5.1.3. Organoleptic evaluation of bamboo seed

Three products namely, cooked rice, *kanji* and *payasam* prepared from bamboo seed were evaluated orgnoleptically for different quality attributes like appearance, colour, flavour, texture, taste and overall acceptability.

Cooked rice, *kanji* and *payasam* had a mean score above 7.0 for all the parameters. Among the three products, bamboo seed *payasam* was found to be the most acceptable product with higher mean score for all the parameters except for texture. For texture, bamboo seed *kanji* obtained the maximum score. The medium gel consistency of bamboo seed may have contributed a better texture for bamboo seed *kanji.* Compared to the cooked rice prepared from parboiled rice; bamboo seed rice had a better mean score only for flavour. Compared to *kanji* prepared from rice, bamboo seed *kanji* had a better mean score for flavour and taste.

The better mean scores noticed for appearance, colour, flavour, taste and overall acceptability of bamboo seed and rice *payasam* was mainly due to the other ingredients used for its preparation. Compared to bamboo seed *payasam,* rice *payasam* had better mean score for all the parameters except flavour. The evaluation of the products revealed that bamboo seed had an acceptable flavour and taste and it is as suitable as rice for preparation of various products.

5.2. Physical qualities of bamboo seed flour

Physical qualities of roasted and unroasted bamboo seed flour were assessed initially and after three months of storage.

The bulk density of roasted bamboo seed flour was obtained as 0.90 g/ml initially and it decreased to 0.87 g/ml after three months of storage. In unroasted flour the bulk density was recorded as 0.80 g/ml initially and after three months of storage.

A higher value for bulk density was obtained for roasted bamboo seed flour both initially and finally. The bulk density obtained for bamboo seed flour was found to be in line with the bulk density of rice flour (0.77 - 0.85 g per ml) reported by Singh *et al* (2003) and Singh *et al* (2005a) and lower than the bulk density of potato flour (0.92 g per ml) given by Singh *et al* (2005b). Bhattacharya *et al.*(1972) reported the bulk density of rice flour as 0.83 to 0.92 g/ml. Bulk density had positive relationship with cooking time (Singh *et al.*, 2005a). The lower value for bulk density noticed in unroasted bamboo seed flour might be due to the high amount of moisture in unroasted bamboo seed flour than in roasted bamboo seed flour. Flours with higher bulk density could serve as good thickeners in food products (Adebowale *et al*, 2005).

Water absorption index is an indicator of the ability of flour to absorb water, depends on the availability of hydrophilic groups, which bind water molecule and on the gel forming capacity of the macro molecules. Water absorption index (WAI) in roasted bamboo seed flour was 14.56 initially, which showed slight decrease (14.52) after three months of storage. In unroasted flour, water absorption index was 12.92 initially and 12.82 after three months of storage. Roasted bamboo seed flour had higher water absorption index both initially and finally. Water absorption by flour is mainly due to swelling and solubility of starch granules which inturn depends on amylose content (Kaur *et al.*, 2002). Low amylose starch granules were weak and fragile, so tend to swell and disintegrate (Jangchud *et al*, 2000). The texture of cooked grain and its gloss are principally determined by the amylose - amylopectin ratio of the starch. Increasing the amylose content improves the capacity of the starch granule to absorb water and expand in volume without collapsing because of the greater capacity of amylose to hydrogen bond or retrograde.

Water solubility index is used as a measure for starch degradation. Water solubility index (WSI) of roasted bamboo seed flour was 0.068 initially and 0.067 after three months of storage. In the case of unroasted flour it was obtained as 0.06 and 0.05 respectively. Water solubility ratio was lower for unroasted flour both initially and finally.

Water absorption index and water solubility index in potato flour as reported by Singh *et al* (2005b) was 8.8 and 0.14 respectively. WAI observed in the present study was higher than the WAI of potato. WSI noticed in the present study was lower than the WSI of potato. WAI is positively correlated to the high protein and low fat content of food stuff (Sosulski *et al*, 1976). Water solubility index of bamboo seed flour was lower than rice (0.915) as reported by Ganjyal *et al* (2006). Lower values for WAI and WSI were noticed in unroasted flour than roasted flour.

In roasted bamboo seed flour initial starch content was 60.96 percent. After three months of storage, it decreased slightly to 60.60 percent. In the case of unroasted flour initial starch content was found to be 62.30 percent. Final starch content of unroasted bamboo seed flour was obtained as 61.32 percent. Starch content is found to be high in unroasted bamboo seed flour. Lower starch content noticed in roasted bamboo seed flour may be due to the dextrinisation of starch while roasting. The starch content in flour was lower than the starch content of whole bamboo seed.

Gluten content was also analysed in roasted and unroasted bamboo seed flour. Gluten was not found in both flours initially and after storage. As gluten is not present in bamboo seed, it might not be suitable for baking. Bamboo seed could be recommended for gluten free diets.

Retrogradation of gelatinised starch is a reorganisation process involving both amylose and amylopectin, with amylose undergoing retrogradation at a more rapid rate than amylopectin (Jacobson *et al,* 1997). Retrogradation properties of bamboo seed indicated that the syneresis percentage in roasted and unroasted bamboo seed flour increased with advancement in days of observation and maximum syneresis was observed on 12^{th} day. A decrease in syneresis percentage was noticed in both the flours after three months of storage period. Varavinit *et al.* (2002) showed low degree of retrogradation in grains with low amylose content. Higher degree of retrogradation noticed in the present study may be due to the higher amylose content in bamboo seed.

5.3. Acceptability of products from bamboo seed flour

Various traditional products were prepared using roasted and unroasted bamboo seed flour by standard procedures initially and after three months of storage of the flour. *Puttu, idiyappam* and *ada* were prepared using roasted bamboo seed flour and *appam, unniyappam* and *murukku* were prepared using unroasted bamboo seed flour. The products were compared with the concerned traditional rice products.

5.3.1. Organoleptic evaluation of the products from roasted bamboo seed flour

Bamboo seed *puttu* was found to be better than rice *puttu* in quality attributes namely, appearance, texture and taste initially and finally. During initial evaluation, bamboo seed *puttu* had better score for colour, flavour and overall acceptability than rice *puttu*. Bamboo seed *puttu* had the characteristic colour and taste of bamboo seed. The steam applied while cooking of bamboo seed *puttu* contributed a soft texture to it.

Bamboo seed *idiyappam* and rice *idiyappam* had mean score above 7.5 for different quality attributes. In initial evaluation the quality attributes namely, appearance, texture, taste and overall acceptability had higher mean score than rice *idiyappam*. For colour and flavour of bamboo seed *idiyappam*, a better score was noticed only during initial evaluation. Both the products did not show much difference in quality attributes.

Bamboo seed *ada* and rice *ada* had mean score above 7.5 for different quality attributes in both evaluations. Appearance and taste of bamboo seed *ada* obtained highest mean score in both periods compared to rice *ada*. The mean score for colour, flavour, texture and overall acceptability of bamboo seed *ada* faired better only during initial evaluation.

When the three products prepared from roasted bamboo seed flour were compared, bamboo seed *puttu* ranked best in both initial and final evaluation with highest mean score in all the parameters except for flavour. For flavour, bamboo seed *ada* had maximum mean score. It was mainly due to the added ingredients in bamboo seed *ada*. Bamboo seed *puttu* was identified as the most acceptable product from roasted bamboo seed flour followed by bamboo seed *ada* and bamboo seed *idiyappam*.

5.3.2. Organoleptic evaluation of the products from unroasted bamboo seed flour

Bamboo seed *appam* had highest mean score for appearance and taste in both initial and final evaluation. Bamboo seed *appam* had better score for colour, flavour and overall acceptability only during initial evaluation. The texture of rice *appam* was better than bamboo seed *appam*. Initially, both the product had same score for texture, but in final evaluation rice *appam* faired a better score than bamboo seed *appam*.

Initially, bamboo seed *unniyappam* had higher mean score for colour, flavour, texture, taste and overall acceptability. But, in final evaluation, bamboo seed *unniyappam* obtained a better mean score only for appearance. Bamboo seed *unniyappam* had a mean score above 7.9 for different quality attributes in both initial and final evaluation.

Bamboo seed *murukku* obtained high mean score for appearance, flavour, texture and overall acceptability. Initially, the colour of bamboo seed *murukku* had a better score than rice *murukku*. But, in final evaluation the mean score for colour was same in the two products. In final evaluation the mean score for the taste of bamboo seed *murukku* was less compared to rice *murukku*.

When the three products prepared from unroasted bamboo seed flour were compared bamboo seed *unniyappam* had highest mean scores for quality attributes namely colour, flavour, taste and overall acceptability in both initial and final evaluation. Higher scores for colour, flavour, taste and overall acceptability of bamboo seed *unniyappam* might be due to added ingredients. Bamboo seed *murukku* obtained highest mean rank scores for texture. Highest score obtained for texture of bamboo seed *murukku* might be due to the crispiness by deep fat frying. Compared to rice flour, bamboo seed flour is not highly suitable for preparing *appam*.

Among the three products prepared using unroasted bamboo seed flour bamboo seed *unniyappam* was the most acceptable product in initial and final evaluation followed by bamboo seed *murukku* and bamboo seed *appam*.

Products prepared from roasted and unroasted bamboo seed flour had good acceptance. Studies have revealed the role of amylose (Juliano 1985) and protein (Martin and Fitzgerald, 2002) on textural characteristics of products. Amylose has been directly correlated to the texture. Low amylose flours provided soft and sticky texture to products. (Juliano 1985) Proteins affect the amount of water the grain absorbs early in cooking, and the availability of water early in cooking will determine the hydration of the protein and the concentration of the dispersed and viscous phases of the starch, which will determine the texture of the cooked grain (Martin and Fitzgerald, 2002). Liquid retention is an index of the ability of the proteins to absorb water which in turn influence the texture and mouth feel characteristics of food (Cheftel *et al.*, 1985 and Okezie and Bello, 1988). Higher protein content and low fat content of bamboo seed flour might have contributed a better texture for products as indicated by Matz (1972), Sosulski *et al.*, (1976) and Islam and Johansen (1987). Water absorption capacity of flour is important in the development of ready to eat foods and a high absorption capacity may assure product cohesiveness. Bamboo seed had good water absorption capacity and is found to be a viable material for the preparation of ready to eat snacks.

5.4. Shelf life of bamboo seed flour

The bamboo seed flour was evaluated for bacteria, fungi and yeasts initially and at the end of third month of storage. Microbial enumeration was done both in roasted and unroasted bamboo seed flour.

According to Brown (1996) the microbial load of powdered food stuffs depends mainly on the processing techniques used and their keeping quality depends on type of packaging and temperature of storage. Misra and Kulshrestha (2003) reported that storage of flour for 6 months did not result in any significant changes in the nutritional parameters, except for moisture and ascorbic acid.

Bacterial count in roasted bamboo seed flour was 1×10^5 cfu g^{-1} in both initial and final evaluation. In unroasted bamboo seed flour, an increase in bacterial count was observed during final evaluation. Fungal growth was not detected in roasted flour initially and at the end of storage period. In unroasted flour, fungal growth was not detected initially, but at the end of storage fungal count of 1×10^{3}cfu g^{-1} was noticed. Yeast growth was not detected in both roasted and unroasted bamboo seed flour initially and at the end of storage.

The shelf-life study of flour conducted by Vaidehi and Sunanda (1982) reported that aluminium containers and sealed polyethylene pouches are suitable for storage of flour and it will protect the flour from infestation by insects and fungi. Bamboo seed flour was packed in 200 gauge polythene bags and kept for storage under ambient storage conditions. The packaging material used in the study well protected the flour from moisture absorption and excess microbial contamination.

Insect infestation of roasted and unroasted bamboo seed flour was also evaluated initially and at the end of storage. Insect infestation was not noticed in both roasted and unroasted bamboo seed flour.

Summary

6. SUMMARY

The present study entitled **"Quality evaluation of bamboo seed and its products"** was attempted to evaluate the cooking, biochemical, nutritional and organoleptic qualities of bamboo seed. The study also aimed to assess the physical qualities, organoleptic qualities and keeping qualities of bamboo seed flour stored for three months.

Cooking time of 70 min was taken for obtaining optimum cooked bamboo seed. The water uptake by bamboo seed while cooking was found to be 6.90 ml/g of bamboo seed with a volume expansion ratio of 2.16. Grain elongation ratio in bamboo seed was recorded as 0.89.

The amylose content in bamboo seed was 34.4 percent. The gelatinisation temperature index in bamboo seed was found to be high. A medium gel consistency of 48.20 mm was observed in bamboo seed.

The moisture content in dried and milled bamboo seed was found to be 6.70 percent. The analysis of protein content in bamboo seed revealed that it contains 13.78 percent protein. The fat content in bamboo seed was observed as one percent.

Starch content in bamboo seed was 62.56 percent. Reducing sugar and total sugar in bamboo seed was 0.41 and 0.99 percent respectively. Fibre content in bamboo seed was recorded as 0.92 percent.

The calcium content in bamboo seed was obtained as 30.60 mg $100g^{-1}$. The iron content in bamboo seed was 5.94 mg $100g^{-1}$. Bamboo seed contains good amount of phosphorus and it was found to be 158.60 mg $100g^{-1}$.

In vitro starch digestibility of bamboo seed was found to be 50.16 percent. *In vitro* availability of calcium, iron and phosphorus of bamboo seed was also estimated and it was found to be 20.20, 10.72 and 20.72 percent respectively.

The major nutritional and biochemical qualities like moisture, protein, fat, fibre, calcium, iron and phosphorus of bamboo seed were compared with the values for these components in rice and wheat as given by National Institute of Nutrition (NIN), Hyderabad and bamboo seed was found to be nutritionally superior than rice and wheat.

For evaluating the organoleptic qualities of bamboo seed, three products namely cooked rice (by straining method), *kanji* and *payasam* were prepared using bamboo seed. Cooked rice, *kanji* and *payasam* had mean score above 7.00 for all the parameters. Among the three products bamboo seed *payasam* was found to be the most acceptable product with higher mean score for all the parameters except for texture followed by bamboo seed *kanji* and cooked rice.

Roasted and unroasted flour were prepared from bamboo seed and was evaluated for various physical qualities initially and after three months of storage. The bulk density of roasted flour decreased during storage whereas in unroasted flour it remained same (0.80 g/ml). The bulk density of roasted bamboo seed flour was 0.90 g/ml initially and it decreased to 0.87 g/ml after three months of storage. In unroasted flour the bulk density was recorded as 0.80 g/ml initially and after three months of storage.

Water absorption index, water solubility index and starch decreased during three months of storage in both roasted and unroasted flour. Water absorption index in roasted bamboo seed flour was 14.56 initially, which showed slight decrease (14.52) after three months of storage. In unroasted flour, water absorption index was 12.92 initially and 12.82 after three months of storage. Water solubility index of roasted bamboo seed flour was 0.068 initially and 0.067 after three months of storage. In the case of unroasted flour it was obtained as 0.06 and 0.05 respectively.

In roasted bamboo seed flour, initial starch content was obtained as 60.96 percent. After three months of storage it decreased slightly to 60.60 percent. In the case of unroasted flour initial starch content was found to be 62.30 percent. Final starch content of unroasted bamboo seed flour was 61.32 percent. No gluten was found in both roasted and unroasted flour initially and after three months of storage.

Retrogradation properties of bamboo seed were analysed. The syneresis percentage in roasted and unroasted bamboo seed flour increased with advancement in days of observation and maximum syneresis was observed on 12^{th} day. A decrease in syneresis percentage was noticed in both the flours after three months of storage period.

The roasted and unroasted flours prepared from bamboo seed was evaluated for organoleptic qualities by preparing different products. *Puttu*, *idiyappam* and *ada* were prepared using roasted flour and *appam*, *unniyappam* and *murukku* were prepared using unroasted flour and evaluated for various quality attributes initially and with the flour stored for three months. The prepared products were compared with the concerned traditional rice products.

Among the three products prepared using roasted bamboo seed flour; bamboo seed *puttu* was the most acceptable product in initial and final evaluation followed by bamboo seed *ada* and bamboo seed *idiyappam*. Among the products prepared using unroasted bamboo seed flour; bamboo seed *unniyappam* was the most acceptable product in initial and final evaluation followed by bamboo seed *murukku* and bamboo seed *appam*.

The roasted and unroasted bamboo seed flour was evaluated for bacteria, fungi and yeasts initially and at the end of third month of storage. Bacteria was detected in both roasted and unroasted bamboo seed flour and it increased in unroasted bamboo seed flour during storage. Fungal count was not detected in roasted bamboo seed bamboo seed flour in both evaluations. But, in unroasted bamboo seed flour fungal count was noticed (1×10^3 cfu g^{-1}) at the end of three months of storage. Yeast was not detected in both roasted and unroasted bamboo seed flour. Insect infestation was not noticed in both roasted and unroasted bamboo seed flour.

Bamboo seed is a rich source of protein and minerals. Nowadays tribals are the main users of bamboo seed. The health benefits of bamboo seed has gained importance and is widely used in the pharmaceutical industry. Bamboo seed being a rich source of protein and iron, it can be used as a supplementary food for children and other vulnerable groups. As gluten is not present in bamboo seed, it can be recommended for people with gluten allergy. Bamboo seed with low starch digestability can also be recommended for diabetic patients. This study shows that bamboo seed can be used as an acceptable food stuff in our day to day preparations and ready to eat snacks are viable with bamboo seed flour. Incorporation of bamboo seed flour into food products can lead to the development of natural, nutritious and adaptable functional foods.

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Appendix

APPENDIX I

Score card for organoleptic evaluation of bamboo seed and bamboo seed flour based products

Name of the judge:
Date :

Characteristics	Score				
	1	2	3	4	5
Appearance					
Colour					
Flavour					
Texture					
Taste					
Overall acceptability					

9 point Hedonic scale

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

Signature:

APPENDIX II

RECIPE FOR THE PREPARATION OF COOKED RICE

Ingredients

Grain – 100 g
Water – as required

Procedure

Washed and cleaned grain was added to sufficient amount of boiling water. Cook it well. After cooking strain the excess water to get the cooked rice.

APPENDIX III

RECIPE FOR THE PREPARATION OF *KANJI*

Ingredients

Grain – 100 g
Water – as required

Procedure

Washed and cleaned grain was added to sufficient amount of boiling water. Cook it well. When it is well cooked, serve the *kanji* as a thick porridge.

APPENDIX IV

RECIPE FOR THE PREPARATION OF *PAYASAM*

Ingredients

Grain – 1/2 cup
Milk – 4 cups
Sugar – 1 cups

Procedure

Cook the grain with sufficient water in a pressure cooker. Add milk and sugar to the well cooked mixture and cook in pressure cooker again. Simmer it before whistle came. Keep on low flame for 10 min.

APPENDIX V

RECIPE FOR THE PREPARATION OF *PUTTU*

Ingredients

Roasted flour – ½ Kg

Grated coconut – 200 g

Water – as required

Salt – to taste

Procedure

Moisten the roasted flour with salt water. Put a handful of grated coconut in the *puttu* maker and fill half with moistened flour followed by another handful of grated coconut till the *puttu* maker is full. Close the lid and steam it for 2 min to get *puttu*.

APPENDIX VI

RECIPE FOR THE PREPARATION OF *IDIYAPPAM*

Ingredients

Roasted flour – 2 cups

Grated coconut – 200 g

Water – as required

Salt – to taste

Procedure

Heat water in a vessel and bring it to boil, add a pinch of salt. Make soft and thick dough by adding boiling water. The dough is then extruded through an *idiyappam* maker to get long threads of dough on a plate (You can use *idli* plate for this). Add grated coconut above it. Steam it well to get *idiyappam*.

APPENDIX VII

RECIPE FOR THE PREPARATION OF *ADA*

Ingredients

Roasted flour – 2 cup
Jaggery – 100 g
Grated coconut – 200 g
Cardamom – 2 nos
Water – as required

Procedure

Prepare jaggery syrup with thick consistency. Add grated coconut and cardamom into it and mix well. Heat water in a vessel and bring to boil. To this add roasted flour and stir well so as to make a thick paste. Spread a thin layer of this flour paste on a banana leaf. Spread the jaggery mix above it and fold the leaf. Steam it well to get *ada.*

APPENDIX VIII

RECIPE FOR THE PREPARATION OF *APPAM*

Ingredients

Flour – 1 cup

Cooked rice – 2 tbsp

Grated coconut – 3 tbsp

Yeast – a pinch

Salt & sugar – to taste

Procedure

To the flour, cooked rice and coconut were added and ground together to get a batter of medium consistency. Add yeast to it and allow fermenting overnight. The batter is poured in a heated kadai to prepare *appam.*

APPENDIX IX

RECIPE FOR THE PREPARATION OF *UNNIYAPPAM*

Ingredients

Flour – 2 cup
Jaggery – 200 g
Coconut pieces (small) – 50 g
Cardamom – 4 nos
Banana (small) – 2 nos
Oil – To fry

Procedure

To the flour add jaggery syrup, cardamom and coconut (square pieces). The batter is kept aside for 5 hours. Add banana paste to it and mix well before cooking. Heat oil in *unniyappam* pan and pour the batter into it and fry well to make *unniyappam.*

APPENDIX X

RECIPE FOR THE PREPARATION OF *MURUKKU*

Ingredients

Flour – 3 cups
Bengal gram flour – 1 cup
Black gram powder – ½ cup
Asafoetida powder – one pinch
Cumin seeds – 1 tbsp
Salt – to taste
Oil – to fry

Procedure

Take a big vessel and add flour, fried bengal gram flour, black gram powder, cumin seeds, required quantity of salt and a pinch of asafoetida powder and mix well after pouring a ladle full of hot oil to the flour mixture. After which prepare the dough by adding little quantity of water and knead it into a soft and smooth consistency. Stuff the *murukku* press with dough and press the *murukku* to a greased plate. Slowly put the pressed *murukku* into hot oil. Deep fry till it attains a golden yellow colour, drain the excess oil to get *murukku*.

QUALITY EVALUATION OF BAMBOO SEED AND ITS PRODUCTS

By

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ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

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ABSTRACT

The study on "**Quality evaluation of bamboo seed and its products**" was undertaken to evaluate the cooking, biochemical, nutritional and organoleptic qualities of bamboo seed. The study also aimed to assess the physical qualities, organoleptic qualities and keeping qualities of bamboo seed flour stored for three months.

Cooking time of 70 min was taken for obtaining optimum cooked bamboo seed. The water uptake by bamboo seed while cooking was found to be 6.90 ml/g with a volume expansion ratio of 2.16. Grain elongation ratio in bamboo seed was recorded as 0.89. The amylose content in bamboo seed was found to be 34.4 percent. The gelatinisation temperature index in bamboo seed was high. A medium gel consistency of 48.20 mm was observed in bamboo seed.

The moisture content in dried and milled bamboo seed was found to be 6.70 percent. Bamboo seed contains 13.78 percent protein. The fat content in bamboo seed was one percent. Starch content in bamboo seed was 62.56 percent. Reducing sugar and total sugar in bamboo seed was 0.41 and 0.99 percent respectively.

Fibre content in bamboo seed was 0.92 percent. The calcium, iron and phosphorus contents of bamboo seed were 30.60 mg, 5.94 mg and 158.60 mg respectively per 100g of bamboo seed. *In vitro* starch digestibility of bamboo seed was found to be 50.16 percent. *In vitro* availability of calcium, iron and phosphorus of bamboo seed was also estimated and it was found to be 20.20, 10.72 and 20.72 percent respectively.

The organoleptic qualities of bamboo seed were evaluated by preparing three products namely cooked rice, *kanji* and *payasam*. Cooked rice, *kanji* and *payasam* had mean score above 7.00 for all parameters. Among the three products, bamboo seed *payasam* was found to be the most acceptable product with higher mean score for all the parameters except for texture. For texture bamboo seed *kanji* had the maximum score.

Roasted and unroasted flours prepared from bamboo seed were evaluated for various physical qualities. The bulk density of roasted flour decreased during storage whereas in unroasted flour it remained same (0.80 g/ml). Water absorption index, water solubility index and starch content decreased during three months of storage in both roasted and unroasted bamboo seed flour. Gluten was not found in both roasted and unroasted bamboo seed flour initially and at the end of storage.

The evaluation of retrogradation property in bamboo seed flour revealed that the syneresis percentage increased with advancement in days of observation. However a decrease in percentage of syneresis was noted during storage in both roasted and unroasted bamboo seed flour.

Products namely *puttu*, *idiyappam* and *ada* were prepared using roasted flour and *appam*, *unniyappam* and *murukku* were prepared using unroasted bamboo seed flour. Bamboo seed *puttu* was identified as the most acceptable product from roasted bamboo seed flour. Among the products prepared using unroasted bamboo seed flour bamboo seed *unniyappam* was the most acceptable one followed by bamboo seed *murukku* and bamboo seed *appam*.

The roasted and unroasted bamboo seed flour was evaluated for bacteria, fungi and yeasts initially and at the end of third month of storage. Presence of bacteria was detected in both roasted and unroasted flour and the count increased in unroasted flour during storage. Fungal count was not detected in roasted bamboo seed flour in both evaluations. But, in unroasted flour fungal count was noticed (1×10^{3} cfu g^{-1}) at the end of three months of storage. Presence of yeast was not detected in both roasted and unroasted flour. Insect infestation was not noticed in both roasted and unroasted bamboo seed flour.