QUALITY EVALUATION OF BANANA BY-PRODUCTS

By

RAJI M. JOHN

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Home Science

(FOOD SCIENCE & NUTRITION)

Faculty of Agriculture
Kerala Agricultural University

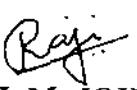
Department of Home Science
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2001

DECLARATION

I hereby declare that the thesis entitled **"Quality evaluation of banana by-products"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
27-10-2001



RAJI M. JOHN

CERTIFICATE

Certified that the thesis, entitled **"Quality evaluation of banana by-products"** is a record of research work done independently by **Mrs.Raji M. John,** 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.

Smt.Omana Pavunny
Chairperson, Advisory Committee
Assistant Professor
Department of Fish Processing Technology
College of Fisheries
Panangad

Panangad
27-10-2001.

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mrs.Raji M. John,** a candidate for the degree of **Master of Science in Home Science** with major in **Food Science and Nutrition**, agree that the thesis entitled **"Quality evaluation of banana by-products"** may be submitted by Mrs.Raji M. John, in partial fulfilment of the requirement for the degree.

5.1.2002

Smt.Omana Pavunny
(Chairperson, Advisory Committee)
Assistant Professor
Department of Fish Processing Technology
College of Fisheries
Panangad

5/1/02

Dr.V. Indira
Associate Professor and Head
Department of Home Science
College of Horticulture
Vellanikkara
(Member)

5/1/02

Dr.V. USHA
Associate Professor
Department of Home Science
College of Horticulture
Vellanikkara
(Member)

5/1/02

Dr.M.V.Rajendran Pillai
Associate Professor
Department of Plant Pathology
College of Horticulture
Vellanikkara
(Member)

5.1.2002

EXTERNAL EXAMINER
DR. K. S. KUMARI
Prof & and Head
Dept. of Home Science
St. Teresa's College
Ernakulam.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to ***Smt.Omana Pavunny,*** *Assistant Professor, Department of Fish Processing Technology, College of Fisheries, Panangad and the Chairperson of my advisory committee, for her valuable suggestions and encouragement for the successful completion of this work.*

I am deeply obliged to ***Dr.V.Indira,*** *Associate Professor and Head, Department of Home Science, College of Horticulture and member of my advisory committee, for her critical evaluation and valuable suggestions, which was a great help for the completion of the thesis.*

I am indeed grateful to ***Dr.V.Usha,*** *Associate Professor, Department of Home Science and member of my advisory committee for her suggestions and timely help extended to me for the preparation of the thesis.*

I also would like to thank to ***Dr.M.V.Rajendran Pillai,*** *Associate Professor, Department of Plant Pathology and member of advisory committee for providing the necessary guidelines and valuable suggestions in the progress of this study.*

I sincerely thank Smt.Graceamma Kurien, Assistant Professor, Department of Agricultural Statistics for all the valuable suggestions in carrying out the statistical analysis.

May I express my sincere gratitude to Dr.Rema Menon, Associate Professor, Banana Research Station, Kannara for providing the necessary samples for conducting the research work.

Special thanks are due to my dearest friends Suman, Maya, Mini, Mole, P., Rani, Vandana, Saima, Sabeena and Shiji for their help, warm company, support and encouragement. I also thank my seniors and juniors for their company.

The help rendered by Smt.Joicy T. John to carry out the statistical analysis is sincerely acknowledged.

My sincere thanks to Sri.Joy and his family, JMJ Computer Centre, Thottappady, for the neat and prompt typing of the thesis.

The award of Junior Fellowship by KAU is greatly acknowledged.

I also take this opportunity to thank my Amma, Pappa and Aji for their great concern, constant prayers and encouragement, which had always been my source of solace.

I express my sincere gratitude to my mother in law and father in law for their keen interest and constant prayers.

I express my heartfelt thanks to my husband for his support, deep concern, understanding and encouragement especially during the last stages of preparation of this thesis.

Above all, I humbly bow my head before God Almighty, whose constant blessing enabled me to complete this endeavour successfully.

Raji

Raji M. John

CONTENTS

Chapter	Title	Page No.
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	2
3	MATERIALS AND METHODS	21
4	RESULTS	27
5	DISCUSSION	63
6	SUMMARY	78
	REFERENCES	i-vi
	APPENDICES	
	ABSTRACT	

To My Family

CONTENTS

Chapter	Title	Page No.
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	2
3	MATERIALS AND METHODS	21
4	RESULTS	27
5	DISCUSSION	63
6	SUMMARY	78
	REFERENCES	i-vi
	APPENDICES	
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1	Moisture content of different by-products of selected banana varieties	28
2	Protein content of different by-products of selected banana varieties	29
3	Fat content of different by-products of selected banana varieties	31
4	Starch content of different by-products of selected banana varieties	33
5	Fibre content of different by-products of selected banana varieties	35
6	Iron content of different by-products of selected banana varieties	37
7	Calcium content of different by-products of selected banana varieties	39
8	Phosphorus content of different by-products of selected banana varieties	40
9	Potassium content of different by-products of selected banana varieties	42
10	Sodium content of different by-products of selected banana varieties	44
11	Vitamin C content of different by-products of selected banana varieties	46
12	Organoleptic evaluation of pickles prepared from different varieties of banana by-products during six month of storage	49
13	Overall acceptability of pickles prepared from different varieties of banana by-products during six month of storage	52

14	Organoleptic evaluation of vattals prepared from different varieties of banana by-products during six month of storage	56
15	Overall acceptability of vattals prepared from different varieties of banana by-products during six month of storage	58

LIST OF APPENDICES

Appendix No.	Title
I	Processed products from banana by-products
II	Score card for organoleptic evaluation of processed banana by-products

Introduction

INTRODUCTION

Banana is one of the oldest fruit of the world. It is also one of the major fruit crops of India and is cultivated extensively in Kerala. Banana plant with every part being useful to man in many respect as food and otherwise is a versatile plant and is known as "God's gift to mankind" (Rao, 1999).

Banana has a lot of vistas for utilization apart from its use as dessert fruit. Usually the fruits are used for table as well as culinary purposes whereas the by-products are being wasted. An efficient disposal and recycling of these wastes can help to minimize pollution hazards, add vital nutrients to our foods and feeds and bring down the cost of production of processed foods (Maini, 1997).

The by-products of banana include flower bud, peel, pseudostem and rhizome. These portions are edible and many products can be prepared with these parts and they are rich source of carbohydrate, minerals and fibres (Maini, 1997).

Detailed study on the nutritive value of these edible portions of different banana varieties and on the quality evaluation of the processed products have not been carried out so far. Hence the present study was undertaken with the following objectives.

1. To analyse the nutrient content of edible portions other than fruits of five selected banana varieties.
2. To evaluate the acceptability and shelf life of standardised banana by-products.

Review of Literature

2. REVIEW OF LITERATURE

Literature relevant to the study entitled 'Quality evaluation of banana by-products' is reviewed in this chapter under the following sections.

2.1 Utilization of fruit and plant by-products

2.2 Nutrient composition of banana by-products

2.3 Development and organoleptic evaluation of processed products from banana and banana by-products

2.4 Shelf life of processed products from banana and banana by-products

2.1 Utilization of fruit and plant by-products

Horticultural wastes are churned out at harvesting, handling, transportation, storage, marketing and processing due to non-availability of proper post-harvest management facilities in developing countries (Maini, 1997).

According to Simmonds and Stover (1966) the heart of growing pseudostem is eaten in India and banana stem is commonly used as a vegetable and have medicinal properties. Shantha and Siddappa (1970) reported that when the pseudostem is cut down starch must be extracted quickly as it declines rapidly within two days. Banana pseudostem contains high level of water. So they must be fed fresh (Fzoulkes, 1978).

The central core of banana pseudostem constitute 10-15 per cent of total stem and can be used as a vegetable (Maini, 1997). According to Singh and Uma (1997) pseudostem core is used as a vegetable and unripe banana fruit as well as the inner core of pseudostem is regularly cooked as a curry in banana growing

areas. Plantain stem raita is prepared from banana pseudostem (Kavitha *et al.*, 1999). The tender inner portion of core of the stem of fruited banana plant is used as a vegetable and eaten after cooking (Rao, 1999).

The juice of pseudostem of *Musa Paradisiaca* and *Musa Sapie M. Paradisiaca* was administered to patients suffering from Urolithiasis and recurrence was observed in patients over a period of 14 weeks (Pillai, 1996).

Simmonds and Stover (1966) reported that the male bud of banana, after removing the fibrous outer bracts is eaten as a boiled vegetable in south east Asia. In Philippines the bud of 'Saba' banana variety is used for cooking. They also stated that the buds of *Musa balbisiana* were preferred as a vegetable in many areas of Southern Asia and the use of banana corms, shoots and male buds as food is widespread in Africa.

Cauliflower stalks and cabbage heads are good for human use (Nand, 1993). Banana flower bud is used as a vegetable and the end of inflorescence of banana is cooked as a vegetable in Bengal (Singh and Uma, 1997).

According to Maletto *et al.* (1973) banana peel is used as a food. Chung and Meyers (1979) reported that bioprotein can be made from banana skin by fermentation process at laboratory level. In Southern China banana skin is used in the preparation of meals (Jianhi *et al.*, 1995). According to Pavunny (1996) jelly is prepared from banana peel rind. Eighty per cent of banana plant can be used as a food material.

The fleshy part of the jack fruit peel is used as a vegetable (Nand, 1993). According to Pavunny *et al.* (1993) candy is prepared from pineapple core. Maini

(1997) reported that pineapple core is used in the making of juice, wine and syrup and he also reported that tomato core is used in meals and in the making of seed oil.

Through fermentation technology some value added products like alcohol, citric acid and lactic acid were produced from by-products (Tandon *et al.*, 1993). Ripe mango peel may be utilized in manufacturing of alcohol while unripe mango peel may be pickled (Anand and Maini, 1993). Pineapple peels and cores are useful in manufacturing alcohol and citric acid (Maini, 1997). According to Singh and Uma (1997) banana peel is used in the preparation of jelly and marmalade and ethyl alcohol production.

In Utter Pradesh water melon rind after removing the green portion is used as a raw material for Tuti-fruiti. It is estimated that 4000-5000 tonnes of this product is manufactured and demand of Tuti-fruiti is increased in U.P. (Maini, 1997). He also stated that orange and lime peels are used in essential oil production.

Natural colours are extracted from blue grapes skin (Maini, 1997).

According to Nand (1993) tamarind seeds and Mahua seeds are useful. Jack fruit seed is used in cooking. From mango seed kernel, okra and jack fruit seeds, flour is prepared.

Water melon seed kernels are extensively used in sweets, bakery product and ice creams. Beverages are prepared after grinding these kernels along with other herbs (Maini, 1997).

Curry powders are made from wild type of pomegranate seeds. Cucumber seed kernels and Pumpkin seed kernels are used in beverages and bakery products (Maini, 1997).

Essential oils are produced from orange and lime seeds and from tomato seeds, oils and meal are prepared (Maini, 1997).

Banana rhizome is eaten as a vegetable and it is also used as a medicine. (Jackson, 1989, Singh and Uma, 1997).

From discarded green fruits nutritious meal suitable for human consumption are prepared (Singh and Uma, 1997).

Adams (1978) describes a procedure for making vinegar from ripe rejected bananas. In the Davao area of philippines waste bananas are converted into sun dried chips.

Candy, chutney, jelly, pickle and preserves are prepared from immature pineapples. Ready to serve beverages, vinegar, wine were obtained from the "Mill juice" of pineapples after canning (Pavunny *et al.*, 1993).

The Cashew apple residue was utilised for making various products like drink, jam, chutney and preserve. All these products were nutritionally and organoleptically, acceptable (Joshi *et al.*, 1993).

Chutney is made from apples and peeled pineapples after extracting juice (Nand 1993). Over ripe bananas are used in the preparation of beverages like whey banana shake and whey banana (Shekilango *et al.*, 1997).

Banana peels and pulp are used as animal feed (Maletto *et al.,* 1973). The green field residues like leaves and pseudostems are used as animal feed (Annelli *et al.,* 1975).

Banana pseudostems are used as a source of cattle feed during dry periods or when forage is scarce (Fzoulkes, 1978). According to Sharaf *et al.* (1979) banana peel is mixed with diet of animals.

In Honduras and Panama about 16,000 tonnes of ripe banana peels are discarded and it is used as a cattle feed, (Goewart and Nicholas, 1980).

In Japan and Taiwan waste bananas are used as animal feed (Anon, 1983a). Banana leaves are used for animal feed (Jackson, 1989). Tandon *et al,* (1993) stated that for the manufacturing of protein rich animal feed, fermented mango wastes are used.

According to Maini (1997) orange peels, seeds and pulp, lime peel, seeds and pulp, pineapple peel, core and trimming shreds, tomato core, peel and seeds, potato peels and coarse solids are utilized as animal feed. Pineapple bran has a great demand as a cattle feed in the Hawaiian island.

A survey was conducted in Ogun state in Nigeria proves that their most common feed for sheep and goats were cassava, yam peel, cowpea husk, and kitchen waste banana peels, plantain peels, pineapple waste, palm kernel meal, maize and sorghum fermentation wastes (Onwuka, *et al.*, 1997).

Banana peel, chopped banana stems, banana rhizome, leaf sheath and banana leaves were used as animal feed (Singh and Uma, 1997). This can form a

better raw material for commercial livestock value added animal feed in philippines.

Banana pseudostem and root stock are used as feed for cattle and sheep (Rao, 1999).

Fruit and vegetable by-products are utilized for fuel and fertilizer production to reduce the hazard of environment and to increase the productivity (Viswanath and Nand, 1989). Organic mannures are prepared from fruit and vegetables by-products (Anand and Maini, 1993).

Nand (1994) indicated that banana peel, mango peel and stone, citrus peel, rag and seeds, pineapple skin and core, grapes stem, skin and seed, guava peel and core with seeds, tomato skin, potato peel, apple peel and seeds are used for biogas production.

Wastes produced by the banana industry are analysed in terms of their quantity, toxicity to the environment and biodegradability. Wastes include reject banana fruits which are left on plantain, suckers, flowers, crowns and leaves and they are utilized for biogas production to reduce the environment pollution (Abarca, 1996).

Maini (1997) stated that some fruit and vegetable by-products can be used in biogas generation and making field mannures. Pineapple peel, core, trimming shreads are used in biogas production.

Singh and Uma (1997) stated that banana peel are enormously used in biogas production.

Banana fibre is in the class of lignocellulosic fibres such as jute, sisal and abaca. Dried banana fibres from the leaf sheaths are used throughout the tropics for making weak rope and fibre containers. The Tropical Product Research Institute in London has received the properties and small scale extraction and processing of banana fibres (Jarman , 1977).

Fibre is obtained from banana pseudostem core and leaf sheath for industrial uses (Singh and Uma, 1997).

Clinical investigation and research findings point out to the favourable effect of a high fibre diet in the management of disease conditions like diabetes mellitus, cardiovascular diseases, obesity and gastro intestinal disorders (Kavitha *et al.*, 1999).

According to Annelli *et al.* (1975) for pulp and paper making banana by-products are used. Banana starch produced in Costa Rica was used as glue in manufacturing card board for banana boxes (Kayisu *et al.*, 1981, Kayisu and Hood, 1981, Lii *et al.*, 1982).

According to Maini (1997) the method of starch extraction from banana pseudostem has been standardized. Singh and Uma (1997) stated starch is extracted from banana rhizome and pseudostem core.

Banana peel is used in the manufacturing of dye, shoe polish and paste (Singh and Uma, 1997). From banana rhizome paper and dye will be prepared. Banana leaf sheath will be used as a wrapping material and shelter. Banana leaves are used as eating plates, wrapping material and medicinal applications.

Peeled leaf sheaths are used fresh or after drying as packing material for flowers, betal leaves, fruits etc. They are stripped into shreds, dried and used for tying packages and making garlands (Rao, 1999). Banana leaves are extensively used in India as a platter especially in South India. In some areas plant is often cultivated for leaves as much as for fruits.

Nand (1993) extracted pectin from citrus peels. Tandon *et al.* (1993) stated that from mango by-products pectin can be extracted.

Maini (1997) indicated that from orange, mango and lime peels and seeds pectin is extracted. Fat and tannins are extracted from mango kernels. From pineapple peel, core and trimming shreds bromeline is manufactured.

2.2 Nutrient composition of banana by-products

The fruit and vegetable wastes are rich source of carbohydrates, proteins, fat, minerals and fibres (Maini, 1997).

Local grasses and weeds, cultivated forages, some tree leaves and banana pseudostem were more degradable and had nutritive value than cereal residues like maize stover (Shem and Kasonta, 1996).

Gopalan *et al.* (1989) analysed the moisture content of banana rhizome, plantain flower bud and plantain stem and reported that these banana by-products contained 85.1, 89.9, 88.3 g of moisture 100 g^{-1} respectively.

Banana pseudostem contain high level of water. Its dry matter content is 8 per cent. The dry matter of peel of mature green plantain is 14.7 per cent (Collin and Dalmic, 1991).

Maini (1997) reported the moisture content in banana peel, central core of banana pseudostem, outer hard fibrous sheath of banana stem and press juice from stem as 79.2g 100 g^{-1}, 93.1g 100 g^{-1}, 91.9g 100 g^{-1}, and 98.6g 100 g^{-1} respectively. Moisture content is higher in the banana peel than in the unripe plantain pulps (Izonfuo and Omuarc, 1998).

Rao (1999) analysed the moisture content of plantain flowers and plantain stem and reported that flower bud contain 89.9g and plantain stem contain 88.3g of moisture per 100 g.

Banana was deficient in essential amino acids with the exception of phenylalanine. Neither the pulp nor the peel yielded good protein efficiency ratio values when used at 6 per cent protein in diets for rats (Sharaf *et al.*, 1979).

According to Gopalan *et al.* (1989) the protein content of plantain stem, flower bud and rhizome were 0.5, 1.7 and 0.4 g $100g^{-1}$ of the edible portion respectively.

According to Maini (1997) the protein content of banana peel, central core of banana stem, outer hard fibrous sheath and press of juice from stem varied from 0.05 to 0.83 g per 100g.

Izonfuo and Omuarc (1998) reported that the crude protein content is higher in the plantain peel than in the unripe plantain pulps. Rao (1999) indicated that plantain flower contain more protein (1.7g) than Banana (1.2g) and green plantain (1.4g).

The fat content of banana rhizome, plantain flower, plantain stem and green plantain was found to be 0.2, 0.7, 0.1 and 0.2g $100g^{-1}$ of the edible portion

(Gopalan *et al.*, 1989). Maini (1997) found that the fat content of banana peel and central core of stem were 0.78 and 0.03 g per 100 g respectively. According Izonfuo and Omuare (1998) there is higher fat in plantain peels than in unripe plantain pulp. Banana flower bud contained 0.7 g of fat while stem contained 0.1g per $100g^{-1}$ of edible portion (Rao, 1999).

Shantha and Siddappa (1970) observed maximum starch content of banana at the time of flowering.

There is a linear increase in starch content from immature to mature stage of plantain. It was reduced to 40 per cent on ripening which indicate a rapid change in carbohydrate metabolism during ripening (Singh *et al.*, 1980).

A study of sugars in banana peels showed the peels contained 14.6 per cent in dry weight basis. This sugar is 19 per cent fructose, 23 per cent glucose and 56 per cent sucrose on dry weight basis (Goewart and Nicholas, 1980).

Physical and chemical properties of banana starch were studied by Kayisu *et al.* (1981), Kayisu and Hood, (1981) and Lii *et al.* (1982) and found that it contained 16 per cent of amylose.

According to Gopalan *et al.* (1989) the carbohydrate content of banana rhizome, plantain flower bud and plantain stem were 11.8, 5.1 and 9.7 g per 100g respectively.

High levels of carbohydrate was observed in banana at the flower bud development stage (Koshy, 1989).

According to Maini (1997) banana peel, central core of banana stem, outer hard fibrous sheath and press juice from stem contained 5, 1.20, 2.44, 0.41 g per 100 g of carbohydrates respectively.

About 20-25 tonnes of banana pseudostem from 1,000 banana plant when extracted provide 5 per cent edible starch (Maini, 1997).

Carbohydrate content was higher in banana pulp than in peel at different stages of ripening (Izonfuo and Omuarc, 1998). Rao (1999) indicated that plantain flower contain 5.1g of carbohydrate and plantain stem contain 9.7g of carbohydrate per 100g.

Fruits and vegetables contain the indigestible material called fibre which add bulk to the stool (Duke, 1988). Gopalan *et al.* (1989) stated that banana rhizomes, plantain flower and plantain stem contain 1.1, 1.3, 0.8 g per 100g of fibre respectively. According to Llanes (1990) total fibre content is higher in fruit peel than in the pulp.

Fifteen banana pseudostems of different varieties and 15 dominant grass were collected from plantation and natural grass lands at Petang. Banana pseudostem contained more crude fibre than natural grasses (Uchida , 1994).

Fibre content of banana peel, central core of pseudostem and outer hard fibrous sheath of banana stem was found to be 1.72, 0.68 and 1.81 g 100 g^{-1} respectivcly (Maini, 1997).

According to Kavitha *et al.* (1999) the crude fibre content of plantain stem raita is 0.69 g and Total Dietary Fibre is 7.80g per 100g. Plantain flower and plantain stem contain fibre 1.3 and 0.8 g 100 g^{-1} of fibre respectively (Rao, 1999).

According to Gopalan *et al.* (1989) mineral content of banana rhizome is 1.4 g per 100 g. Calcium, phosphorous and Iron contents of banana rhizomes are 25 mg, 10 mg and 1.1 mg per 100 g respectively. Mineral content of plantain flower is 1.3 g per 100 g. Calcium, phosphorous, iron, potassium and sodium content of plantain flower is 32 mg, 42 mg and 1.6 mg 185 mg and 20.1 mg respectively. Plantain stem contain calcium (10 mg) phosphorous (10 mg) and iron (1.1 mg) 100 g^{-1} respectively. Green plantain contain calcium (10 mg), phosphorous (29 mg) and iron (6.27 mg) per 100g of edible portion.

Uchida (1994) analysed 15 banana pseudostems of different varieties and 15 dominant grass species from plantations and natural grass lands at Petang. Calcium, Potassium, chlorine, iron and zinc content of pseudostems were higher than those of grasses. The pseudostem contained considerably higher concentration of potassium.

Mineral content of banana peel, banana pseudostem central core, outer hard fibrous sheath and press juice of pseudostem is 2.11 g, 1.04 g, 0.98 g and 0.63 g 100 g^{-1} respectively (Maini, 1997).

Plantain flower and green plantain have higher amounts of potassium than ripe banana (Rao, 1999).

According to Izonfuo and Omuaric (1998) potassium was the most abundant mineral present in green peel and green pulp with estimated values of 37g kg^{-1} in green peel and 8.4 g kg^{-1} in green pulp. Small increase in potassium content was found in plantain peel and pulp during ripening. Iron, calcium and sodium levels showed similar variation but phosphorous levels decreased as

ripening progressed. The concentration of copper and magnesium ions remained fairly constant. The estimated values for copper were 13 mg kg^{-1} and 10 mg kg^{-1} for peel and pulp respectively. The magnesium content of the pulp is 41 mg kg^{-1} which remained constant where as that of peel increases as the fruit ripened. The low sodium content (350 mg kg^{-1}) makes plantain of value added item in the treatment of hypokalaemia.

According to Rao (1999) calcium, phosphorous, iron, magnesium, sodium and potassium content of plantain flower is 32 mg, 42 mg, 1.6 mg, 54 mg 20.1 mg, and 185.0 mg 100 g^{-1} of edible portion.

The vitamin C content of green plantain is 24 mg per 100 g of edible portion (Gopalan *et al.,* 1989). According to Gopalan *et al.* (1989) the level of vitamin C in banana rhizome, plantain flower and plantain stem is 1 mg, 16 mg and 7 mg 100 g^{-1} respectively.

Prasad (1998) stated that banana fruit is a rich source of vitamin C. Rao (1999) analysed the vitamin C content of plantain flower and plantain stem and is about 16 mg and 7 mg 100 g^{-1} of edible portion respectively.

The chlorophyll content of peel declines from 100 to 50 µg per g fresh weight to almost zero during ripening (Srinivasan, 1974). The peel had 5-6 µg per g fresh weight mostly of α-carotene (7%), β-carotene (14%) and lutein (56%) (Gross, 1976).

The chlorophyll is present in the peel in concentrations of 12-13 mg cm^{-2} of the fruit surface in banana and plantains (Scymoure, 1987).

Carotene, thiamine, riboflavin and niacin content of plantain flower is 27 mg, 0.05, 0.02, 0.4 mg 100 g^{-1} respectively. Plantain stem contains thiamine, riboflavin and niacin 0.02, 0.01 and 0.2 mg 100 g^{-1} respectively (Rao, 1999).

According to Balakrishnan (1980) the intact pseudostem of robusta after harvesting continued to translocate nutrients to the developing sucker. According to Aravindakshan (1981) biochemical constituents in banana during the post-harvest period of ripening and storage varied considerably with respect to variety, specific situation, time of harvest, method of ripening and storage conditions.

2.3 Development and organoleptic evaluation of processed products from banana and banana by-products

Banana is the major fruit crop of Kerala. Usually the fruits of banana are used for table as well as culinary purposes, the by-products are being wasted. Attempts were made for the home scale processing of the by-products to develop different value added products (Pavunny, 1996).

Studies showed that Robusta, Harichal, Red banana, Kunnan, Nakitechi, Pachakadali and Thenkunnan varieties are suitable for the preparation of banana figs (Jacob, 1967). According to the author drying of ripe banana in sun or by mechanical method has yielded palatable soft and non-sticky product called banana figs. Dupaigne (1967) stated that among dried ripe banana products, figs are more important. According to Bongeswar and Sreenivasan (1977) banana can be dehydrated by osmosis in sugar syrup at 70 per cent concentration Chadha (1992) stated that ripe banana can be readily processed into figs. According to Pavunny (1997) figs can be prepared from banana fruit. Rao (1999) stated that banana fig is

the popular name for dried ripe fruits. Juicy varieties are generally preferred for preparing figs. Banana figs have a sweet taste and contain 50 per cent or more reducing sugars. They are consumed as such or in puddings and beverages.

Dupaigne (1967) stated that among dried unripe banana, banana flour is the most important. Banana powder prepared from ripe banana was found to contain many of the nutrients that were normally required for the general well being of the body (Patel and Nagar, 1974). According to Pavunny (1997) flour is prepared from raw banana and is a very famous product. Singh and Uma (1997) stated that unripe banana is used to prepare banana flour. Moraes *et al.* (1998) stated that ripe banana flour prepared from banana has potential as supplementay food for school and nursery children in rural areas. According to Rao (1999) banana powder prepared from ripe banana is rich in sugar. Banana powder is prepared from the pulp of ripe fruits after mashing and drying in drum and spray driers. Banana flour is prepared from unripe fruit. Starch contents of banana flour is more. Banana flour is raised as infant food in Kerala.

In East Africa ripe banana is used to make a beer with a low alcohol content (Acland, 1971). In Burundi in East Africa banana occupy 25 per cent of arable land and majority of the fruit is used for beer making (Anon, 1983a)

Adams (1978) describes a procedure for making vinegar from ripe banana. Wine and vinegar are also produced from ripe banana (Anon, 1983b). According to Singh and Uma (1997) 'Cavendish bananas' are found to be best for the wine, while 'Pisang Awak' variety is the best for beer preparation.

Banana is a staple food for people in Uganda in East Africa. A significant income for many farmers is derived from beverage products prepared from banana (Aked and Kyamuhangire, 1996).

According to Pavunny (1997) juice, wine, halwa, sweets and figs can be prepared from banana fruit. Palyankodan and Robusta are good for the preparation of sweets. Nendran scored more for halwa and banana figs and Palayankodan and Poovan were found to be the best varieties for wine preparation. Compared to other varieties of banana Robusta and Chenkadali are good for juice production.

Over ripe banana and acid whey are combined to form a nutritious beverage called whey banana shake and whey banana (Shekilango *et al.*, 1997).

According to Singh and Uma, (1997) banana jam, jelly, banana puree, sweet coat banana, dehydrated bananas slices are becoming popular. Nectar, flakes and preserve are also prepared from ripe banana.

Banana chips is one of the processed products of banana which can be easily produced (Hameed, 1981). According to Kurian *et al.*, (1985) among the different varieties of banana, Nendran is well known for its multifarious use. Unripe banana can be readily processed into canned slices, deep fried chips (Chadha, 1992). According to Pavunny (1997) from raw banana chips are prepared and is a very famous product. According to Singh and Uma, (1997) banana chips from Nendran is the popular product from unripe banana. Fully matured but unripe banana is cut into chips and consumed after frying in oil (Rao, 1999).

Banana fruits are reported to be used for making baby foods in Kerala State (Malathi *et al.*, 1993). According to the authors green tip banana is needed in

the preparation of the weaning food mixes. Weaning food mixes are used in vulnerable stage of infancy. Banana is given to infants of six months in combination with sesame, horse gram, and skim milk as a supplementary food (Prema and Joseph, 1996).

Crowther (1979) stated that the most important processed product from banana is banana puree.

Candy can be prepared from the central core of banana pseudostem (Hameed, 1981).

Giridharilal *et al.*, (1986) developed pickles and vattals from different parts of four banana varieties namely Nendran, Palayankodan, Poovan and Robusta.

White portions of banana peel could be utilized to prepare good quality jam (Maini *et al.*, 1993b) and the peel could be utilized to prepare nutritious cheese (Maini *et al.*, 1993a).

According to Pavunny (1996) pickles and vattals can be prepared from banana flower bud, peel, pseudostem and rhizome. Jelly is prepared from fruit peel. When acceptability test were conducted, Robusta scored (75%) highest in jelly from the fruit peel. The variety Nendran scored maximum for the products like pickle from peel (90%) and rhizome (85%). Vattal from Palayankodan scored next followed by pseudostem and flower bud pickles from Palayankodan. Vattal is prepared from banana by-product along with rice and spices. Jelly and marmalade is prepared from banana peel (Singh and Uma, 1997).

The different by-products developed could be successfully prepared by rural women and would provide additional income to the farming community, provided viable technology and market support are made available (Pavunny, 1996).

2.4 Shelf life of processed product from banana and banana by-products

During storage a number of chemical changes occur which makes the product either unfit for consumption or sometimes rejection on aesthetic grounds. Information on changes during storage in pickles are scanty (Verma *et al.*, 1986).

Fruits and vegetables are more prone to spoilage than cereals due to their nature and composition. This happens in the process of their harvesting, handling transport, storage, marketing and processing (Anand and Maini, 1993).

Microbial quality is one of the most critic quality parameters in a dynamic system such as food. There are different threats in food quality originating from microbial sources. Spoilage causing organisms causes off odour and off-taste and lead to economic losses (Rao, 1998).

The concept of spoilage by microorganisms are the primary cause of the end of shelf life and that hence reducing initial microbial populations is a strategy to extend shelf life (Zagory, 1999).

According to Jacob (1967) banana figs are stored in air tight tins and they can be stored for some months in cardboard cartons lined with polythene.

The dehydrated ripe banana product can be preserved upto one year or more, depending upon the packaging material used and storage condition (Bongeswar and Sreenivasan, 1977).

The most common form of processing plantains is plantain chips from thinly sliced green fingers fried in vegetable oil. The shelf life of plantain chips was six months (Nieva *et al.*, 1975).

According to Singh (1983) dried banana had an unlimited shelf life under proper storage conditions and losses of vitamins were found to be less after dehydration than with other preservation methods.

Hameed (1981) investigated the suitability of flexible packages and innert gas packaging in sealed tins for the storage of fried 'Nendran' banana chips. It was found that for banana chips fried in fresh coconut oil 300 gauge high density polyethylene and 400 gauge low density poly ethylene bag packaging are satisfactory upto two months while packing in tins under CO_2 is satisfactory upto six months at room temperature. Chips fried in ground nut oil and packed under similar conditions were inferior.

Banana chips is one of the processed products of banana which can be produced easily and if proper packaging are provided will store well for months together (Khader *et al.*, 1985).

According to Pavunny (1996) the dried vattal prepared from banana by-product of different varieties of banana can be stored in air tight containers and can be fried in oil for use when required. Pavunny (1996) also observed that pickle and jelly could be stored upto six months without deterioration. The vattal could be stored for one year.

Materials and Methods

3. MATERIALS AND METHODS

The methods used to evaluate the quality of banana by-products are given under the following heads.

3.1 Selection of banana varieties

3.2 Collection of samples

3.3 Nutrient analysis of banana by-products

3.4 Preparation of processed products from banana by-products

3.5 Organoleptic evaluation of processed banana by-products

3.6 Keeping quality of processed products

3.7 Statistical analysis

3.1 Selection of banana varieties

Five banana varieties were selected for the study from Central Nursery, Vellanikkara, Kerala Horticulture Development Programme, Vellanikkara and Banana Research Station, Kannara. The by-products like peel, pseudostem, flowerbud and rhizome from each variety were selected for the study.

The banana varieties selected are

1) Nendran (*Musa* AAB 'Nendran')

2) Poovan (*Musa* AAB 'Rasthali')

3) Palayankodan (*Musa* AAB 'Mysore')

4) Robusta (*Musa* AAA 'Robusta')

5) Kunnan (*Musa* AB 'Kunnan')

3.2 Collection of samples

From each of the selected varieties flower buds were collected before harvesting the bunches, pseudostem, peel and rhizome were collected after harvest.

3.3 Nutrient analysis of banana by-products

Triplicate samples of banana by-products of five banana varieties were analysed for different nutrients like

1) Moisture

2) Protein

3) Fat

4) Starch

5) Fibre

6) Iron

7) Calcium

8) Phosphorus

9) Potassium

10) Sodium

11) Vitamin C

3.3.1 Moisture

Moisture content of the selected dried banana by-products of five banana varieties was estimated using the method of A.O.A.C. (1980).

3.3.2 Protein

The protein content was analysed in dried samples. The nitrogen content of the samples was estimated using the method suggested by Snell and Snell (1963) which was then multiplied by a factor of 6.25 to get the protein content.

3.3.3 Fat

The fat content of the dried samples was estimated using the method of A.O.A.C. (1955).

3.3.4 Starch

The starch content was analysed in the dried samples colorimetrically as suggested by Sadasivam and Manikam (1992).

3.3.5 Crude fibre

Crude fibre content of the dried samples was estimated by acid-alkali digestion method as suggested by Chopra and Kanwar (1978).

3.3.6 Iron and Calcium

For estimating the iron and calcium contents of the samples, diacid extract of the dried samples were prepared and were estimated in an Atomic Absorption Spectrometer (Perkin-Elmer, 1982).

3.3.7 Phosphorus

The phosphorus content was analysed in the dried samples colorimetrically after preparing a diacid extract.

3.3.8 Sodium and potassium

For estimating the sodium and potassium content of the samples, diacid extract of the dried samples were prepared and were estimated in a Flame Photometer.

3.3.9 Vitamin C

The vitamin C content of the fresh samples were estimated by the method of A.O.A.C. (1955) using 2,6,dichlorophenol indophenol dye.

3.4 Preparation of the processed products from banana by-products

Processed products namely pickle and vattal were prepared using all the four edible parts of the five selected varieties. The procedure developed by Pavunny (1996) was used to prepare the processed products. The receipes of banana by-product pickles and vattals were given in Appendix-I. The processed products were stored at ambient storage conditions for a period of six months. The pickles prepared from banana by-products were stored in sterilized bottles and the vattals were stored in sealed polythene bags.

3.5 Organoleptic evaluation of processed banana by-products

Organoleptic evaluation of the processed products was carried out using score card method (Swaminathan, 1974) by a panel of ten selected judges at monthly intervals for a period of six months. For vattals organoleptic evaluation was carried out only after frying.

Selection of judges

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

For pickle colour, taste, flavour and texture were included as the quality attributes and for vattal four quality attributes like appearance, colour, taste and crispness were evaluated. Each of the above mentioned quality attributes was assessed by a five point hedonic scale. The score card used for evaluation is given in Appendix-II.

3.6 Keeping quality of processed products

Microbial count of the stored products was carried out for a period of six months at monthly intervals under ambient storage conditions. For culturing bacteria and fungus, the following media were prepared.

Martin's Rose Bengal media

The culture media for fungus was prepared using the procedure given by Martin (1950).

Dextrose	- 10 g
Peptone	- 5 g
KH_2PO_4	- 1 g
$MgSO_4.7H_2O$	- 0.5 g
Agar	- 15 g
Rose Bengal	- 0.035 g
Streptomycin	- 30 mg
Distilled water	- 1 litre

Nutrient Agar media

Nutrient agar media of the following composition was used for culturing bacteria:

Peptone	- 5 g
Beef extract	- 3 g
Agar	- 15 g
Distilled water	- 1 litre

Procedure for microbial count

Sterilised petridishes were used for the microbial enumeration. One gram of pickle and 1 g of powdered vattal were used as the sample. Considering the low count of micro organisms one gram of sample was directly used without further serial dilution. In culture room the samples were spread in the sterilised petridish over which melted and cooled culture media was poured, and kept for three days for the development of colonies. The number of colonies formed in the culture media were analysed and is taken as the microbial count.

3.7 Statistical analysis

Analysis of data was conducted by using statistical techniques such as analysis of variance, Duncan's multiple range test and Friedmanns test.

Results

4. RESULTS

The results of the study entitled "Quality evaluation of banana by-products" are presented under the following sub-headings.

4.1 Nutritional composition of banana by-products

4.2 Organoleptic evaluation of processed products from banana by-products

4.3 Keeping quality of processed products from banana by-products

4.1 Nutritional composition of banana by-products

Banana by-products like flower bud, peel, pseudostem and rhizome of five banana varieties were collected from the banana orchards of KHDP, Vellanikkara, Central Nursery, Vellanikkara and Banana Research Station, Kannara. The edible parts of these varieties were analysed for eleven nutrients i.e., moisture, protein, fat, starch, fibre, iron, calcium, phosphorus, potassium, sodium and vitamin C. The results of the nutrient composition of by-products of banana varieties are presented in Tables from 1 to 11.

4.1.1 Moisture

The moisture content of banana by-products different varieties are given in Table 1. The mean moisture content of different banana by-products ranged from 82.96 per cent in banana peel to 91.62 per cent in banana pseudostem. The banana flower bud and rhizome had mean moisture content of 90.25 per cent and 86.74 per cent respectively.

Table 1. Moisture content of different by-products of selected banana varieties (g 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	91.33 [a]	84.67 [a]	93.31 [a]	86.13 [a]
Poovan	91.00 [a]	81.00 [a]	91.22 [ab]	87.46 [a]
Palayankodan	89.68 [a]	85.30 [a]	93.78 [a]	87.73 [a]
Robusta	89.27 [a]	82.10 [a]	88.38 [b]	85.76 [a]
Kunnan	90.00 [a]	81.73 [a]	91.40 [ab]	86.63 [a]
Mean	90.25	82.96	91.62	86.74

The moisture content of flower bud of Nendran is higher (91.33%) compared to flower bud of Poovan (91%), Palayankodan (89.68%), Robusta (89.27%) and Kunnan (90%). The raw fruit peel of Palayankodan had a higher moisture content (85.30%) than the other four banana varieties namely Nendran (84.67%), Robusta (82.10%), Kunnan (81.73%) and Poovan (81.00%).

The moisture content of pseudostem of Palayankodan was 93.78 per cent which was found to be higher than the pseudostem of Nendran (93.78%), Kunnan (91.40%), Poovan (91.22%) and Robusta (88.38%). The rhizome of Palayankodan (87.73%) had higher moisture content compared to the rhizomes of Poovan (87.46%), Kunnan (86.63%), Nendran (86.13%) and Robusta (85.76%).

According to DMRT, the different varieties of banana flower buds were classified into single group a and were not significantly different from each other. The different varieties of banana peel and rhizome were also classified into a sole group namely a. The peel and rhizome of different banana varieties did not differ significantly on the basis of moisture content.

The different varieties of banana pseudostem were grouped into three. The group a and ab had two members each and the group b had only one member (Robusta) in it. The varieties of pseudostem included in the same class were not significantly different from each other but differ significantly from the pseudostems of other classes statistically.

Analysis of variance indicated that there is no significant difference between the varieties of banana flower bud (F value = 0.7790), banana peel (F value = 2.3183), banana pseudostem (F value = 3.3978) and banana rhizome (F value = 0.6349) but there is significant difference between the by-products of banana (F value = 56.97) with respect to moisture content at one per cent level.

4.1.2 Protein

The protein content of banana by-products of different varieties are presented in Table 2.

The mean protein content of different banana by-products ranged from 0.38 g in banana rhizome to 1.95 g in banana flower bud. The banana peel and pseudostem had a mean protein content of 0.77 g and 0.50 g respectively.

Table 2. Protein content of different by-products of selected banana varieties (g 100 g^{-1}) (FWB*)

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	2.14 [a]	0.77 [a]	0.59 [a]	0.47 [a]
Poovan	1.50 [a]	0.79 [a]	0.47 [ab]	0.35 [a]
Palayankodan	1.88 [a]	0.83 [a]	0.61 [a]	0.47 [a]
Robusta	1.99 [a]	0.76 [a]	0.46 [ab]	0.32 [a]
Kunnan	2.24 [a]	0.68 [a]	0.35 [b]	0.31 [a]
Mean	1.95	0.77	0.50	0.38

* Fresh weight basis

The protein content of different varieties of flower bud varied from 1.50 g to 2.24 g 100 g^{-1}. The highest and lowest values were found in flower buds of Kunnan and Poovan respectively and Palayankodan and Robusta flower buds were found to have a protein content of 1.88 g and 1.99 g 100 g^{-1} respectively which was higher than Poovan flower bud (1.50 g).

The protein content of raw fruit peel of Kunnan (0.68 g) was found to be lower than that of Robusta (0.76 g), Nendran (0.77 g), Poovan (0.79 g) and Palayankodan (0.83 g).

In the case of pseudostem the highest and lowest values of protein were observed in Palayankodan (0.61 g) and Kunnan (0.35 g) respectively. Pseudostem of Nendran (0.59 g), Poovan (0.47 g) and Robusta (0.46 g) had higher value than that of Kunnan. The protein content of rhizomes of Palayankodan (0.47 g) and Nendran (0.47 g) was found to be higher than that of Poovan (0.35 g), Robusta (0.32 g) and Kunnan (0.31 g).

The flower bud, peel and rhizome of different varieties of banana had been classified statistically into a single group a and there was no significant difference between the varieties of banana flower bud, peel and rhizome. On the basis of protein content the varieties of banana pseudostem were grouped statistically into three groups. The group a and ab had two members and group b had a single member in it. The members of different groups were significant difference between themselves.

Analysis of variance indicated that there is no significant difference between the varieties of banana flower bud (F value = 1.1217), peel (F value =

0.6791), pseudostem (F value = 2.5857) and rhizome (F value = 1.7469) but there is significant difference between different banana by-products (F value = 19.418) in protein content at one per cent level.

4.1.3 Fat

The mean fat content of banana by-products varied from 0.12 g in banana peel to 0.86 g in banana pseudostem (Table 3). The by-product, flower bud had mean fat content of 0.67 g 100 g^{-1} which was found to be higher than the fat content of banana rhizome (0.26 g).

Table 3. Fat content of different by-products of selected banana varieties (g 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	0.55^{bc}	0.77^{b}	0.14^{b}	0.21^{a}
Poovan	0.65^{bc}	0.86^{ab}	0.14^{b}	0.29^{ab}
Palayankodan	0.93^{a}	0.73^{b}	0.09^{c}	0.25^{b}
Robusta	0.74^{ab}	1.01^{a}	0.08^{c}	0.20^{b}
Kunnan	0.51^{c}	0.95^{a}	0.18^{a}	0.37^{a}
Mean	0.68	0.86	0.12	0.26

Among the flower buds of different varieties Palayankodan flower buds was found to be the best with respect to fat content. The lowest fat content was observed in Kunnan flower bud.

The highest and lowest values of fat content among banana peels were observed in Robusta (1.01 g) and Palayankodan (0.73 g) respectively.

The fat content varied from 0.08 to 0.18 per cent among the pseudostem of different varieties. The highest and lowest values were observed in Kunnan and Robusta respectively.

The rhizome of Kunnan had higher fat content compared to Poovan, Palayankodan, Nendran and Robusta.

DMRT classified the varieties of banana flower buds into four groups on the basis of fat content. The flower buds of Palayankodan (0.93 g), Robusta (0.74 g) and Kunnan (0.51 g) included in groups a, ab and c respectively. Nendran (0.55 g) and Poovan (0.65 g) was found to be in the same group bc which showed that it had significant difference from other varieties of banana flower buds.

On the basis of DMRT the different varieties of banana peel were classified into three groups. The groups a and b had two members each namely peels of Robusta (1.01 g) and Kunnan (0.95 g), Nendran (0.77 g) and Palayankodan (0.73 g) respectively. The group ab had single member in it. Banana peel of different varieties included in the same class were not significantly different from each other but differ significantly from the varieties of other classes statistically.

According to DMRT, the varieties of banana pseudostem were classified into three groups. The group b and c had two members each namely pseudostem of Nendran (0.14 g) and Poovan (0.14 g) in group b and Palayankodan (0.09 g) and Robusta (0.08 g) in group c. The variety Kunnan (0.18 g) was grouped as a single group a. The rhizomes of Nendran (0.21 g), Palayankodan (0.25 g) and Robusta (0.20 g) came to be in the same group b. The group a had two members in it and they were namely rhizomes of Kunnan (0.37 g) and Nendran (0.21 g). The rhizome of Pooven (0.29 g) was included into a single group ab. The members of

same group had no significant difference between themselves but they differ significantly from the varieties of other classes.

Significant variation in fat content was observed (at one per cent level) between the varieties of banana peel (F value = 7.3875) and pseudostem (F value = 39.6916) and between different by-product (F value = 7.681) with respect to fat content. But there is no significant difference between the varieties of banana flower bud (F value = 6.3948) and rhizome (F value = 5.5099) in fat content of one per cent level.

4.1.4 Starch

The starch content of banana by-products of different varieties are presented in Table 4.

Table 4. Starch content of different by-products of selected banana varieties (g 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	5.66 [a]	5.45 [a]	9.54 [a]	9.60 [a]
Poovan	4.76 [a]	5.41 [a]	9.88 [a]	10.16 [a]
Palayankodan	4.59 [a]	5.25 [a]	9.61 [a]	9.96 [a]
Robusta	4.65 [a]	4.85 [a]	8.83 [a]	10.81 [a]
Kunnan	4.51 [a]	5.42 [a]	9.21 [a]	9.53 [a]
Mean	4.83	5.28	9.41	10.01

The mean starch content was found to be highest in banana rhizome (10.01 g) and lowest value was observed in flower bud (4.83 g).

The starch content of flower bud varied from 4.51 to 5.66 per cent among different varieties. The highest and lowest values were observed in Nendran and Kunnan respectively.

The highest and lowest values of starch content in banana peels was observed in Nendran (5.45 g) and Robusta (4.85 g) respectively.

The starch content of pesudostems of different varieties were found to be highest in Poovan (9.88 g) and lowest value in Robusta (8.83 g). The pseudostem of Palayankodan (9.61 g), Nendran (9.54 g) and Kunnan (9.21 g) were higher than Robusta. The starch content of rhizome of Robusta (10.81 g) was found to be higher than rhizome of Poovan (10.16 g), Palayankodan (9.96 g), Nendran (9.60 g) and Kunnan (9.53 g).

Statistically the banana flower buds, peel, pseudostem and rhizome of different varieties were classified into a single group 'a' and there is no significant difference between banana varieties within the same by-products on the basis of starch content.

Analysis of variance indicated that the variation with respect to starch content between banana by-products (F value = 82.885) was significant at one per cent level but the variation in starch content was found to be insignificant between varieties of banana flower bud (F value = 0.4938), peel (F value = 0.2038), pseudostem (F value = 0.2402) and rhizome (F value = 0.5860).

4.1.5 Fibre

The mean fibre content of banana by-products of different varieties are furnished in Table 5.

The mean fibre content of different banana by-products varied from 0.99 per cent to 1.87 per cent with banana rhizome having the lowest and banana peel with the highest value.

Table 5. Fibre content of different by-products of selected banana varieties (g 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	1.05 [b]	2.36 [a]	1.24 [a]	1.00 [bc]
Poovan	1.21 [b]	1.87 [ab]	1.09 [a]	1.17 [a]
Palayankodan	1.19 [b]	1.44 [b]	0.96 [a]	1.12 [ab]
Robusta	1.32 [ab]	2.60 [a]	1.11 [a]	0.68 [d]
Kunnan	1.55 [a]	1.10 [b]	1.43 [a]	0.96 [c]
Mean	1.26	1.87	1.17	0.99

The fibre content varied from 1.05 to 1.55 per cent among the flower buds of different varieties. The highest and lowest values were observed in Kunnan and Nendran respectively.

The highest and lowest values of fibre content among banana peel was observed in Robusta (2.60%) and Kunnan (1.10%) respectively.

The fibre content of the pseudostems of different banana varieties were found to be highest in Kunnan (1.43%) and lowest in Palayankodan (0.96%). The pseudostem of Nendran (1.24%), Robusta (1.11%) and Poovan (1.09%) were higher than Palayankodan.

The fibre content of rhizomes of Poovan (1.17%) was found to be higher than Palayankodan (1.12%), Kunnan (0.96%), Nendran (1.00%) and Robusta (0.68%).

DMRT classified the varieties of banana flower buds into three groups on the basis of fibre content. The flower bud with the highest fibre content was found to be in Kunnan (1.55 g) and was included in the group a and it differed significantly from other varieties of banana flower buds. The varieties Poovan

(1.21 g), Palayankodan (1.19 g) and Nendran (1.05 g) were included in the same group b. The group ab had a single member namely Robusta (1.32 g). The varieties of banana peel was also classified into three groups. The group a and b had two members each and they are Nendran (2.36 g) and Robusta (2.60 g) and group a and Palayankodan (1.44 g) and Kunnan (1.10 g) in group b. Poovan peel (1.87 g) was included in group ab and was significantly different from the banana peel of other varieties.

The pseudostem of banana varieties were grouped into one group a and they were not significantly different from each other.

The rhizome of Poovan, Palayankodan, Nendran, Kunnan and Robusta were given under separate groups a, ab, bc, c and d respectively and they were significantly different from each other.

Analysis of variance revealed significant variation in fibre content in different varieties of banana rhizome (F value = 27.0356) at one per cent level. Significant variation was also observed in the fibre content of banana by-products (F value = 6.1809) but no significant variation was observed in different varieties of banana flower buds (F value = 4.0429), banana peel (F value = 6.4692) and pseudostem (F value = 1.1034) at one per cent level.

4.1.6 Iron

The mean iron content of different banana by-products varied from 1.02 mg to 1.29 mg 100 g^{-1} (Table 6). The highest value was observed in banana flower bud. The mean iron content of banana rhizome (1.07 mg) was found to be higher than banana peel (1.02 mg) and banana pseudostem (1.02 mg).

Table 6. Iron content of different by-products of selected banana varieties (mg 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	1.19 [bc]	1.14 [a]	1.06 [a]	1.23 [a]
Poovan	1.44 [a]	0.93 [bc]	1.16 [a]	0.81 [c]
Palayankodan	1.55 [a]	0.84 [c]	1.18 [a]	1.16 [ab]
Robusta	1.15 [bc]	1.11 [ab]	0.82 [b]	1.06 [b]
Kunnan	1.11 [c]	1.06 [ab]	0.87 [b]	1.09 [ab]
Mean	1.29	1.02	1.02	1.07

The iron content of the banana flower bud varieties varied from 1.11 mg in Kunnan to 1.55 mg in Palayankodan. The iron content of flower bud of Nendran (1.19 mg), Poovan (1.44 mg) and Robusta (1.15 mg) was found to be higher than the peel of Robusta (1.11 mg), Poovan (0.93 mg), Palayankodan (0.84 mg) and Kunnan (1.06 mg).

The highest iron content was reported in pseudostem of Palayankodan (1.18 mg) and lowest in Robusta (0.82 mg) among the pseudostem of five varieties of banana by-products. The pseudostem of Nendran (1.06 mg), Poovan (1.16 mg), Kunnan (0.87 mg) had a higher iron content than the Robusta (0.82 mg).

Nendran rhizome (1.23 mg) was found to be the highest in iron content followed by Palayankodan (1.16 mg), Kunnan (1.09 mg) and Robusta (1.06 mg). Poovan rhizome (0.81 mg) had the lowest iron content among the varieties.

With respect to iron content, different varieties of banana flower buds were classified statistically into three classes. Both the groups a and bc had two members each and group c had one member. Banana peel of different varieties were also classified statistically into four groups. The group a, bc and c

accommodating only one variety of banana peel each. The peel of Robusta and Kunnan varieties was included in group ab. The pseudostem of different varieties of banana were grouped into two classes. The pseudostem of banana varieties Palayankodan, Poovan and Nendran was in the group a and Kunnan and Robusta were included in group b. Statistically, the banana rhizome were classified into four groups on the basis of iron content. The group ab contained two members each and the group a, b and c contained one member. The varieties included in the same class were not significantly different from each other but different from varieties of other classes statistically.

Analysis of variance indicated that there is significant difference between the varieties of banana pseudostem (F value = 11.8445) and banana rhizome (F value = 13.8458) and significant difference between different by-products of banana (F value = 19.538). But there is no significant difference observed in different varieties of banana flower bud (F value = 4.4228) and banana peel (F value = 5.6313) with respect to iron content at one per cent level.

4.1.7 Calcium

The calcium content of by-products of different banana varieties is given in Table 7.

The mean calcium content was found to be highest and lowest in flower bud (26.97 mg) and pseudostem (13.47 mg) respectively. Banana peel had a mean calcium content of 26.38 mg and rhizome contained 26.3 mg 100 g^{-1} of calcium.

Table 7. Calcium content of different by-products of selected banana varieties (mg 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	25.59 ^{c}	23.55 ^{b}	14.60 ^{a}	30.83 ^{a}
Poovan	31.50 ^{a}	24.52 ^{b}	14.06 ^{ab}	24.93 ^{c}
Palayankodan	26.22 ^{bc}	31.28 ^{a}	13.72 ^{ab}	21.13 ^{d}
Robusta	27.80 ^{b}	30.22 ^{a}	12.39 ^{b}	26.58 ^{bc}
Kunnan	23.75 ^{d}	22.32 ^{b}	12.61 ^{b}	28.12 ^{b}
Mean	26.97	26.38	13.47	26.32

Based on calcium content of by-product of banana flower buds, they were grouped into five categories statistically. The groups a, b, bc, c and d contained only one member each which are Poovan (31.50 mg), Robusta (27.80 mg), Palayankodan (26.22 mg), Nendran (25.59 mg) and Kunnan (23.75 mg). The banana peel of different varieties were classified into two groups. The group a contained two members in it and they were Palayankodan (31.28 mg) and Robusta (30.22 mg). The varieties Poovan (24.52 mg), Nendran (23.55 mg) and Kunnan (22.32 mg) were included in group b. The varieties included in group a are significantly different from varieties included in group b. Different pseudostem varieties of Poovan (14.06 mg) and Palayankodan (13.72 mg) and Kunnan (12.61 mg) and Robusta (12.39 mg) were included in the group ab and b respectively. Nendran pseudostem (14.60 mg) was included as a sole group a. The rhizome of different banana varieties were classified statistically into five different groups. The variety Nendran (30.83 mg) had highest calcium content among rhizomes and was grouped in category a. The varieties Kunnan (28.12 mg), Robusta (26.58 mg), Poovan (24.93 mg) and Palayankodan (21.13 mg) were included in the separate groups b, bc, c and d respectively. The varieties included

in the same class were not significantly different from each other but different from varieties of other classes statistically within the same banana by-products.

Analysis of variance indicated that there is significant variation between the varieties of banana flower bud (F value = 35.4613), banana peel (F value = 37.5853) and banana rhizome (F value = 33.857) and different banana by-products (F value = 77.278) with respect to calcium content. But there is no significant difference between different varieties of banana pseudostem (F value = 3.3332) at one per cent level.

4.1.8 Phosphorus

The phosphorus content of banana by-products of different varieties and the mean phosphorus content of by-products of banana are presented in Table 8.

The mean phosphorus content of the banana by-products varied from 11.96 mg 100 g^{-1} to 42.07 mg 100 g^{-1}. The highest and lowest phosphorus content were observed in flower buds and pseudostems of banana respectively. The mean phosphorous content of banana peel (20.09 mg) was found to be higher than banana rhizome (15.41 mg).

Table 8. Phosphorus content of different by-products of selected banana varieties (mg 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	36.79 ^{c}	21.63 ^{a}	11.95 ^{ab}	16.90 ^{a}
Poovan	39.01 ^{b}	19.04 ^{b}	13.06 ^{a}	15.54 ^{a}
Palayankodan	44.52 ^{a}	18.96 ^{b}	11.14 ^{ab}	12.52 ^{b}
Robusta	45.69 ^{a}	19.63 ^{b}	10.39 ^{b}	16.54 ^{a}
Kunnan	44.36 ^{a}	21.72 ^{a}	13.28 ^{a}	15.53 ^{a}
Mean	42.07	20.09	11.96	15.41

The varieties of banana flower buds were grouped into three classes statistically based on their phosphorus content. Robusta flower bud (45.69 mg) with the highest phosphorus content among flower buds was grouped in category a along with flower buds of Palayankodan (44.52 mg) and Kunnan (44.36 mg) indicating that they are not significantly different from each other but different from varieties of other categories statistically. The groups b and c contained only one member which are flower buds of Poovan (39.01 mg) and Nendran (36.79 mg) respectively.

In the case of banana peel of different varieties, they were classified statistically into two groups. The group a contained two members and they were peels of Kunnan (21.72 mg) and Nendran (21.63 mg). The group b had three members in it and they were Robusta (19.63 mg), Poovan (19.04 mg) and Palayankodan (18.96 mg). There is significant variation between the members of group a and group b with respect to phosphorus content.

The pseudostem of different varieties were classified statistically into three groups. Both the groups a and ab had two members each which were Kunnan (13.28 mg) and Poovan (13.06 mg) in group a and Nendran (11.95 mg) and Palayankodan (11.14 mg) respectively. The group b contained only one member Robusta (10.39 mg) with the lowest phosphorus content among different varieties of banana pseudostem. The varieties included in the same class were not significantly different from each other but different from varieties of other classes statistically.

DMRT classified the different varieties of banana rhizome into two groups. Group a had four members in it and they were rhizomes of Nendran (16.90 mg), Robusta (16.54 mg), Poovan (15.54 mg) and Kunnan (15.53 mg). Palayankodan rhizome (12.52 mg) was included in a single group b. The varieties included in group a was significantly different from group b.

Analysis of variance indicated that there is significant variation between the varieties of banana flower bud (F value = 38.0450), peel (F value = 7.2408) and rhizome (F value = 16.5697) and between the by-products of banana (F value = 84.420) at one per cent level with respect to their phosphorus content. But there is no significant variation between the varieties of banana pseudostem (F value = 4.8575) at one per cent level.

4.1.9 Potassium

The potassium content of the different banana by-products are given in Table 9. The mean potassium content ranged from 85.75 mg (pseudostem) to 192.8 mg (rhizome). The banana flower bud had a mean potassium content of 190.1 mg which was found to be higher than peel (124.7 mg) and pseudostem (85.75 mg) of banana.

Table 9. Potassium content of different by-products of selected banana varieties (mg $100\ g^{-1}$)

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	191.9 [a]	126.3 [a]	83.13 [b]	189.5 [c]
Poovan	188.9 [bc]	123.1 [bc]	87.88 [a]	190.6 [c]
Palayankodan	191.4 [a]	124.8 [ab]	87.35 [a]	190.6 [c]
Robusta	187.6 [c]	125.6 [a]	81.85 [b]	195.7 [b]
Kunnan	190.7 [ab]	121.5 [c]	88.56 [a]	197.8 [a]
Mean	190.1	124.3	85.75	192.8

The potassium content of Nendran flower bud (191.9 mg) was found to be higher than that of flower buds of Palayankodan (191.4 mg), Kunnan (190.7 mg), Poovan (188.9 mg) and Robusta (187.6 mg).

The highest potassium content was reported in Nendran peel (126.3 mg) and lowest in Kunnan peel (121.5 mg) among the peels of five banana varieties. The peels of Robusta (125.6 mg), Palayankodan (124.8 mg) and Poovan (123.1 mg) had a higher potassium content than Kunnan (121.5 mg). Pseudostem of Kunnan (88.56 mg) was found to be highest in potassium content followed by Poovan (87.88 mg), Palayankodan (87.35 mg), Nendran (83.13 mg) and Robusta (81.85 mg). The potassium content of the rhizome of Kunnan (197.8 mg) was found to be higher than that of Robusta (195.7 mg), Poovan (190.6 mg), Palayankodan (190.6 mg) and Nendran (189.5 mg).

DMRT classified the different varieties of banana flower bud and peel into four groups, rhizome into three groups and pseudostem into two groups on the basis of potassium content. The group a of flower bud had two members and the group ab, bc and c had only one member each. The group ab, bc and c of banana peel had only one member in each but group a included two members. The pseudomstem of different banana varieties include group a and group b which contained three and two members respectively. Banana rhizome of different varieties had three groups that was group a, b and c. The group a and b had single members but group c had three members in it. The varieties included in the same class were not significantly different from each other but different from varieties of other classes with in the same banana by-product statistically.

Analysis of variance also revealed that there is significant variation in the potassium content between the varieties of banana flower bud (F value = 8.6161), peel (F value = 12.7151), pseudostem (F value = 13.0496) and rhizome (F value = 60.4363) and significant variation between by-products (F value = 70.232) of banana at one per cent level.

4.1.10 Sodium

The mean sodium content of by-products of different banana varieties are furnished in Table 10.

The mean sodium content of different banana by-products varied from 18.76 mg to 27.31 mg with banana peel having the lowest and banana rhizome with the highest value. The by-products, flower bud and pseudostem had mean sodium content of 19.64 mg and 20.52 mg respectively.

Table 10. Sodium content of different by-products of selected banana varieties (mg 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	21.05 ^{a}	19.55 ^{a}	20.67 ^{bc}	27.02 ^{a}
Poovan	18.03 ^{b}	18.39 ^{a}	23.38 ^{a}	25.58 ^{a}
Palayankodan	18.21 ^{b}	18.45 ^{a}	18.19 ^{d}	27.30 ^{a}
Robusta	18.33 ^{b}	18.79 ^{a}	18.71 ^{cd}	27.81 ^{a}
Kunnan	22.56 ^{a}	18.62 ^{a}	21.66 ^{ab}	28.83 ^{a}
Mean	19.64	18.76	20.52	27.31

The sodium content of different varieties of flower bud varied from 18.03 mg to 22.56 mg 100 g^{-1}. The highest and lowest values were found in the flower bud of Kunnan and Poovan respectively. The flower buds of Nendran and

Robusta were found to have a sodium content of 21.05 mg and 18.33 mg 100 g^{-1} respectively which was higher than that of Palayankodan flower bud (18.21 mg).

The sodium content of Poovan peel (18.39 mg) was found to be lower than that of peels of Palayankodan (18.45 mg), Kunnan (18.62 mg), Robusta (18.79 mg) and Nendran (19.55 mg).

In the case of pseudostem the highest and lowest values of sodium were observed in Poovan (23.38 mg) and Palayankodan (18.19 mg) respectively. Kunnan (21.66 mg), Nendran (20.67 mg) and Robusta (18.71 mg) pseudostem had higher values than Palayankodan pseudostem. The sodium content of rhizome of Kunnan (28.83 mg) was found to be higher than Robusta (27.81 mg), Palayankodan (27.30 mg), Nendran (27.02 mg) and Poovan (25.58 mg).

The varieties of banana flower bud were grouped statistically into two groups. The group a had two members and group b had three members in it. The members of different groups had significant difference between themselves. The peel and rhizome of different varieties of banana were grouped statistically into a single group (a) and there was no significant difference between varieties of banana peel and rhizome on the basis of sodium content. The pseudostem of Poovan, Kunnan, Nendran and Robusta and Palayankodan were given under separate groups a, ab, bc, cd and d respectively and they were significantly different from each other.

Significant variation was observed (at 1% level) between the varieties of banana flower bud (F value = 1.5018) and banana pseudostem (F value = 9.7457) and between different by-products (F value = 63.360) with respect to sodium

content. But there is no significant difference was observed between the varieties of banana peel (F value = 0.4805) and banana rhizome (F value = 1.5018) in sodium content at one per cent level.

4.1.11 Vitamin C

The vitamin C content of banana by-products of different varieties and the mean vitamin C content of the banana by-products are presented in Table 11.

The mean vitamin C content of the banana by-products varied from 0.6943 mg to 12.35 mg 100 g^{-1}. The highest and lowest vitamin C contents were observed in flower bud and peel of banana respectively. The vitamin C content of pseudostem of banana was found to be higher than rhizome (0.83 mg) and peel (0.70 mg).

Table 11. Vitamin C content of different by-products of selected banana varieties (mg 100 g^{-1})

Variety	Banana by-products			
	Flower bud	Peel	Pseudostem	Rhizome
Nendran	11.59 [a]	0.77 [a]	3.37 [a]	0.82 [a]
Poovan	11.90 [a]	0.67 [a]	3.90 [a]	0.82 [a]
Palayankodan	11.69 [a]	0.74 [a]	4.13 [a]	0.84 [a]
Robusta	13.59 [a]	0.66 [a]	4.04 [a]	0.79 [a]
Kunnan	12.98 [a]	0.64 [a]	4.82 [a]	0.87 [a]
Mean	12.35	0.70	4.05	0.83

The vitamin C content varied from 11.59 mg to 13.59 mg among the flower buds of different varieties. The highest and lowest values were observed in Robusta and Nendran respectively.

The highest and lowest values of vitamin C content among banana peels was observed in Nendran (0.77 mg) and Kunnan (0.64 mg) respectively.

The vitamin C content of pseudostems of different varieties were found to be highest in Kunnan (4.82 mg) and lowest in Nendran (3.37 mg). The vitamin C content of pseudostem of Palayankodan (4.13 mg), Robusta (4.04 mg) and Poovan (3.90 mg) were higher than Nendran. But the vitamin C content of rhizome of Kunnan (0.87 mg) was found to be higher than rhizome of Palayankodan (0.84 mg), Poovan (0.82 mg), Nendran (0.82 mg) and Robusta (0.79 mg).

Statistically the banana flower bud, peel, pseudostem and rhizome of different varieties were categorized into a single group (a) and was found to be statistically insignificant between banana varieties with respect to the vitamin C content.

Analysis of variance indicated that there is no significant difference between the different varieties of banana flower bud (F value = 1.7527), peel (F value = 1.9216), pseudostem (F value = 0.6886) and rhizome (F value = 0.2281) but there is significant difference at one per cent level between the different banana by-products (F value = 52.793) with respect to vitamin C content.

4.2 Organoleptic evaluation of processed products from banana by-products

The organoleptic studies of the banana by-products after processing were assessed by score card method. Each character was scored using a five point hedonic scale by a panel of ten judges for four quality attributes namely colour, taste, flavour and texture in pickles and appearance, colour, taste and crispness in

vattals. The four quality attributes were described on a five point scale and the total score was obtained out of twenty. The mean scores obtained for pickles and vattals of different varieties for a period of six months are furnished in Table 12 to 15.

From Table 12 it can be seen that, in pickles of banana flower buds of different varieties had highest mean for colour in Palayankodan and lowest in Robusta. The highest scores obtained for palayankodan was in the fourth month (3.7) and the lowest at the sixth month (3.4) of storage. The variety Robusta scored a maximum of 2.8 at the first month and the score was 2.6 at the sixth month of storage.

For the second quality attribute namely, taste, the mean score was highest in Palayankodan, which scored the maximum (3.9) at the fourth and fifth months and minimum (2.4) at the first month of storage. The lowest score was assigned to Robusta flower bud, which was 2.4 at the first month of storage, and the score was maximum (2.8) at the fifth month.

The scores of flavour was highest in Palayankodan flower bud pickles and lowest in Robusta flower bud. The maximum score for Palayankodan was obtained at the first month (3.8) and minimum at the sixth month of storage (3.2). Robusta flower bud scored maximum (2.8) at the third month and minimum (2.4) at the sixth month of storage.

In texture, the Nendran flower bud scored 3.6 at the second month and it was maximum (4.2) at the sixth month of storage. The lowest value was assigned to Robusta having a maximum (3.3) at fourth month and minimum (3.1) at the sixth month of storage.

Table 12. Organoleptic evaluation of pickles prepared from different varieties of banana by-products during six month of storage

Quality attributes	Storage period (months)	Flower bud					Peel					Pseudostem					Rhizome				
		N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K
Colour	1	3.2	3.1	3.5	2.8	2.6	4.4	3.9	4.2	4.1	3.7	3.1	3.1	3.4	3.6	3.2	4.0	3.5	3.5	3.4	3.0
	2	3.3	3.0	3.5	2.3	2.7	4.4	4.1	4.5	4.1	3.9	3.1	3.1	3.6	3.6	3.0	4.1	3.9	3.5	3.5	3.1
	3	3.4	3.1	3.6	2.6	2.7	4.3	4.1	4.0	4.1	3.9	3.1	3.0	3.5	4.2	3.0	4.2	3.9	3.6	3.7	3.0
	4	3.4	3.0	3.7	2.7	2.7	4.2	4.0	4.0	4.0	3.9	3.2	3.0	3.7	4.1	3.2	4.3	3.9	3.9	3.5	3.1
	5	3.2	3.0	3.5	2.6	2.6	4.2	3.8	4.0	4.1	3.6	3.1	3.3	3.9	4.2	3.5	4.1	3.9	4.1	3.7	3.1
	6	3.0	2.9	3.4	2.6	2.7	4.4	3.8	3.9	4.1	3.4	2.9	3.4	3.9	4.0	3.3	4.1	4.0	3.8	3.7	3.2
Taste	1	2.8	3.3	3.6	2.4	3.3	4.1	3.2	4.0	4.0	3.7	3.0	3.1	3.6	4.0	3.0	4.5	3.9	3.9	3.6	3.1
	2	2.9	3.4	3.8	2.6	3.2	4.2	3.8	4.0	4.0	3.4	3.2	3.1	3.3	4.0	2.9	4.4	3.5	3.8	3.5	3.2
	3	3.1	3.5	3.8	2.6	3.1	4.3	3.9	4.1	4.1	4.1	3.0	3.0	3.6	4.3	3.1	4.2	3.9	3.8	3.5	3.2
	4	3.1	3.4	3.9	2.9	3.0	4.4	3.5	4.1	4.0	4.1	3.4	3.2	3.7	4.5	3.1	4.2	4.0	3.7	3.4	3.2
	5	3.2	3.3	3.9	2.8	3.2	4.5	3.7	3.8	4.2	4.0	3.3	3.3	3.8	4.7	3.2	4.2	3.9	3.6	3.7	3.3
	6	3.0	3.2	3.7	2.7	3.1	4.6	3.7	4.4	4.3	3.8	3.2	3.5	4.0	4.8	3.4	4.4	3.5	3.9	3.9	3.3
Flavour	1	3.0	3.2	3.8	2.6	2.9	4.0	3.8	3.8	4.1	3.7	3.2	3.8	3.5	3.9	3.1	4.1	3.4	3.5	3.1	3.6
	2	3.3	3.3	3.4	2.6	2.8	4.1	3.9	3.9	4.3	4.3	3.2	3.3	3.6	4.0	3.1	4.2	3.6	3.6	3.7	3.6
	3	3.1	3.2	3.4	2.8	3.2	4.3	4.0	3.9	4.3	4.4	3.1	3.2	3.8	4.3	3.1	4.3	3.7	3.6	3.6	3.6
	4	3.1	3.2	3.5	2.5	3.0	4.2	4.1	3.9	4.4	4.3	3.4	3.2	3.5	3.8	3.3	4.3	3.7	3.9	3.7	3.7
	5	2.9	3.1	3.3	2.5	3.2	4.1	3.6	3.6	3.9	4.0	3.2	3.3	3.8	4.2	3.0	4.6	3.7	3.9	3.9	3.9
	6	2.7	3.1	3.2	2.4	3.0	4.1	3.9	3.5	3.6	3.5	3.1	3.3	3.7	4.4	3.2	4.6	3.8	3.8	3.7	3.9
Texture	1	3.6	3.3	3.5	2.9	2.8	4.2	3.5	3.8	3.6	3.2	2.9	3.0	3.3	3.5	3.1	3.7	3.6	3.8	3.1	3.4
	2	3.8	3.3	3.7	3.1	3.0	4.2	3.9	3.9	4.1	3.8	2.8	3.0	3.2	3.6	3.1	3.8	3.6	3.5	3.6	3.4
	3	3.9	3.5	3.9	3.5	3.2	4.1	4.1	4.2	4.5	3.7	3.3	3.3	3.9	3.8	3.1	3.8	3.8	3.9	3.7	3.4
	4	4.0	3.5	4.1	3.3	3.3	4.5	4.3	4.3	4.5	3.7	3.3	3.2	3.8	4.2	3.4	4.0	4.0	4.1	3.8	3.6
	5	4.1	3.4	4.1	3.4	3.1	4.6	4.2	4.3	4.5	3.8	3.4	3.5	4.1	4.5	3.6	4.3	3.8	4.1	3.8	3.7
	6	4.2	3.5	4.2	3.5	3.1	4.6	4.0	4.3	4.6	3.7	3.6	3.8	4.1	4.6	3.7	4.3	3.8	4.3	3.7	3.8

N - Nendran Po - Poovan Pa - Palayankodan R - Robusta K - Kunnan

When the total score (Table 13) for all the quality attributes of banana flower bud was considered, the highest score was obtained for Palayankodan and lowest score was obtained for Robusta. The variety Palayankodan obtained the maximum of 15.2 at the fourth and minimum of 14.4 at the first month and second month of storage. Robusta obtained a maximum (11.5) at the third month and a minimum (10.6) at the second month of storage.

Statistical analysis of data revealed that significant difference at one per cent level (probability 0.000) existed between the pickles of different varieties of banana flower buds but there was no significant difference in the organoleptic qualities during the period of storage at one per cent level (Probability 0.2029).

Taking the pickles of different varieties of banana peels the mean score for colours was highest in Palayankodan and lowest in Kunnan. Palayankodan scored maximum (4.5) at the second month and minimum (3.9) at the sixth month of storage while Kunnan scored maximum (3.9) at the second, third and fourth month of storage and minimum (3.4) at the sixth month of storage.

In taste, the variety Nendran was found to have the highest score but the variety Poovan had the lowest score. Nendran scored maximum (4.6) at the sixth month of storage and a minimum 4.1) at the first month of storage. The variety Poovan scored a maximum (3.9) at the third month and a minimum (3.2) at the first month of storage.

The mean score for flavour varied from 4.0 to 4.3 at the first and third of storage respectively. The score was 4.1 at the sixth month of storage. The variety

Palayankodan peel was found to have the lowest score a maximum (3.9) at the second, third and fourth month and a minimum (3.5) at the sixth month of storage.

For the fourth quality attribute namely texture, the mean score varied from 4.1 (first month) to 4.6 (fifth and sixth month) and 3.2 (first month) to 3.8 (second and fifth month) in Nendran and Kunnan respectively. The lowest score was assigned to Kunnan and highest for Nendran.

In Table 13, the total score of banana peel for all the quality attribute was found to be highest for Nendran peel and lowest for Kunnan peel. The variety Nendran obtained a maximum score of 17.7 at the sixth month and minimum score of 16.7 at the first month of storage. Robusta peel obtained 16.1 (maximum) at the third month and 14.3 (minimum) at the first month of storage.

When the data was analysed statistically, it was found that there was significant difference at one per cent level (probability 0.0000) between the pickles of different varieties of banana peel whereas no significant difference was existed at monthly intervals (probability 0.0641).

Taking the pickles of different varieties of banana pseudostem, the scores for colour for Robusta was maximum (4.2) at the third and fifth month and minimum (3.6) at the first month of storage. For Nendran the maximum score was 3.2 (fourth month) and minimum score was 2.9 (sixth month) of storage.

The mean score for taste for pickle was lowest in Nendran and highest in Robusta pseudostems. The variety in Robusta scored a maximum of 4.8 at the sixth month and minimum of 4.0 at the first and second months of storage while

Table 13. Overall acceptability of pickles prepared from different varieties of banana by-products during six month of storage

Quality attributes	Storage period (months)	Flower bud					Peel					Pseudostem					Rhizome				
		N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K
Total score	1	12.6	13.2	14.4	10.7	11.6	16.7	14.4	15.8	15.8	14.3	12.2	13.0	13.6	15.0	12.4	16.3	14.4	14.7	13.2	13.1
	2	13.3	13.5	14.4	10.6	11.7	16.9	15.7	16.3	16.5	15.4	12.3	12.5	13.7	15.2	12.1	16.5	14.6	14.4	14.2	13.3
	3	13.5	13.8	14.7	11.5	12.2	17.0	16.1	16.2	17.0	16.1	12.5	12.5	14.8	16.6	12.3	16.5	15.3	14.9	14.5	13.2
	4	13.6	13.8	15.2	11.4	12.0	17.3	15.9	16.3	16.9	16.0	13.3	12.6	14.7	16.6	13.0	16.8	15.6	15.6	14.4	13.7
	5	13.4	13.4	14.8	11.3	12.1	17.4	15.3	16.3	16.7	15.4	13.0	13.4	15.6	17.6	13.3	17.2	15.3	15.7	15.1	14.0
	6	13.4	13.3	14.5	11.2	11.9	17.7	15.4	16.1	16.6	14.4	12.8	14.0	15.7	17.8	13.6	17.4	15.1	15.8	15.0	14.2

N - Nendran Po - Poovan Pa - Palayankodan R - Robusta K – Kunnan

Nendran scored maximum of 3.4 at the fourth month and minimum of 3.0 at first and third month of storage.

In flavour, the variety Robusta pickle was found to have the highest mean score while the variety Kunnan pickle had a lowest mean score. The variety Robusta scored maximum of 4.4 at the sixth month and minimum of 3.8 at the fourth month of storage. The variety Kunnan scored maximum of 3.3 at the fourth month and minimum of 3.0 the fifth month of storage.

The mean score for texture in pseudostem pickles were found to be highest for Robusta and lowest for Nendran. Robusta scored maximum of 4.6 at the sixth month and minimum of 3.5 at the first month of storage but Nendran scored maximum of 3.6 at the sixth month and minimum of 2.8 at the second month of storage.

Taking the total score (Table 13) for different quality attributes if banana pseudostem, it was found that the highest score was assigned to Robusta while the lowest score was for Nendran. Robusta scored the maximum (17.8) at the sixth month and minimum (15.0) at the first month of storage, but Nendran scored the maximum (13.3) at the fourth month and a minimum (12.2) at the first month of storage.

Statistical analysis of data revealed that significant difference at one per cent level (probability 0.0002) existed between the pickles of different varieties of banana pseudostem, but no significant difference (probability 0.0230) existed at monthly intervals.

Considering the pickles of different varieties of banana rhizome, the first quality attribute colour was highest in Nendran having a maximum of 4.3 at the fourth and a minimum of 4.0 at the first month of storage. The lowest score in Kunnan having a maximum (3.2) at the sixth month and minimum (3.0) at the first and third months of storage.

In taste, the pickles of variety Nendran rhizome was found to have the highest score while the variety Kunnan rhizome had the lowest score. Nendran scored a maximum (4.5) at the first month and a minimum (4.2) at the third, fourth, and fifth months of storage. Kunnan scored a maximum (3.3) at the fifth and sixth month and a minimum of 3.1 at the first month of storage.

For the third quality attribute namely flavour, the mean score for pickle was highest in Nendran rhizome, it ranged from 4.1 at the first month and 4.6 at fifth and sixth months of storage. Lowest score was assigned to Robusta rhizome, which was 4.6 (maximum) at the sixth month and 3.6 (minimum) at the first month of storage.

The mean score for texture for pickle varied from 3.5 (second month) to 4.3 (sixth month) of minimum and maximum score respectively for Palayankodan. The variety Kunnan was found to have the lowest score with maximum of 3.8 at the sixth month and minimum of 3.4 at the first, second and third months of storage.

The total score of banana rhizome for all the quality attributes were considered, the highest score was obtained for Nendran and lowest score was found for Kunnan. The variety Nendran scored 17.4 (maximum) at the sixth month

and 16.3 (minimum) at the first month of storage. The variety Kunnan scored 14.2 (maximum) at the sixth month and 13.1 (minimum) at the first month of storage.

When the data was analysed it was found that there was significant difference at one per cent level (probability 0.0000) in different varieties of banana rhizome pickles where as no significant difference existed at monthly intervals (probability 0.0221)

From Table 14 it can be seen that in vattals of different varieties of banana flower bud, the mean score for appearance was highest in Palayankodan and lowest in Robusta. Palayankodan scored 4.0 (maximum) at the first month and 3.8 (minimum) at the fourth month of storage while Robusta scored 3.2 (maximum) at the second month and 3.0 (minimum) at the first month of storage.

The mean score for colour was found to be highest for Poovan flower bud and lowest for Robusta flower bud. Poovan flower bud and Robusta flower bud scored a maximum of 3.8 and 3.2 at the first month of storage. While Poovan flower bud scored a minimum of 3.2 at the fifth and sixth month and Robusta scored a minimum of 2.9 at the third, fourth, fifth and sixth months of storage.

For the third quality attribute namely taste, the mean score was highest in Palayankodan flower bud with a maximum score of 3.3 at the second and sixth month and minimum score of 3.0 at the first month of storage. The lowest score was assigned to Robusta flower bud which was 2.5 (maximum) at the second month and 2.0 (minimum) at the fifth and sixth month of storage.

The mean score for crispness of banana flower bud vattals was highest in Palayankodan flower bud and lowest in Poovan flower bud. Palayankodan

Table 14. Organoleptic evaluation of vattals prepared from different varieties of banana by-products during six month of storage

Quality attributes	Storage period (months)	Flower bud					Peel					Pseudostem					Rhizome				
		N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K
Appea-rance	1	3.4	3.7	4.0	3.0	3.1	3.8	4.0	3.6	3.0	3.5	3.7	3.7	4.0	3.9	3.5	3.7	3.8	3.7	3.6	3.5
	2	3.2	3.8	3.9	3.1	3.2	3.8	4.0	3.5	3.1	3.5	3.5	3.6	4.0	3.9	3.1	3.5	3.4	3.6	3.8	3.4
	3	3.3	3.8	3.9	3.2	2.9	3.7	4.1	3.4	3.0	3.4	3.5	3.7	4.1	3.8	3.0	3.8	3.8	3.6	3.7	3.4
	4	3.0	3.7	3.8	3.1	3.1	3.6	4.0	3.5	3.1	3.5	3.6	3.5	4.1	3.8	3.2	3.8	3.8	3.5	3.7	3.4
	5	3.1	3.9	3.9	3.1	3.1	3.6	4.0	3.5	3.1	3.4	3.6	3.4	4.0	3.7	3.2	3.8	3.7	3.5	3.5	3.2
	6	3.0	3.9	3.9	3.1	2.9	3.6	4.0	3.5	3.0	3.3	3.6	3.4	4.0	3.8	3.2	3.7	3.7	3.5	3.4	3.2
Colour	1	3.4	3.8	3.5	3.2	3.4	3.1	3.4	3.2	3.0	3.0	4.0	3.2	3.8	3.6	3.3	3.6	3.1	4.2	3.8	3.2
	2	3.5	3.3	3.4	3.1	2.9	3.1	3.4	3.0	2.9	3.1	3.9	3.4	3.8	3.7	3.3	3.6	3.3	4.2	3.9	3.0
	3	3.1	3.4	3.6	2.9	3.1	3.1	3.3	2.9	2.9	3.1	4.0	3.3	3.7	3.8	3.4	3.6	3.2	4.1	3.5	3.1
	4	3.2	3.5	3.5	2.9	2.9	2.9	3.4	3.1	3.0	3.1	4.0	3.4	3.5	3.8	3.4	3.5	3.2	4.0	3.4	3.2
	5	3.2	3.2	3.2	2.9	3.0	3.1	3.3	2.9	3.0	3.0	3.9	3.3	3.6	3.6	3.4	3.4	3.0	4.0	3.9	3.1
	6	3.2	3.2	3.2	2.9	3.0	3.0	3.3	3.1	3.1	3.0	4.1	3.5	3.8	3.6	3.2	3.4	3.0	4.0	3.9	3.0
Taste	1	3.2	3.0	3.0	2.4	3.1	3.1	3.8	3.0	3.1	3.5	4.0	3.8	4.5	4.1	3.6	3.8	3.2	4.0	3.5	3.1
	2	3.0	3.3	3.3	2.5	3.0	3.1	3.7	3.2	3.2	3.4	3.9	3.8	4.5	4.0	3.8	3.3	3.5	4.1	3.6	3.0
	3	3.1	3.2	3.2	2.4	2.8	3.1	3.5	3.1	3.0	3.5	4.0	3.9	4.4	4.0	3.7	3.6	3.3	4.2	3.7	3.1
	4	3.1	3.2	3.2	2.2	2.9	3.4	3.5	3.3	3.0	3.3	4.0	3.8	4.5	4.1	3.5	3.7	3.3	4.2	3.8	3.0
	5	3.2	3.2	3.2	2.0	2.9	3.2	3.4	3.2	3.2	3.2	3.9	4.0	4.4	4.1	3.5	4.0	3.3	4.3	3.8	2.9
	6	3.3	3.3	3.3	2.0	2.8	3.1	3.4	3.1	3.3	3.5	3.8	3.8	4.4	4.1	3.5	4.0	3.7	4.3	3.6	2.9
Crisp-ness	1	3.9	4.0	4.1	3.8	3.4	3.7	4.0	3.8	4.3	3.8	3.8	4.1	4.2	4.0	3.9	3.6	3.5	3.5	3.7	3.4
	2	3.8	4.0	4.1	3.4	3.3	3.7	4.1	3.7	4.2	3.9	3.8	4.1	4.2	4.1	3.9	3.2	3.4	3.4	3.5	3.3
	3	3.7	4.2	4.2	3.6	3.1	3.6	3.9	3.9	4.3	3.6	3.8	4.1	4.2	4.0	3.8	3.6	3.4	3.3	3.7	3.3
	4	3.7	4.0	4.1	3.4	2.9	3.6	4.1	3.6	4.0	3.8	3.7	4.0	4.1	3.9	3.8	3.5	3.4	3.4	3.8	3.2
	5	3.7	4.2	4.1	3.5	2.9	3.5	4.1	3.9	4.0	3.8	3.7	3.9	4.2	4.0	3.7	3.3	3.5	3.3	3.5	3.2
	6	3.6	4.0	4.0	3.5	3.0	3.4	3.9	3.8	4.0	3.7	3.6	3.9	4.1	4.0	3.7	3.3	3.5	3.3	3.5	3.2

N - Nendran Po - Poovan Pa - Palayankodan R - Robusta K – Kunnan

flower bud and Poovan flower bud scored a maximum of 4.2 at the third and fifth month respectively. Palayankodan scored a minimum of 4.0 at the sixth month and Poovan scored a minimum of 4.0 at the first, second and sixth month of storage.

In Table 15 when the total score for all quality attributes of banana flower bud vattals were considered, the highest score was obtained for Palayankodan and lowest score was for Robusta. The variety Palayankodan obtained 15.0 (maximum) to 14.5 (minimum) at the first and sixth month of storage respectively. The variety Robusta obtained a maximum score of 12.4 at the first and minimum score of 11.1 at the fifth and sixth month of storage.

Statistically analysis of data revealed that when significant difference at one per cent level (probability 0.0000) existed between the different varieties of banana vattals but there was no significant difference at one per cent level (probability 0.0200) existed at monthly intervals.

Taking the different varieties of banana peel the mean score for appearance was highest in Poovan and lowest in Robusta. Poovan peel scored 4.1 (maximum) at the third and 4.0 (minimum) at the first, second, fourth, fifth and sixth months of storage. Robusta scored a maximum of 3.1 at the second, fourth and fifth and minimum of 3.0 at the first, third and sixth months of storage.

The mean score for colour was found to be highest for Poovan peel and lowest for Robusta peel. The scores for Poovan was maximum (3.4) at the first, second and third and minimum (3.3) at the third, fifth and sixth months of storage. The scores of Robusta peel was maximum (3.1) at the sixth month and minimum (2.9) at the second and third months of storage.

Table 15. Overall acceptability of vattals prepared from different varieties of banana by-products during six month of storage

Quality attributes	Storage period (months)	Flower bud					Peel					Pseudostem					Rhizome				
		N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K	N	Po	Pa	R	K
Total score	1	13.9	14.5	15.0	12.4	13.0	13.6	15.1	13.6	13.4	13.7	15.5	14.8	16.5	15.6	14.2	14.7	13.6	15.4	14.6	13.2
	2	13.5	14.4	14.9	12.1	12.4	13.7	15.2	13.4	13.4	13.9	15.1	14.9	16.5	15.7	14.0	13.6	13.6	15.3	14.8	12.7
	3	13.2	14.6	14.9	11.9	11.9	13.5	14.8	13.3	13.2	13.6	15.3	14.9	16.4	15.6	13.8	14.6	13.7	15.2	14.6	12.8
	4	13.0	14.4	14.6	11.6	11.8	13.5	15.0	13.5	13.1	13.7	15.3	14.6	16.2	15.6	13.9	14.5	13.7	15.1	14.7	12.8
	5	13.2	14.5	14.6	11.5	11.9	13.4	14.8	13.5	13.3	13.4	15.1	14.6	16.2	15.4	13.8	14.7	13.5	15.1	14.6	12.5
	6	13.1	14.4	14.5	11.5	11.8	13.1	14.6	13.5	13.4	13.5	15.1	14.6	16.3	15.5	13.6	14.4	13.5	15.0	14.5	12.3

N - Nendran Po - Poovan Pa - Palayankodan R - Robusta K – Kunnan

For the third quality attribute namely taste, the mean score of banana peel was highest in Poovan and lowest in Palayankodan. The variety Poovan scored 3.8 (maximum) at the first and 3.4 (minimum) at fifth and sixth months of storage, while Palayankodan scored 3.3 (maximum) at the fourth and 3.0 (minimum) at the first month of storage.

The mean score for crispness was highest in Robusta peel scored 4.3 (maximum) at the first, third and fourth months and 4.0 (minimum) at the sixth month of storage. The mean score for crispness was lowest in Nendran peel scored minimum of 3.4 at the sixth month and maximum of 3.7 at the first and second month of storage.

In Table 15 the total score of vattals of banana peel for all the quality attributes was found that the highest score varied from 14.6 to 15.2 for Poovan at the sixth and second month of storage, while the lowest score of Robusta was 13.4 (maximum) at the first and fourth months of storage.

When the data was analysed statistically, it was found that there was significant difference at one per cent level (probability 0.0010) existed between the vattals prepared from different varieties of banana peel but there was no significant difference existed at monthly intervals (probability 0.0156).

Considering the vattals of different varieties of banana pseudostem, the mean score for appearance was highest in Palayankodan and lowest in Kunnan. The variety Palayankodan scored 4.1 (maximum) at the third and fourth months and the variety Kunnan scored 3.5 (maximum) at the first month of storage.

In colour, the variety Palayankodan was found to have the highest score of 4.1 (maximum) at the sixth month and 3.9 (minimum) at the second and fifth month of storage. While the variety Poovan had the lowest value at a maximum score of 3.5 and minimum score of 3.2 at the sixth and first months respectively.

For the third quality attribute namely taste, the mean score was highest in Palayankodan and lowest assigned to Kunnan. The variety Palayankodan scored 4.5 (maximum) at the first, second and fourth months and 4.4 (minimum) at the third, fifth and sixth months of storage. The variety Kunnan scored maximum of 4.0 at the fifth and sixth months and minimum of 3.3 at the second month of storage.

The mean score of pseudostem vattals for crispness was found to be highest for Palayankodan and lowest for Kunnan. Palayankodan pseudostem scored a maximum of 4.0 at the first, second, third and fifth months and minimum of 4.1 at the fourth and sixth months of storage. While Nendran pseudostem scored and maximum of 3.8 at the first, second and third months and minimum of 3.6 at the sixth month of storage.

Taking the total score (Table 15) of vattals for the different quality attributes of banana pseudostem, it was found that highest score for Palayankodan was 16.5 (maximum) at the first and second month and 16.2 (minimum) at the fourth and fifth months of storage.

Statistical analysis of data showed significant difference (probability 0.0002) difference at one per cent levels between the vattals prepared from

pseudostem of different banana varieties where as no significant difference (probability 0.0321) existed at monthly intervals.

Taking the different varieties of banana rhizome, the mean score for appearance was highest in Poovan and lowest in Kunnan. The variety Kunnan scored a maximum of 3.8 at the first, third and fourth months and minimum of 3.4 at the second month of storage. The variety Kunnan scored maximum of 3.5 at the first month and minimum of 3.2 at the fifth and sixth months of storage.

For the second quality attribute namely colour, the mean score of banana rhizome was highest in Palayankodan and lowest in Poovan. The variety Palayankodan scored maximum of 4.2 at the first and second months and minimum of 4.0 at the fourth, fifth and sixth months of storage. The variety Poovan scored maximum of 3.3 at the second month and minimum of 3.0 at the fifth and sixth months of storage.

The mean score of banana rhizome for taste was found to be highest for Palayankodan of 4,3 (maximum) at the fifth and sixth months and 4.0 (minimum) at the first month of storage. The lowest score was assigned for Kunnan of 3.1 (maximum) at the first and third months and 2.9 (minimum) at the fifth and sixth months of storage.

The mean score for crispness was found to be highest in Robusta and lowest in Kunnan rhizomes. The variety Robusta scored 3.8 (maximum) at the fourth month and 3.5 (minimum) at the fifth and sixth months of storage. The variety Kunnan scored 3.4 (maximum) at the first month and 3.2 (minimum) at the fourth, fifth and sixth months of storage.

The total score of vattals (Table 15) of banana rhizome for all quality attributes were considered, the highest score was obtained for Palayankodan and lowest score was obtained for Kunnan. The variety palayankodan scored 15.4 (maximum) at the first month and 15.0 (minimum) at the sixth month of storage. The variety Kunnan scored 13.2 (maximum) at the first month and 12.3 (minimum) at the sixth month of storage.

When the data was analysed statistically, it was found that there was significant difference of one per cent level (probability 0.0002) between the vattals prepared from different varieties of banana rhizomes but there was no significant difference (probability 0.3471) existed at monthly intervals.

4.3 Keeping quality of products from banana by-products

The keeping quality of the products namely pickles and vattals prepared from banana by-products was assessed by conducting microbial studies for a period of six months at monthly intervals and the results obtained is as follows. Both were found to be free from microbial contamination upto fifth month. In the sixth month pickle prepared from Kunnan flower bud (one cfu g^{-1} of bacteria and one cfu g^{-1} of fungi) and Nendran pseudostem (one cfu g^{-1} of fungi) showed microbial contamination and vattals prepared from poovan pseudostem showed one cfu g^{-1} of fungi. Pickles and vattals prepared from other varieties were free from microbial contamination upto sixth months of storage.

Discussion

5. DISCUSSION

The study on "Quality evaluation of banana by-products" was attempted to assess the nutritional composition of banana by-products, acceptability and keeping quality of the processed products prepared from by-products of different varieties.

The banana by-products were analysed for different nutrients like moisture, protein, fat, starch, fibre, iron, calcium, phosphorus, potassium, sodium and vitamin C. The acceptability of the processed products from banana by-products was assessed by organoleptic evaluation, using score card, based on a five point hedonic scale, for different parameters like colour, taste, flavour and texture for pickles and appearance, colour, taste and crispness for vattals. The products were stored for a period of six months and the quality attributes were assessed at monthly intervals. The keeping quality of pickles and vattals prepared from banana by-products was assessed for a period of six months at monthly intervals by taking the microbial count. The results of the study are discussed under the following headings.

5.1 Nutritional composition of banana by-products

5.2 Organoleptic evaluation of processed products from banana by-products

5.3 Keeping quality of processed products from banana by-products

5.1 Nutritional composition of banana by-products

The mean moisture content of different banana by-products ranged from 82.96 to 91.62 per cent with the highest in banana pseudostem and lowest in

banana peel. The mean moisture content of banana by-products was found to be in accordance with the values reported by Gopalan *et al.* (1989), Maini (1997) and Rao (1999).

The moisture content of different varieties of banana flower buds ranged from 89.27 per cent (Robusta) to 91.33 per cent (Nendran). The moisture content of Palayankodan and Robusta varieties were found to be similar to the values reported by Gopalan *et al.* (1989) and Rao (1999), But in Poovan, Nendran and Kunnan, the values reported by Gopalan *et al.* (1989) was found to be lower. The values obtained in different varieties were not significantly different from each other.

The moisture content of banana peel of different varieties ranged from 81.00 per cent (Poovan) to 85.30 per cent (Palayankodan). Peels of five banana varieties had similar moisture content. Statistically there is no significant difference between the varieties of banana peel.

The moisture content of different varieties of banana pseudostems ranged from 88.38 per cent to 93.78 per cent with the highest in Palayankodan and lowest in Robusta. Maini (1997) reported that the moisture content of banana pseudostem as 93.1 per cent which was found to be almost similar to the values obtained in the pseudostem of Nendran (93.31%) and Palayankodan (93.78%).

Different varieties of banana pseudostem were categorised statistically into three groups. The group a and ab had two members each, they were Palayankodan and Nendran in group a and Kunnan and Poovan in group ab. Robusta pseudostem was included in a sole group b. The varieties of pseudostem

included in the same class were not significantly varied from each other but significantly varied from pseudostem of other varieties statistically.

Among rhizomes, the highest moisture content was observed in Palayankodan and lowest in Robusta. Statistically there is no significant variation observed among the varieties of banana rhizomes.

Analysis of variance indicated that there is no significant difference between the varieties of banana flower buds, banana peels, banana pseudostem and banana rhizome. But there is significant difference between the by-products of banana with respect to moisture content.

The mean protein content of different banana by-products varied from 0.38 per cent in banana rhizome to 1.95 per cent in banana flower bud. This was found to be almost similar to the protein content reported by Gopalan *et al.* (1989) and Maini (1997).

The mean protein content of different banana by-products ranged from 0.38 to 1.95 g with lowest in banana rhizome and highest in banana flower bud.

The protein content of flower buds, peels and rhizome of Nendran, Poovan, Palayankodan, Robusta and Kunnan were found to be similar statistically. The pseudostems of Poovan and Robusta, which had a protein content of 0.4717 g and 0.4633 g respectively differed significantly from all other varieties in their protein content. The protein content of pseudostem of different varieties of banana ranged from 0.35 per cent to 0.61 per cent.

Analysis of variance indicated that there is no significant difference between the varieties of banana flower buds, peel, pseudostem and rhizome but

there is significant difference between different banana by-products in the protein content.

With respect to mean fat content in different banana by-products it ranged from 0.12 g to 0.86 g with the highest in banana peel and lowest in banana pseudostem. The mean fat content of banana by-products was found to be in accordance with the values reported by Gopalan *et al.* (1989) and Rao (1999). But the fat content banana peel and banana pseudostem was higher than the values reported by Maini (1997).

The flower buds of Palayankodan variety with highest fat content was grouped as a single entity and differed significantly from all other varieties with respect to fat content. While analysing the different varieties of banana flower buds it was found that Poovan and Nendran had almost similar fat content and differed significantly from all other varieties. The variety Kunnan had a fat content of 0.5 per cent which was the lowest and it differed significantly from all other varieties.

Among the peels of different varieties, Robusta was found to be the best with respect to fat content. The peel of Robusta and Kunnan were coming under the same group statistically. They differed significantly from other varieties in the fat content. The variety Poovan with a fat content of 0.86 per cent was significantly different from other varieties of banana peels. The fat content of Nendran and Palayankodan was found to be the same group statistically and different from the values of other varieties.

The variety with the highest fat content namely Kunnan pseudostem was included as a single group a and had the highest fat content. The pseudostems

of varieties Poovan and Nendran had similar fat content and significantly different from other varieties. The varieties of Robusta and Palayankodan pseudostems had similar fat content and not significantly different from each other.

Among the varieties of banana rhizome, Kunnan with a fat content of 0.37 per cent was found to be the best and it differed significantly from all other varieties except Nendran rhizome. Rhizomes of Palayankodan and Robusta were found to be almost similar in their fat content. Analysis of variance indicated significant variation in fat content was observed between the varieties of banana peel and pseudostem and between different by-products with respect to fat content. But there is no significant difference observed between the varieties of banana flower buds and rhizome in fat content.

Regarding the mean starch content of banana by-products the highest value was observed in banana rhizome (10.01 g) and lowest in banana flower bud (4.83 g). The values of banana pseudostem (9.41 g) and banana peel (5.28 g) was found to be lower than banana rhizome. According to Maini (1997) the carbohydrate content of banana peel and pseudostem was 5 g and 1.20 g respectively. Rao (1999) analysed the carbohydrate content of banana flower bud and pseudostem and found that they contain 5.1 g and 9.7 g per 100 g.

The flower bud and peel of Nendran variety had the highest amount of starch. Shantha and Siddappa (1970) observed maximum starch content at the time of flowering.

Regarding the starch content of banana pseudostems, Poovan had highest and Robusta had lowest starch content. The starch content of banana

rhizome was highest in Robusta and lowest in Kunnan. There is no significant difference was observed between the five varieties of different banana by-prioducts.

Analysis of variance indicated that the variation with respect to starch content between banana by-products was significant but the variation in starch content was found to be insignificant between varieties of banana flower bud, peel, pseudostem and rhizome.

The fibre content of different varieties of banana by-products varied from 0.98 to 1.87 per cent which were found to be in banana rhizome and banana peel respectively. These observations were found to be almost similar to the values reported by Gopalan *et al.* (1989) and Rao (1999) in banana rhizome, flower bud and pseudostem. The value reported by Maini (1997) was found to be similar in banana peel but in pseudostem it was found to be less.

In the fibre content of banana flower buds, Kunnan flower bud got the highest value and Nendran flower bud got the least value. Flower buds of Nendran, Palayankodan and Poovan had almost similar fibre content and are significantly different from flower buds of Kunnan and Robusta.

Among the peels of different banana varieties Robusta with the highest content of fibre differed significantly from other varieties except Nendran. Peels of Poovan was significantly different from other varieties. The varieties Palayankodan and Kunnan peels are similar in the fibre content and not significantly different from each other. The five varieties of banana pseudostems

were almost similar in their fibre content and no significant variation was observed between each other.

The fibre content of different varieties of banana rhizomes ranged from 0.67 g (Robusta) to 1.17 g (Poovan). The fibre content of Poovan and Palayankodan were found to be similar to the values reported by Gopalan *et al.* (1989) but in Robusta, Kunnan and Nendran the values reported by Gopalan *et al.* (1989) was found to be lower.

Analysis of variance revealed significant variation in fibre content in different varieties of banana rhizome. Significant variation was also observed in the fibre content of banana by-products but no significant variation was observed in different varieties of banana flower buds, peels and pseudostem.

The mean iron content of different banana by-products ranged from 1.28 mg to 1.01 mg with the highest in banana flower bud and lowest in banana peel. The values were almost similar to those reported by Gopalan *et al.* (1989) and Rao (1999). The mean iron content of banana peel, pseudostem and rhizome were found to be almost similar and were significantly different from banana flower bud.

The iron content of different varieties of banana flower bud ranged from 1.10 mg (Kunnan) to 1.55 mg (Palayankodan). The iron content of Palayankodan variety was found to be almost similar to the values reported by Gopalan *et al.* (1989) and Rao (1999) but in Poovan, Nendran, Robusta, Kunnan the values reported by Gopalan *et al.* (1989) and Rao (1999) were found to be higher.

The variety Nendran peel, with the highest iron content was grouped as a single entity and differed significantly from all other varieties. The peel of varieties Robusta and Kunnan was coming under the same group in their iron content and significantly different from other varieties. The varieties of Poovan and Palayankodan peels were significantly different from each other.

The varieties of banana pseudostem like Palayankodan, Poovan and Nendran was in the same group and were not different significantly with each other. The pseudostems of Robusta and Kunnan were coming under the same group statistically. The iron content of banana rhizomes ranged from 1.23 mg to 0.81 mg with the highest in Nendran and lowest in Poovan rhizomes. The varieties like Palayankodan and Kunnan rhizomes are not significantly different from each other. But the varieties of Nendran, Poovan and Robusta were significantly different from each other. Analysis of variance indicated that there is significant difference between the varieties of banana pseudostem, and banana rhizome and significant difference between different by-products of banana with respect to iron content. But there is no significant difference in different varieties of banana flower bud and banana peel with respect to iron content.

The mean calcium content of different banana by-products varied from 13.47 mg in banana pseudostem to 26.97 mg in banana flower bud. The mean calcium content of banana pseudostem and rhizome has almost similar value reported by Gopalan (1989). But the mean calcium content of banana flower bud was high (32 mg) according to Gopalan (1989) and Rao (1999). The flower bud,

peel and rhizome of banana are not significantly different. But they differ significantly with pseudostem of banana.

Poovan flower buds had the highest amount of calcium among banana flower bud and this variety differed from all others with respect to calcium content. There is significant variation between varieties of banana flower buds. The calcium content of peels of Poovan, Nendran and Kunnan were found to be almost similar. The calcium content of Palayankodan and Robusta peels were coming under the same group statistically. The pseudostem of different varieties of banana had higher calcium content than the values reported by Gopalan *et al.* (1989). The Poovan and Palayankodan pseudostems was in the same group and Robusta and Kunnan pseudostems was in the same group in their calcium content. These varieties of banana pseudostems were significantly different from Nendran pseudostems. Regarding the calcium content of different varieties of banana rhizome, significant variation was observed between Nendran, Kunnan, Robusta, Poovan and Palayankodan rhizome. Analysis of variance indicated that there is significant variation between the varieties of banana flower buds, banana peel, banana rhizome and different banana by-products but no significant difference was observed between different varieties of banana pseudostem.

The mean phosphorus content of different banana by-products varied from 11.46 mg in banana pseudostem to 42.07 mg in banana flower bud. This was found to be in accordance with the values reported by Gopalan *et al.* (1989) and Rao (1999).

The phosphorus content of Palayankodan, Robusta and Kunnan was found to be in the same group statistically. But the flower bud of Nendran and Poovan was significantly different from each other and other varieties of banana flower buds. There is no significant difference in the phosphorus content between the peels of Nendran and Kunnan and between Poovan, Palayankodan and Robusta peels.

The phosphorus content of pseudostems of Poovan and Kunnan were found to be in the same group. Nendran and Palayankodan pseudostems were coming under the same group in their phosphorus content. Robusta pseudostem had lower phosphorus content which is significantly different from other varieties. Among the varieties of rhizome the Nendran, Robusta, Poovan and Kunnan were found to be almost similar in their phosphorus content. Palayankodan rhizome with the lowest phosphorus content is significantly different from other varieties of banana rhizomes. Analysis of variance indicated that there is significant variation between the varieties of banana flower bud, peel and rhizome and between the by-products of banana. But there is no significant variation between the pseudostem of banana varieties.

Regarding the mean potassium content among banana by-products, the highest potassium content was for rhizome and lowest for pseudostem. The flower bud of banana got highest value than the value reported by Gopalan *et al.* (1989) and Rao (1999).

Among the flower buds of different banana varieties Nendran and Palayankodan has in the same group in their potassium content which was higher

than that of other varieties of flower buds. Robusta flower bud had the lowest potassium content and it differed significantly from all other varieties of flower buds.

The peel of Nendran was found to be the best with highest potassium content while Kunnan peel had the lowest potassium content. The potassium content of peels of different banana varieties varied from 126.3 to 121.5 mg. Poovan, Palayankodan and Kunnan peels were significantly different from each other but the peels of Nendran and Robusta were not significantly different.

There is no significant variation observed between the pseudostem of Kunnan, Poovan and Palayankodan with respect to potassium content. Robusta which had the lowest value varied significantly from all others except Nendran pseudostem. The potassium content of Kunnan rhizome was higher than other varieties of banana rhizomes. Robusta and Kunnan were significantly different from each other and differed from other varieties of banana rhizomes.

Analysis of variance revealed that there is significant variation in the potassium content between the varieties of banana flower buds, peel, pseudostem and rhizome and significant variation between by-products of banana.

The mean sodium content of banana by-products varied from 18.76 mg to 27.31 mg with the highest in banana rhizome and lowest in banana peel. The mean sodium content of banana flower bud was found to be almost similar with the values reported by Gopalan *et al.* (1989) and Rao (1999).

The sodium content of different varieties of banana flower buds ranged from 18.03 (Poovan) to 22.56 (Kunnan). The flower buds of Kunnan and Nendran

were found to be the best with highest sodium content while Robusta, Palayankodan and Poovan had lowest sodium content respectively.

Among the peels of different banana varieties, there is no significant variation between the Nendran, Robusta, Kunnan, Palayankodan and Poovan peels. The pseudostem of banana varieties were significantly different from each other. The sodium content of pseudostem of different banana varieties ranged from 18.19 to 23.38 mg 100 g^{-1} with the lowest in Palayankodan and highest in Poovan pseudostem. The rhizome of varieties Kunnan, Robusta, Palayanmodan, Nendran and Poovan had almost similar sodium content and are not significantly different.

Significant variation was observed between the varieties of banana flower bud and banana pseudostem and between different banana by-product. But there is no significant difference observed between the varieties of banana peel and banana rhizome.

With respect to mean vitamin C content the different banana by-products ranged from 0.69 mg 100 g^{-1} to 12.35 mg 100 g^{-1} with the lowest in banana peel and highest in banana flower buds. The mean vitamin C content of banana by-products were found to be lower than that of values reported by Gopalan *et al.* (1989) and Rao (1999).

Robusta flower buds had the highest amount of vitamin C among the banana flower buds and there is no significant difference observed between varieties of the banana flower bud. The vitamin C content of different varieties of banana peel ranged from 0.64 mg to 0.77 mg with the highest in Nendran and

lowest in Kunnan. The varieties of banana peels are not significantly different from each other in their vitamin C content.

The varieties of banana pseudostems and rhizomes were not significantly different from each other. Analysis of variance indicated that there is no significant difference between the different varieties of banana flower bud, pseudostem, peel and rhizome, but there is significant difference between the different banana by-products with respect to vitamin C content.

5.2 Organoleptic evaluation of processed product from banana by-products

The acceptability of by-products of five banana varieties was determined using score card for a period of six months at monthly intervals. Quality attributes viz., colour, taste, flavour and texture for pickles, appearance, colour, taste and crispness for vattals were evaluated for this purpose.

Wide variation was observed in the acceptability of pickles made from by products of different banana varieties. Among the flower buds of different banana varieties, the total score was highest for Palayankodan and lowest for Robusta. This agrees with the observation of Pavunny (1996) who got the highest score for flower bud pickles of Palayankodan among different banana varieties.

Among the pickles made from peels of banana varieties, the total score of Nendran was highest in the first month and maximum score was at the sixth month of storage compared to all other varieties. The variety Kunnan scored lowest initially and also after six months of storage.

According to Pavunny (1996) Nendran scored maximum for the products like pickle from peel. Pickle from Robusta pseudostem scored maximum and Nendran pseudostem scored lowest. Robusta pseudostem scored maximum at the sixth month and Nendran pseudostem scored maximum at the fourth month of storage compared to other varieties of banana pseudostem. The total score among the rhizome of selected banana varieties, pickles from Nendran rhizomes scored the highest and Kunnan rhizome scored the lowest. These results of pseudostem and rhizomes pickles was in accordance with the observation of Pavunny (1996).

Wide variation was seen in the acceptability of vattals prepared from by-products of different banana varieties. In the case of banana flower bud; Palayankodan flower bud obtained the highest total score and robusta flower bud obtained the lowest. Among the peels of banana by-product Poovan scored the maximum and Robusta scored the lowest. Vattals from Palayankodan pseudostem scored the highest and Kunnan pseudostem scored the lowest. The Palayankodan pseudostem and Kunnan pseudostem obtained a maximum score at the initial stages of storage. Among vattals prepared using rhizome of different varieties of banana, Palayankodan scored the highest and Kunnan scored the lowest value. According to Pavunny (1996) the Palayankodan vattal had the highest score compared to vattals prepared from other varieties of banana rhizome.

5.3 Keeping quality of products prepared from banana by-products

The shelf life of the processed products prepared using banana by-products was assessed by conducting microbial studies from a period of six months. The products were found to be free from microbial contamination upto

fifth month. In the sixth month pickles prepared from Kunnan flower bud and Nendran pseudostem and vattals prepared from Poovan pseudostem showed microbial contamination whereas pickles and vattals prepared from other varieties were free from microbial contamination and had good shelf life. The results of the study was in line with the findings of Pavunny (1996). In which the author observed that pickles prepared from banana by-products of different varieties could be stored upto sixth month without deterioration and vattals could be stored for one year under ambient storage condition. In general the pickles and vattals prepared from banana by-products of different banana varieties had good shelf life and could be stored upto a period of six months.

Summary

6. SUMMARY

The study on "Quality evaluation of banana by-products" was made to evaluate the nutritional composition of banana by-products, organoleptic evaluation and keeping quality of processed products from by-products of different banana varieties available and maintained in the Banana Research Station, Kannara; Central Nursery, Vellanikkara and KHDP, Vellanikkara. The five banana varieties selected were Nendran, Poovan, Palayankodan, Robusta and Kunnan. The by-products like flower bud, peel, pseudostem and rhizome were collected from all the varieties for the study.

The nutrient constituents such as moisture, protein, fat, starch, fibre, iron, calcium, phosphorus, potassium, sodium and vitamin C were estimated in the by-products of different banana varieties. The organoleptic evaluation and keeping quality of processed products like pickle and vattal prepared from banana by-products for a period of six month was also evaluated.

The study revealed that the moisture content of by-products of different banana varieties namely flower bud, peel, pseudostem and rhizome ranged from 89.27 to 91.33 per cent, 81.00 to 85.30 per cent, 88.38 to 93.78 per cent and 86.13 to 87.73 per cent respectively. The protein content of the by-product namely flower bud varied from 1.50 g in Poovan to 2.24 g in Kunnan whereas in peel, the variety Kunnan had 0.68 g of protein and Palayankodan had 0.83 g. The protein content of pseudostem ranged from 0.35 to 0.61 g with lowest value in Kunnan and highest in Palayankodan. In rhizome protein content was lowest in Kunnan (0.31 g) and a

highest value of 0.47 g was seen in Nendran and Palayankodan varieties. The fat content of flower bud, peel, pseudostem and rhizome of banana ranged from 0.51 (Kunnan) to 0.93 per cent (Palayankodan), 0.73 (Palayankodan) to 1.01 per cent (Robusta), 0.08 (Robusta) to 0.18 per cent (Kunnan) and 0.21 (Nendran) to 0.37 per cent (Kunnan) respectively. Statistical analysis revealed that there is significant variation in all the varieties of banana peel and banana pseudostem in the fat content.

The starch content in different by-products namely flower bud, peel, pseudostem and rhizome varied from 4.51 (Kunnan) to 5.66 per cent (Nendran), 4.85 (Robusta) to 5.45 per cent (Nendran), 0.83 (Robusta) to 9.88 per cent (Poovan) and 9.53 (Kunnan) to 10.81 per cent (Robusta) respectively. The fibre content of banana flower bud ranged from 1.05 g in Nendran to 1.55 g in Kunnan respectively whereas in the case of peel, the variety Kunnan had 1.10 g of fibre and Robusta had 2.60 g. The fibre content of pseudostem varied from 0.96 to 1.43 g with the lowest in Palayankodan and highest value in Kunnan. In rhizome the fibre content of lowest in Kunnan and 0.96 g and a highest value of 1.17 g was seen in Poovan. The statistical analysis indicated significant variation in all the varieties of banana rhizome in the fibre content.

Among the micronutrients, the iron content of by-products namely flower bud, peel, pseudostem and rhizome ranged from 1.10 to 1.55 mg, 0.93 to 1.14 mg, 0.82 to 1.16 mg and 0.81 to 1.23 mg per 100 g respectively and calcium content ranged from 23.75 to 31.50 mg, 22.32 to 31.28 mg, 12.61 to 14.60 mg and 21.13 to 30.83 mg per 100 g respectively.

Statistical analysis indicated there is significant variation in all the varieties of banana pseudostem and rhizome in iron content and between all the varieties of flower bud, peel and rhizome in the calcium content.

The phosphorus content of by-product of different banana varieties namely flower bud, peel, pseudostem and rhizome varied from 36.79 to 45.69 mg, 18.96 to 21.72 mg, 10.39 to 13.28 mg and 12.52 to 16.90 mg per 100 g respectively. Similarly potassium content varied from 187.6 (Robusta) to 191.9 mg (Nendran), 121.5 (Kunnan) to 126.3 mg (Nendran), 81.85 (Robusta) to 88.56 mg (Kunnan) and 189.5 (Nendran) to 197.8 mg (Kunnan) per 100 g respectively. The statistical analysis indicated significant variation between all the varieties of banana flower bud, peel, pseudostem and rhizome in the phosphorus content.

The sodium content of by-products namely flower bud, peel, pseudostem and rhizome ranged from 18.03 to 22.56 mg, 18.39 to 19.55 mg, 18.19 to 23.38 mg and 25.58 to 28.83 mg per 100 g respectively, similarly the vitamin C content ranged from 11.59 to 13.59 mg, 0.64 to 0.77 mg, 3.37 to 4.82 mg and 0.79 to 0.87 mg per 100 g respectively.

The organoleptic evaluation of the processed products namely pickles and vattals prepared from by-products of different banana varieties were assessed using a five point hedonic scale by ten judges. The quality attributes like colour, taste, flavour and texture of pickles and appearance, colour, taste and crispness of vattals were evaluated.

In pickles, Nendran peel pickle scored the highest and the least was obtained for Robusta flower bud. In the case of vattals, Palayankodan pseudostem scored the highest and least was obtained for Robusta flower bud. In general it can

be seen that pickles made from banana peel and vattals made from banana pseudostem were more acceptable compared to other by-products.

Statistically significant variation was observed among different varieties of banana by-products and the variation was insignificant at monthly intervals of storage in the case of pickles and vattals.

The shelf life of the processed products namely pickles and vattals prepared from banana by-products was observed by conducting microbial studies for a period of six months at monthly intervals.

The products were found to be free from microbial contamination upto fifth month. In end of the sixth month of storage, pickle prepared from Kunnan flower bud and Nendran pseudostem and vattals prepared from Poovan pseudostem showed microbial contamination whereas pickles and vattals prepared from other varieties were free from microbial contamination upto sixth month.

References

REFERENCES

Abarca, L. 1996. Evaluation of the environmental impact of solid wastes produced by the banana industry. *Technologia-en-Marchal* **12**(4):17

Acland, J.D. 1971. *East African Crops*. Longman Publishing Co., London p.24

Adams, M.R. 1978. Small-scale vinegar production from bananas. *Trop. Sci.* **20**:11-19

Aked, J. and Kyamuhangire, W. 1996. Post harvest aspects of highland bananas in Uganda. *Trop. Sci.* **36**:154

Anand, J.C. and Maini, S.B. 1993. Utilization of fruit and vegetable wastes. Golden Jubilee Symposium, Horticultural Society of India, Bangalore, May 24-28. *Abstract of papers* p.371

Annelli, G., Fiorentini, R. and Lepidi, A. 1975. Food and feed from banana by-products. *Trop. Sci.* **18**:448

*Anon. 1983a. *Bibliografia del Banano y otras Musaceas,* Aspectos Agroindustriales. UPEB (Union de paises Exportadores de Banana), Panama. p.676

*Anon. 1983b. *Bibliografia sobre el valor nutritive del p latano y su utilization para la elaboracion de productos industriales,* UPEB, Panama. p.138

A.O.A.C. 1955. *Official and Tentative Methods of Analysis.* 8th ed. Association of Official Agriculture Chemists, Washington, D.C. pp.94-97

A.O.A.C. 1980. *Official Methods of Analysis.* 13th ed. Association of official Analytical chemists, Washington, D.C. pp.53-55

Aravindakshan, K. 1981. Effect of pre and post-harvest treatments on storage and quality of banana cv. Nendran. M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur, India. pp.30-42

Balakrishnan, R. 1980. Studies on growth, development, sucker, production and nutrient uptake at different ploidy levels in banana (*Musa* sp.). Ph.D. (Agri.) thesis, Tamil Nadu Agricultural University, Coimbatore. p.225

Bongeswar, R.S. and Sreenivasan, N. 1977. Product development and storage of banana. *Prog. Hort.* **9**(1):53

Chadha, K.L. 1992. Banana : a complete food. *Indian Hort.* **37**(3):32

Chopra, S.L. and Kanwar, J.S. 1978. *Analytical Agricultural Chemistry*. Kalyani Publishers, Ludhiana. pp.38-42

Chung, S.L. and Meyers, S.P. 1979. Bio-proteins from banana wastes. *Dev. Ind. Microbiol.* **20**:723-732

Collin, M.N. and Dalmic, R. 1991. Evolution de quelques criteres physicochimiques de la banana plantain (cultivars Orishele) an cours de la maturation. *Fruits* **46**:646-648

*Crowther, P.C. 1979. *The Processing of Banana Products for Food Use*. Tropical Products Institute Publishers, London. p.118

Duke, A.K. 1988. Fruits - The Pinkness factor in your health. *Nutrition* **19**(2):17

*Dupaigne, P. 1967. Le controle de la qualite des bananes sechees. *Fruits* **22**(9):27

Fzoulkes, D. 1978. The banana plant as cattle feed : composition and biomass production. *Trop. Anim. Prod.* **3**:45-50

Giridharilal, G.S., Siddappa, G.S. and Tandoor, G.C. 1986. Preservation of Fruits and Vegetables. Indian Council of Agricultural Research, New Delhi. p.218

Goewart, R.R. and Nicholas, H.J. 1980. Banana peel sugars as a source of food stuff for animals or humans. *Nutri. Reports Int.* **22**:207-212

Gopalan, C., Sastri, B.V.R. and Balasubramanian, S.C. 1989. *Nutritive Value of Indian Foods*. National Institute of Nutrition, ICMR, Hyderabad. p.150

*Gross, J. 1976. Carotenoids of banana pulp, peel and leaves. *Lebensml Wiss. Tech.* **14**(9):211

Hameed, R.S. 1981. Processing and Products. *Banana*. Wilson Publishing Company Pvt. Ltd., Madras. pp.40-47

Izonfuo, W.L. and Omuarc, V.O.T. 1998. Effect of ripening on the chemical composition of plantain peels and pulps (*Musa Paradisiaca*) *J. Sci. Fd Agric.* **45**(4):333-336

Jackson, S. 1989. Banana with a differences. *Garden-U.K.* **114**(4):149

Jacob, W.S. 1967. Handling and processing of banana. *Prog. Hort.* **11**:120

Jarman, C.G. 1977. Banana fibre : a review of its properties and small scale extraction and processing. *Trop. Sci.* **19**:173

Jellanick, G. 1985. *Sensory Evaluation of Food, Theory and Practice.* Ellis Horwood Ltd. Chichester England and VCH Verlagsgesellschaft mbH, Weinheim, Federal Republic of Germany. p.204

Jianhi, W., Xue, G.Z., Yu, X., Wang, J.L., Guan, Z.X. and Zhang, X.Y. 1995. Study on banana resources and their processing and utilization in China. Commission for integrated survey of natural resources, *Chinese Acad. Sci.* **57**(1):62

Joshi, G.D., Prab, B.P., Relekar, P.P. and Magdon, M.P. 1993. Studies on utilization of cashew apple waste. Golden Jubilee Symposium, Horticultural Society of India, Bangalore, May 24-28, *Abstract of papers* p.372

Kavitha, P., Easwaran, P. and Mageshwari, U.S. 1999. Development and evaluation of a diet kit with a ready reckoner on the dietary fibre content of selected Indian recipes. *Indian J. Nutr. Dietet.* **36**(8):364

Kayisu, K. and Hood, L.F. 1981. Molecular structure of banana starch. *J. Fd Sci.* **46**:7

Kayisu, K., Hood, L.F. and Vansoert, P.J. 1981. Characterization of starch and fibre of banana fruit. *J. Fd Sci.* **46**:90

Khader, S.P., Rasool, A. and Shah, H.J. 1985. Banana-products for food use. *Prog. Hort.* **47**(11):207

Koshy, M. 1989. Flowerbud Differenciation in Banana. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, India.. pp.24-28

Kurian, T.M., Prabhakaran, P.V. and Varkey, P.A. 1985. Pathcoefficient analysis in nendran variety of banana. *South Ind. Hort.* **33**(1):19

Lii, C.Y., Chang, S. and Yung, Y.L. 1982. Investigation of the physical and chemical properties of banana starches. *J. Fd Sci.* **47**:72

*Llanes, M.A. 1990. Chemical composition of the pulp peel of seven banana clones. *Giencias-de-la-Agric.* **39**:181-184

Maini, S.B. 1997. Value-addition to horticultural wastes. *Indian Hort.* **42**(2):73-78

Maini, S.B., Nanjundaswamy, A.M. and Siddappa, G.S. 1993a. Utilization of banana peel - preparation of cheese from banana peel scraping. Golden Jubilee Symposium. Horticultural Society of India, Bangalore, May 24-28. *Abstract of papers* p.374

Maini, S.B., Nanjundaswamy, A.M. and Siddappa, G.S. 1993b. Utilization of banana peel - preparation of jam from banana peel scraping. Golden Jubilee Symposium. Horticultural Society of India, Bangalore, May 24-28. *Abstract of papers* p.374

Malathi, D., Seshalathan, M.A., Thirumaran, S. 1993. Formulation of banana based weaning food mix. *South Ind. Hort.* **40**(3):60

*Maletto, S., Mussa, P.P. and Luna, F.S. 1973. Banana meal as food and as animal feed. *Annali-della-Facolta-di-Medicina-Veterinaria-di-Torina* **20**:67

Martin, J.P. 1950. Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. *Soil Sci.* **69**:215

*Moraes, J.M., Rocha, L.E., Pedroza, J.P. and Silva, M.G. 1998. Chemical components of the banana (Musa sp.) flour produced by drying. *Revista Brasileira de Engenharia Agricolo* **2**(3):316-318

Nand, D. 1993. Best use of fruit, vegetable waste. Golden Jubilee symposium, Horticultural Society of India, Bangalore, May 24-28. *Abstract of papers* p.24

Nand, K. 1994. Biogas from food wastes. *Indian Fd Ind.* **13**(3):24-25

Nieva, D.K., Wilson, R.J. and Cooke, R.D. 1975. The International Market for Banana Products for Food Use. Tropical Products Institute Publishers, London. p.23

Onwuka, C.F., Adetiloye, P.O. and Afolani, C.A. 1997. Use of house hold wastes and crop residues small ruminant feeding in Nigeria. *Small-Ruminant Res.* **24**(3):233-237

Patel and Nagar, 1974. Bananas fruits and vegetable facts and pointers. *J. Fd Sci.* **35**:62-67

Pavunny, O. 1996. By product utilization in banana. *Proc. Eighth Kerala Sci. Congr.* STEC, Trivandrum. pp.210-212

Pavunny, O. 1997. Vazhappazham - Oru Bhakshyolpannam enna nilayil. *Aishwaryam Viriyum Kadalivanagal,* KHDP Publishing, Cochi. pp.42-44

Pavunny, O., Sudhadevi, P.K. and Radhakrishnan, T.C. 1993. Utilization of immature pineapple fruit and the residues produced during canning Golden Jubilee Symposium, Horticultural Society of India, Bangalore, May 24-28. *Abstract of papers* p.372

Perkin-Elmer. 1982. *Analytical methods for Atomic Absorption Spectrophotometry.* Perkin-Elmer Corporation, USA. p.114

Pillai, R.G. 1996. The core of the pseudostem of Musa in the treatment of urinary stones. *Ancient-science-of-life* **15**(1):65

Prasad, S. 1998. Developing indigenous weaning food based on banana flour. *J. Ind. Hort.* **22**:10

Prema, L. and Joseph, S. 1996. Impact of banana based supplementary food on the nutritional status of infants. *Proc. Eighth Kerala Sci. Congr. STEC.* Trivandrum. pp.277-279

Rao, R.N. 1999. Banana - The God's gift to mankind. *Nutrition* **33**(2):22-25

Rao, V.D. 1998. Food quality assurance : microbiological concerns. *Indian Fd Ind.* **17**(5):282-283

Sadasivam, S. and Manikam, A. 1992. *Biochemical Methods for Agricultural Sciences.* Wiley Eastern Ltd., New Delhi and Tamil Nadu Agricultural University, Coimbatore. pp.28-30

Scymoure, N. 1987. Effect of ethephon on the chlorophyll fractions of banana during ripening. *Hort. Res.* **13**:147

Shantha, H. and Siddappa, G. 1970. Accumulation of starch in banana psudostem and fruit. *J. Fd Sci.* **35**:74-76

*Sharaf, A., Hegazis, M., Sedky, K. 1979. Chemical and biological studies on banana fruits. *Zeitschrift-fur-Ernahramgswissen schaft* **18**(1):8-15

Shekilango, S.A., Jelen, P., Bagdan, G.C. 1997. Productin of Whey-banana beverages from acid whey and over ripe bananas. *Fd Nutri. Sci.* **52**(4):209

*Shem, M.N. and Kasonta, J.S. 1996. Evaluation of locally produced feed resources for small scale dairy production in North Tanzania. A Forum of Tanzanian IFS grantee. Proceedings held at commission for Science and Technology, Tanzania, July 4-5, pp.25-37

Simmonds, N.W. and Stover, R.H. 1966. *Bananas.* 3rd ed., Longman Scientific Publisher Pvt. Ltd., New York. p.406

Singh, H.P. and Uma, S. 1997. Banana-Food and Fruit Crop. *Indian Hort.* **42**(2):19, 27-28

Singh, S., Ram, H.B. and Tripathi, V.K. 1980. Biochemical studies on developing and ripening banana. *Prog. Hort.* **51**(12):5

Singh, K.M. 1983. Dehydration, packaging and storage studies of fruit (banana, jack and mango). M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur, India. pp.22-30

Snell, F.D. and Snell, T.C. 1963. *Colorimetric Methods of Analysis.* D. Van Nostran Co., New Delhi. pp.40-42

Srinivasan, C. 1974. Effect of ethephon on the chlorophyll fractions of banana during ripening. *Hort. Res.* **13**:147

Swaminathan, M. 1974. *Essentials of Food and Nutrition.* Vol.II. Ganesh and Company, Madras. pp.480-481

Tandon, D.K., Garg, N. and Kalra, S.K. 1993. Utilization of mango processing waste. Golden Jubilee Symposium, Horticultural Society of India, Bangalore, May 24-28, *Abstract of papers.* pp.374-375

Uchida, S. 1994. Nutritive value of banana pseudostem produced in Bali as compared to natural grasses. Sustainable animal production and the environment. *Proceedings of the 7th AAAP Animal Science Congress,* Bali, Indonesia, July 11-16. *Poster papers.* pp. 67-68

Verma, R.A., Tripathi, V.K. and Singh, S. 1986. Studies on the effect of packaging material on mango pickle during storage. *Indian Fd Pack.* **40**(1):22

Viswanath, P. and Nand, K. 1989. Microbiological conversion of food processing wastes into food, feed, fuels and chemicals, *Symp. Impact of Pollut. Fd Ind. and Mgt.* CFTRI, Mysore, May 4-5, pp.15-17

Zagory, D. 1999. Effect of post processing, handling and packaging on microbial populations. Post harvest news and Information in fresh fruits and vegetables : quality and food safety. *Post harvest biol. Tech.* **15**(13):313

* Originals not seen

Appendices

APPENDIX-I

PROCESSED PRODUCTS FROM BANANA BY-PRODUCTS

PICKLE

Ingredients

Sample	:	500 g
Gingelly oil	:	150 ml
Chillie powder	:	4 tsp
Green chillie	:	3 Nos
Garlic	:	5 Nos
Ginger	:	1 tsp
Vinegar	:	50 ml
Fenugreek powder	:	1 tsp
Asafoetida powder	:	1 tsp
Citric acid	:	5 g
Salt	:	to taste

Procedure

1. Sliced samples are soaked in 4% salt solution for 30 minutes
2. Drained and cooked by adding sufficient salt to taste for about 10 to 20 minutes
3. Cooked samples were dried in oven to reduce its water content
4. Fry in little oil and drain
5. Sliced green chillie, ginger and garlic are fried in the oil until it turns brown. Drained from oil and add turmeric powder, chillie powder, fenugreek powder and asofoetida and fry for a while
6. Add to the cooked and fried samples mix all the fried ingredients and add citric acid into it
7. Remove from fire and add vinegar to the hot pickle (Add salt if necessary)
8. Transfer into sterile bottles and seal the cap when the product is cooled to the room temperature. Store in a place away from heat and light.

VATTAL

Ingredients

Sample	:	500 g
Raw rice	:	250 g
Pepper powder	:	3 g
Gingelly seeds	:	3 g
Gingelly oil	:	20 ml
Salt	:	To taste

Procedure

1. Soak rice for one hour in water.
2. Drain and grind to a smooth paste.
3. Cook the batter with sufficient water to prevent the formation of lumps.
4. Cook to a thick paste.
5. Add the sample sliced to small pieces and partially cooked with sufficient salt.
6. Add pepper powder, gingelly seeds and stirred well.
7. Remove from fire and flatten a spoonful of the batter on trays smeared with oil.
8. Dry in electric oven at about 70°C.
9. When the samples are dried completely store them in air tight containers or polythene bags.

Source: Pavunny, O. 1996.

APPENDIX-II

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF PROCESSED BANANA BY-PRODUCTS

I. PICKLE

No.	Character	Description	Score	1	2	3	4	5
I	Colour	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
II	Taste	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
III	Flavour	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
IV	Texture	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					

II. VATTAL

I	Appearance	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
II	Colour	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
III	Taste	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					
IV	Crispness	Excellent	5					
		Good	4					
		Fair	3					
		Poor	2					
		Very poor	1					

QUALITY EVALUATION OF BANANA BY-PRODUCTS

By

RAJI M. JOHN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Home Science

(FOOD SCIENCE & NUTRITION)

Faculty of Agriculture
Kerala Agricultural University

Department of Home Science
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2001

ABSTRACT

The study entitled 'Quality evaluation of banana by-products' was undertaken to estimate the nutrient composition of banana by-products and organoleptic evaluation and keeping quality of processed products prepared using the by-products of different banana varieties maintained in the Banana Research Station, Kannara, Central Nursery and KHDP, Vellanikkara.

The banana by-products were analysed for moisture, protein, fat, starch, fibre, iron, calcium, phosphorus, potassium, sodium and vitamin C. The results revealed that among the different varieties, flower bud of Kunnan had the highest protein content and the highest fat content was observed in peel of Poovan variety. Rhizome of Robusta and peel of Robusta were found to be high in starch and fibre respectively. The calcium and iron content was found to be high in flower buds of Poovan and Palayankodan respectively. Flower bud of Robusta was found to be rich in phosphorus. Kunnan rhizome had the highest potassium and sodium content whereas Robusta flower bud had the highest vitamin C content.

Statistically, significant variation was observed between different banana by-products in the case of all nutrients.

Results of the organoleptic evaluation revealed that pickles made from banana peel and vattals made from banana pseudostem were more acceptable.

Statistically significant variation was observed among different varieties of banana by-products and the variation was insignificant at monthly intervals of storage in the case of pickles and vattals.

The keeping quality of pickles and vattals was assessed by taking the microbial count and the result showed that pickles made from flower bud of Kunnan, pseudostem of Nendran and vattal from pseudostem of Poovan showed contamination at the end of the sixth month of storage. In general, it can be concluded that most of the processed products from banana by-products had good keeping quality.