DEVELOPMENT OF JUICE-BASED BEVERAGE AND RIPE-FRUIT POWDER FROM BANANA (*MUSA SPP.*)

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Development of juice-based beverage and ripe-fruit powder from banana (*Musa spp.*)"** is a bona-fide 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.

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Certified that this thesis, entitled **"Development of juice-based beverage and ripe-fruit powder from banana (*Musa spp.*)"** is a record of research work done independently by **Mrs. A. Evelin Mary** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Mrs. A. Evelin Mary,** a candidate for the degree of **Doctor of Philosophy in Horticulture** with major in **Processing Technology,** agree that the thesis entitled **"Development of juice-based beverage and ripe-fruit powder from banana** (***Musa spp.***)" may be submitted by Mrs. A. Evelin Mary in partial fulfilment of the requirements for the degree.

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Dedicated to the Indian Fruit Processing Industry

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ABBREVIATIONS

APD	-	Average Particle Density
BARC	-	Bhaba Atomic Research Centre
BD	-	Bulk Density
BHT	-	Butylated Hydroxy Toluene
CaO	-	Calcium Oxide
cfu	-	colony forming units
CO_2	-	Carbon-di-oxide
DE	-	Dextrose Equivalent
EMC	-	Equilibrium Moisture Content
ERH	-	Equilibrium Relative Humidity
FPO	-	Fruits Products Order
HDPE	-	High Density Poly Ethylene
KMS	-	Potassium Meta-bi-sulphite
LDPE	-	Low Density Poly Ethylene
MAS	-	Months After Storage
N_2	-	Nitrogen
$NaHCO_3$	-	Sodium bi-carbanate
NEB	-	Non-Enzymatic Browning
OD	-	Optical Density
ppm	-	parts per million
PPO	-	Poly Phenol Oxidase
psi	-	pounds per square inch
PVPP	-	Percentage Volume occupied by the Powder Particles
RH	-	Relative Humidity
rpm	-	revolutions per minute
RTS	-	Ready-To-Serve
SDBP	-	Spray Dried Banana Powder
SEM	-	Scanning Electron Microscope
SO_2	-	Sulphur-di-oxide
TSS	-	Total Soluble Solids

Introduction

INTRODUCTION

Banana, a dessert fruit for millions, otherwise known as 'Apple of Paradise' is botanically *Musa spp.* It is one of the most popular fruits in the world in terms of per capita consumption as well as the most widely traded fruit in the world. India is the largest producer of banana accounting for 17.8 per cent of world share followed by Brazil (FAO, 2002). In 1999-2000, India produced 16.81 million tonnes from an area of 490.7 thousand hectares. Among fruit crops in India, banana ranks first in production and third in area under cultivation. Among the States in India, TamilNadu leads in the area and production but for productivity, Maharashtra ranks first (NHB, 2001).

Although India is the largest producer of banana, its share in the world trade is meagre at present. Bulk of banana produced in the country is utilized in domestic market as fresh fruit but for few processed products like chips. There is great scope for processing banana into different value added products that can fetch profit both in the domestic as well as in foreign market.

Owing to the potential of this fruit, the institutes like National Research Center for Banana (NRCB), Trichy, TamilNadu, Central Food Technological Research Institute (CFTRI), Mysore, Bhaba Atomic Research Center (BARC), Mumbai and various State Agricultural Universities have already prioritized banana as one of the major areas of their research. BARC has come out with a novel technique for making clarified banana juice from the variety Basari 10gy without the involvement of external enzymes (Despande, 2004).

Despite the development of value added products from banana, the potential largely remains untapped because of the lack of demand for banana products in domestic market. This is mainly due to the high cost, availability of fresh fruit throughout the year and preference of people to have banana as table fruit with its nutritive and dessert qualities.

However, the liberalization in industrial policy and the onset of globalization, has resulted in creation of more opportunities for export of value added and nutritious products from banana. International Trade Center (ITC), Geneva has predicted a huge demand for banana powder and juice in the United States and European countries.

Banana powder, obtained by drying ripe banana pulp, is used in formulations of health food, baby food, tonics, instant banana juice powder, breakfast cereals and flavourings. In the Western countries, banana powder has high demand as raw material in bakery products, fruit fillings, desserts, dairy products and confectionery. Banana juice, obtained by enzymatic extraction of ripe banana pulp, is used in the manufacture of Ready-To-Serve (RTS) beverages, wine and beer.

Considering the abundance in production and postharvest losses of banana at one end and the demand for natural nutritious food on the other end, the prospects for manufacture of banana powder and juice have brightened up and hence the project "Development of juice-based beverage and ripe-fruit powder from banana (*Musa spp.*)" was proposed with the following objectives.

i) To develop a drying and packaging regime for ripe banana powder.

ii) To develop a Ready-To-Serve (RTS) beverage based on clarified banana juice.

Review of Literature

2. REVIEW OF LITERATURE

Banana, one of the most popular fruits in the world has attracted tremendous research interest. Though India is the largest producer of banana in the world, its share in the world trade is negligible, because the major part goes for fresh fruit consumption and remaining for chips making. Hence an immense scope is there to develop value added products from banana that can be handled comparatively easier with more profit than fresh banana owing to their improved shelf-life and demand in the food industry.

In the present study, an attempt has been made to develop ripe fruit powder and juice based Ready-To-Serve beverage from banana. A review of research work on various aspects of fruit powders and fruit juices are presented here under the titles.

2.1 Dehydration of fruits
2.2 Additives used in fruit powders
2.3 Packaging of fruit powders
2.4 Storage and quality of fruit powders
2.5 Banana juice
2.6 Enzymatic extraction of fruit juices
2.7 Blending of fruit juices
2.8 Ready-To-Serve (RTS) beverage from fruits

2.1 Dehydration of fruits

Dehydration is the removal of the majority of water contained in the fruit or vegetable to a level below its water activity (a_w). The purpose of dehydration is to reduce the moisture content so that spoilage organisms are not able to grow and multiply during storage. The advantages of dehydrated fruits are reduction in volume (8-30 per cent), long shelf-life under ambient conditions and reduced use of additives (Jayaraman and Gupta, 1992).

Patil and Magar (1973) evaluated the varietal difference in the nutrient composition of vacuum dried banana powder (dried at 60°C under 58 cm of vacuum). Of the five varieties screened, Safed velchi, Basrai and Lalkel powders showed fairly good percentage of minerals and vitamins.

Fruit powders prepared from dehydrated fruit shall be free flowing, readily soluble in cold water, possess the colour and flavour of fresh fruit with moisture content not more than 4.5 per cent. They may contain permitted additives like starch, anti-caking agents, approved gums, colouring material and emulsifiers (Kitson and Sugisawa, 1974).

Huet (1974) obtained banana powder by drying banana pulp in a vacuum microwave oven. One kilogram pulp was mixed with 0.8 kg sucrose, 0.2 kg maltodextrin and five grams sodium pyrosulphite, dried at 45°C and 6-8 torr pressure.

Bowrey *et al.* (1980) reported that whole peeled bananas took 72 hours for drying in a solar drier. Garcia *et al.* (1988) found that the drying time for green and ripe slices of banana cv. Gaint Cavendish was 17 to 20 times less in the microwave oven than in the hot air oven. Energy efficiency in microwave drying was approximately 30 per cent.

Banana slices were dehydrated satisfactorily with incorporation of puffing in the drying process. Typical puffing conditions were as follows: water content 27-30 per cent, vapour temperature 152-160°C, internal pressure 0.8 to 1 kg cm^{-2} and treatment duration of one minute. The increased porosity obtained with blowing considerably reduced total drying time in comparison with conventionally air dried samples (Saca and Lozano, 1992).

During freeze-drying, the product was first frozen quickly and then the moisture from the food was removed by sublimation. The advantages of freeze drying were high retention of flavour and nutritional value, minimal damage to the product texture and structure, little change in product shape and colour. The finished product had an open structure that allowed fast and complete rehydration. Disadvantages included high capital investment, processing costs and need for special packaging (Jayaraman and Gupta, 1992).

John and Narasimham (1993) reported the Controlled Low Temperature Vacuum (CLTV) drying of breadfruit. The process involved preheating of breadfruit slices in a through-flow drier at 50°C for one hour followed by drying in a freeze drier which gave a product with dehydration, shrinkage, rehydration and sensory quality equivalent to freeze dried product.

Candelaria and Raymundo (1994) stated that vacuum drying of ripe banana pulp was possible at 40 kPa and 110°C with a drying time of 6-8 hours. Mircea (1995) stated that banana powder could be prepared by passing potassium meta-bi-sulphite (KMS) treated fully ripe pulp through different driers. Tsami *et al.* (1999) observed that high sugar fruit powders exhibited crystallization and caking during storage when incorrectly dried.

Brown (1999) reported about the difficulty of freeze drying pineapples due to high sugar content and difficulty in water vaporization. Fruits and vegetables with initial moisture contents of 85-95 per cent took about 24-30 hours to be freeze dried to a final moisture content of about two per cent.

Ganjyal *et al.* (1999) tried to produce sapota powder by drying sapota fruit pieces in a vacuum oven at different temperatures. They found that total soluble solids and ascorbic acid were highest in the product obtained at 65°C drying temperature. Shah *et al.* (2000) stated that mango, pineapple, citrus, apple, banana, papaya, guava, plum, tomato, watermelon, litchi, strawberry and avacado were amenable for successful freeze dehydration.

Pretreatments like blanching and antioxidant dips prior to osmotic dehydration of apple slices in hypertonic sucrose followed by vacuum drying prevented browning and loss of nutrition during storage (Sharma *et al.*, 2000).

Mui *et al.* (2002) developed a process for drying banana chips. The process involved removal of 90 per cent moisture by air-drying followed by vacuum microwave drying. The resultant banana chips were crisper with markedly higher volatile levels and sensory ratings than air-dried chips.

Vacuum drying of mango pulp was reported by Jaya (2004). Mango pulp was mixed with maltodextrin (0.5 kg per kg dry mango solid), glycerol monostearate and tricalcium phosphate, heated to 70°C, spread to a thickness of three millimeters on teflon coated trays and dried in a vacuum drier. The dried product was conditioned, ground into a powder using hammer mill and packed in aluminium foil laminated pouches.

2.1.1 Spray drying

Spray drying is a means of converting fruit juice directly into powder or granulated form by spraying the fluid into a stream of heated gas and evaporating water from the spray. A cyclone separator collects the resulting fine particles while still in suspension. The process is unique not only in the short drying time involved, but also due to the evaporative cooling, which prevents the solids being heated upto a high temperature.

Brennan *et al.* (1971) tried spray drying of concentrated orange juice. They found that liquid glucose (39-43 dextrose equivalent) as carrier reduced wall deposition, gave a product of acceptable flavour and good free flowing properties. The problems of wall deposition while spray drying were found to be minimized when the chamber wall was cooled to below the sticky point temperature (T_{sp}) of the product.

Lueck and Grothe (1973) attempted spray-drying of fruit juice flavoured milk (40% fruit juice and 60% milk). Spray drying gave a hygroscopic powder which when reconstituted did not have the quality of the original product. Arsdel (1973) stated that fruit juices contained a high percentage of sugar and could not be spray dried in pure form. Usually a diluent such as maltodextrin or corn syrup solid was added and solid content of the spray-dry feed was kept at 30-35 per cent.

Kjaergaard (1974) reported that while spray drying, higher bulk density powders could be achieved by maximum solid content of feed, minimum viscosity of feed, lower drying temperature and rotary atomization. Kerkhof and Schoeber (1974) opined that 15 per cent aroma loss occurred during spray drying. They further stated that components like maltodextrins had the property of binding aromas to their molecules.

Spray drying at temperature of 40-50°C gave products having better taste, colour and shelf-life than those produced by conventional high-temperature spray-drying. Tomato powder produced by low temperature spray drying showed shelf life of two years at 20°C and 60 per cent relative humidity while it was one year for conventionally spray-dried product (Attiyate, 1978).

King (1985) studied the production of banana juice powder using spray drying. Banana juice was mixed with equal volume of milk or soymilk and spray dried. The powder obtained was light yellow in colour with good flavour and taste. Bulk density of powder decreased with increase in drying air temperature, while the hygroscopicity decreased.

Karatas and Esin (1990) illustrated the benefits of introducing rotating scraper blades into the drying chamber. These scraper blades scraped any material deposited on the chamber walls during spray drying, thus increasing the yield of tomato powder to 77 per cent.

Bhandari *et al.* (1993) tested the manufacture of powders from concentrated juices of some fruits using different maltodextrins as spray drying aids. Optimum results were obtained using a ratio of juice to maltodextrin (Dextrose equivalent-DE 6) of 65:35 for black currant, 60:40 for apricot and 55:45 for raspberry with a low inlet temperature of 60-90°C. Mircea (1995) noted that a typical spray drier could produce 70 kilograms banana powder per hour to give yields of 8-11 per cent of the fresh fruit.

Lakshminarayana *et al.* (1997) standardized the technology for ready-to-use banana milk-shake powder. Approximately five kilograms of banana pulp was mixed with 1-5 per cent water, heated to 85-90°C for 5-10 minutes, cooled, blended with 25 litres of cow's milk and homogenized. The mix was further spray dried and blended with ground sugar.

Chen and Tang (1998) observed that the most appropriate conditions for processing carotenoid powder from carrot pulp waste by spray drying consisted of 15 per cent solid content of feed, inlet air temperature of 140°C and outlet air temperature of 95°C.

Loesecke (1998) opined that in spray drying of banana pulp, there were two major types of powder losses; wall losses and entrainment losses. The former was caused by poor atomization in which the material was thrown against the drier walls where it sticked and became charred. The latter was caused by the powder being carried through the exhaust ducts. These losses could be diminished by decreasing the velocity of the exhaust air and installation of efficient dust collectors.

Iordanidov *et al.* (1999) reported that apricot cv. Luiset pulp yielded a spray dried product with crude fibre of 61 per cent, protein 20 per cent and good functional dietary fibre properties.

Jianwen and Liangjuan (2002) studied the effect of acidification and juice concentration on spray drying of longan. The result showed that the optimal amount of citric acid was 0.05-0.1 per cent and juice concentration was 36 per cent.

Borges *et al.* (2002) tried spray drying of pineapple and passion fruit juices mixed with maltodextrin (20-30%) with outlet air temperature of 85-95°C. The yield and apparent bulk density of fruit powder increased with increase in maltodextrin concentration. Rao and Gupta (2002) studied the feasibility of vitamin C enrichment of milk via incorporation of orange juice. The blend comprising 15:85 orange juice to skim milk when spray dried, possessed the best sensory properties.

Mani *et al.* (2002) optimized the ratio of fruit solids: maltodextrin for spray drying of mango juice. Addition of mango juice to maltodextrin in the ratio 55:45 with air inlet temperature of 167°C and outlet temperature of 89°C was found best. Maya (2004) reported that spray drying of the beverage mix containing 1:1 ratio of sapota pulp and milk solids at an inlet temperature of 185°C and outlet temperature of 90°C yielded best quality sapota-milk beverage powder.

2.1.2 Drum drying

Drum drying is generally used for drying of slurries, pulps and purees of food that could withstand high temperature for short time without serious flavour deterioration or loss of solubility. Fruit pulp is applied in a thin uniform layer on one or two revolving, internally heated drums. Heat from condensing steam is transferred by conduction through the metal wall to the thin layer of pulp from which the water is vapourized during partial revolution of the drums. The dried material is scraped from the rotating drum surface by a stationary knife (doctor blade) that is pressed against the drum at appropriate location.

Bose and Dutt (1952) produced ripe mango powder by drum drying. Ripe mangoes were peeled, sliced, mixed with equal volume of water and pulped. The pulp was fed to double drum drier that was kept at a temperature of 287°F corresponding to a steam pressure of 40 psi. Time of dehydration was 6-8 seconds. The dried product obtained in the form of rolls was powdered and packed in moisture proof containers.

Mango pulp and mango custard blend were dried in a double drum drier at a steam pressure of 4.57 kg cm^{-2} with a drum speed of 2-3 revolutions per minute (rpm). The drum dried mango pulp was in the form of a thin paper and was difficult to powder. It was of a deep yellow colour, reconstituted easily in water and possessed the characteristic flavour of the product (Siddappa and Ranganna, 1961).

High quality instant apple sauce flakes that reconstitute readily in cold water were produced with modified atmospheric double drum drier by Lazar and Morgan (1966). Peeled apple slices were steamed for two minutes at 212°F and made into sauce. Sucrose was added to raise the total solids content to 20°Brix and sodium bisulphite was added to obtain about 400 ppm SO_2 in the fresh sauce. Double drum drier with drums of 12 inches diameter and 18 inches long was used which rotated at 1.5 rpm. Steam at 60-70 pounds per square inch (psi) filled the drums and a jet of chilled air was blown over the product film just before the doctor blade scraped it. It was found necessary to discharge the apple solids from the drier into a zone of dehumidified air to prevent caking of the product.

Padival and Srinivasan (1966) reported that cooked pumpkin pulp after homogenization was roller dried at four rpm (drum 7.5" long and 6" diameter) with 70 pound steam pressure to obtain dehydrated pumpkin powder. Talley *et al.* (1966) obtained pure pumpkin powder by concentrating canned puree at atmospheric pressure to about 21 per cent solids and applying to a single drum drier operated at a steam pressure of 75 psi and speed of five rpm.

Hoover (1973) reported the method for production of pumpkin flakes. The pumpkin pieces were ground, to which starch and corn syrup solids were mixed and the mixture was heated to 210-212°F and then drum dried. The best combination was 45 per cent pumpkin solids, 16 per cent starch and 39 per cent corn syrup.

Mashed potatoes treated with sodium bisulphite were dried in single drum drier (2 feet diameter x 3 feet width) operated at a steam pressure of 95 psi and normal drum speed of 2.0-2.4 rpm (Sapers *et al.*, 1974). Torrey (1974) reported successful drum drying of banana pulp at 155°C drum temperature with a drum speed of four rpm after addition of 0.3% ascorbic acid (dry weight basis).

Green mango powder was prepared in an atmospheric drum drier by Gangopadhyay *et al.* (1976). The pH of green mango pulp was adjusted to 5.0 and heated to 80-85°C. During heating, corn starch and tricalcium phosphate were added to improve the flowability of the finished product. Dehydration was carried out in a drum drier heated by steam at 50 psi and rotating at four rpm. The time of contact was about 15 seconds.

Mixture of mango pulp and skim milk powder in 1:1 ratio was drum dried with a roller of six inches diameter and eight inches long at rotation of 2-3 rpm and steam pressure of 50 psi (Jayaraman *et al.*, 1976). According to Kopelman and Saguy (1977), drum drying had much faster dehydration rate and better steam efficiency compared to conventional beetroot dice dehydration. Beet slurry was successfully dried using a double drum drier (60 cm length x 35 cm diameter) operated at 123°C with 18 seconds retention time to get beet powder with 3.8-4.0 per cent moisture.

Slurry containing appropriate amounts of banana pulp, ground nut/soy flour, sugar and corn starch was homogenized, dried in a drum drier at a steam pressure of 45 psi and drum speed 3.5 rpm to yield a free flowing sweet protein enriched banana powder (Sethy *et al.*, 1978).

Free flowing protein enriched mango powder was developed by Kasnavia (1984). Mango pulp (1500 g), corn starch (38.5 g), sugar (200 g), defatted edible quality groundnut flour and skim milk powder (108 g) were mixed and $NaHCO_3$ (13.67 g) was added to adjust the pH to 5.5. The mix was then drum dried (four rpm drum speed, 30-45 psi pressure and 0.15 mm drum clearance) to obtain free flowing mango powder.

Malted sorghum and malted cowpea flours were blended in the proportion of 70:30 to prepare a malted weaning food. Cold water slurry (30% w/v) of the blend was cooked and dried on a twin roller drier (56 cm diameter and 61 cm length) revolving at five rpm with 4.5 bar steam pressure (Malleshi *et al.*, 1989).

Ruales *et al.* (1990) reported that drum drying of banana pulp mixed with full fat soyabean flour in the ratio 60:40 resulted in highly nutritious flakes. Dehydrated maize-banana mix was prepared by Adeyemi *et al.* (1991). The slurry containing maize grits, banana and soya fraction was drum dried to give a product with bulk density of 0.3-0.41 g ml^{-1}. The control sample with skim milk in place of soya gave highest value (0.46 g ml^{-1}) for bulk density.

Ilangantileka *et al.* (1991) reported that 3.3 rpm drum speed and 35° blade angle was the best for drum drying of mung bean slurry to produce dehydrated mung bean flakes. Mircea (1995) noted that drum drying of banana pulp gave a final yield of 13 per cent of the fresh fruit with a moisture content of 8-12 per cent which was further reduced to two per cent by drying in a tunnel or cabinet drier at 60°C.

Occena *et al.* (1997) reported that drum drying inactivated the trypsin inhibitors present in bean meal. Greensmith (1998) tried drum drying of banana pulp using two per cent anti-caking additive. The drum temperature was maintained at 171°C that gave a drying ratio of 4.4:1.

A dehydrated product based on dried milk and pumpkin flakes was developed by Fernandez *et al.* (1998). Pumpkin flakes (4.84% moisture) obtained by roller drying at a steam pressure of six atmosphere, 0.75 m^2 contact surface and one rpm were added to dried whole milk and sugar to develop the product. Loesecke

(1998) reported that ripe banana pulp could be successfully drum dried at a temperature of 169-173°C with a drum speed of 3-12 rpm.

Phongkitwithoon *et al.* (1999) drum dried banana cv. Gros Michel puree mixed with one per cent soy-lecithin. They indicated that drum surface temperature had significant effects on browning rate. Valdez *et al.* (2001) reported that sweet potato flakes manufactured by drum drying technique yielded 11 per cent on the first production run and 13 per cent on the second production run.

Jong *et al.* (2002) reported that yield and quality of drum dried potato flakes were high when the drum rotation speed was one rpm. Maya (2004) obtained good quality sapota-milk beverage powder by roller drying of beverage mix containing sapota and milk in the ratio of 1:0.5 with drum speed of seven rpm and 4 kg cm^{-2} steam pressure.

2.1.3 Cabinet drying

Khurdia and Roy (1974) reported a procedure for production of guava powder by cabinet drying. Whole guavas were lye peeled, cut into quarters, scooped out the seed core and exposed to burning sulphur @ 2.5 g kg^{-1} fruit for four hours and subsequently dehydrated for 18 hours at 60 ± 5°C in a cross flow drier to a moisture level of three per cent. The dried slices were powdered in a grinding machine to obtain good quality guava powder.

Torrey (1974) reported that ripe sliced banana dipped in aqueous solution of calcium hydroxide took 160 hours to dry at 65°C in a cabinet drier. Cooke *et al.* (1976) observed that stable mango foam produced by adding polyglyceryl stearate (1.5% dry solids basis) and mixed in a domestic mixer at maximum speed for ten minutes could be dried at 70°C within 20 minutes to get a readily re-hydratable powder with two per cent moisture content.

Ripe mango slices steeped in 40°Brix syrup in presence of 3000 ppm SO_2, 0.2 per cent ascorbic acid and one per cent citric acid for 18 hours were successfully dehydrated in an electric cabinet through flow drier at 60°C for 8-12 hours by Teaotia *et al.* (1976). Papaya fruit pulp and enriched papaya fruit slabs incorporated with one per cent skim milk powder and groundnut protein isolate were dried at 60°C in a cross flow hot air drier by Krishnamoorthy and Varma (1978).

Bael fruit powder with ten per cent moisture was prepared by drying the pulp containing sulphur dioxide at 55-60°C for 17-18 hours. The sheets were cut into pieces, further dried to less than four per cent moisture in the cabinet drier at 60 ± 5°C and powdered. (Roy and Singh, 1979a).

Ambadan (1985) developed a delicious dehydrated product from sapota. The method involved horizontal halving, drying in an electrical drier maintained initially at 70°C and finally at 55°C for four days (eight hours operation per day).

In osmotic dehydration, a simultaneous flux of water and solutes from and into the material take place. The method can be used as a pre-treatment before air drying in order to reduce the water content of fruit to the range of 30-70 per cent. Osmotic dehydration decreased colour changes and increased flavour retention in dried fruits (Lenart and Lewicki, 1988).

According to Bains *et al.* (1989), products obtained by drying apple puree at lower temperature (70°C) in cabinet drier retained better colour and flavour characteristics than the products dried at higher temperature. They found that two-stage operation with a two hour initial drying at 102°C followed by finish drying at 85°C for 3.5 hours gave a good quality product.

Nogueira and Park (1992) found that the best conditions for obtaining quality banana-passa (a dehydrated product) by cabinet drying were a temperature of 70°C and air flow of 1.5 meters per second. Chavan *et al.* (1993) reported that blanched and sulphured ber fruits could be dried in a cabinet drier at 60°C for 40-48 hours. The resultant dehydrated ber could be eaten as such or after reconstitution in 40 per cent sugar solution.

Mugula *et al.* (1994) tried to produce banana powder of Silk variety by oven-drying of ripe slices at 60°C for 54 hours to a moisture content of 13.73 per cent followed by milling of dried slices. Mir and Nath (1995) dried mango puree and sugar mix of 30°Brix in a cross flow cabinet drier at 65°C. They found that free SO_2 was lost more rapidly than total SO_2 during drying.

Aruna *et al.* (1998) reported that papaya pulp mixed with wheat flour could be dried in a cabinet drier at 60°C. The powdered product was used into recipes such as custard powder, ice-cream powder and other processed products.

Hassan and Ahamed (1998) had developed foam-mat dried pineapple juice powder. Egg albumin (one per cent) was added to pineapple juice, blended for ten minutes in a blender, spread on a tray at three millimeters thickness and dried at 55-60°C for five hours in a cabinet drier to reduce moisture content to six per cent. The product was detrayed, ground with one per cent magnesium stearate, passed through 0.5 mm sieve and vacuum packed in 300 gauge high density polyethylene (HDPE) bags.

Sapota slices were dehydrated in air draft oven and vacuum oven by Ganjyal *et al.* (1998) to reduce the moisture content to 8.5 - 12.5 per cent. The drying time varied from 15-35 hours in air draft oven and for 14-31 hours in vacuum oven. The dehydrated sapota was powdered using a grinder and a ball mill to particle size of 105 microns. The powder retained natural colour and aroma of the original ripe fruit.

Sagar and Khurdiya (1998) attempted production of improved products using ripe mango powder. Mango fruit was cut into six length wise slices, dipped in an equal amount of 70°Brix sugar solution containing 0.1 per cent potassium meta-bi-sulphite (KMS), heated for two minutes at 90°C and soaked in the same solution overnight to ensure complete immersion. Next day the slices were drained and dried in a cross flow cabinet drier at 58-60°C to a final moisture level of about five per cent.

These slices were powdered with the help of a powder mill and sieved with 30 mesh sieve. Mango shake obtained by mixing mango powder with milk, water and sugar in the ratio of 6:12:6:1 was rated the best.

Waskar *et al.* (1998) reported that dehydration time for freshly harvested palak, methi and coriander leaves were the lowest and percentage yield of dry matter was the highest in cabinet drying. The dehydrated products possessed excellent colour and appearance.

Osmotic dehydration of sapota slices (0.5 to 1 cm thick) using dry sugar containing 1500 ppm SO_2 and 0.3 per cent citric acid in the ratio of 1:1 for eight hours followed by oven drying for eight hours yielded good quality sapota chunks (Maya, 1999). Heating of ripe mango (cv. Dasehari) slices in an equal weight of sugar syrup (70°Brix) containing 0.1 per cent KMS at 90°C for two minutes followed by drying in cabinet drier at 60°C gave the best dehydrated product (Sagar and Khurdiya, 1999).

Singh and Tomar (2000) reported that mango slices steeped for 18 hours in 70°Brix sugar syrup containing 0.5 per cent citric acid gave better dehydrated product. Pokharkar and Mahale (2000) observed that osmotic dehydration of banana slices in 65°Brix solution followed by cabinet drying at 46°C for 9-16 hours gave a bright yellow product which was chewy with moisture content of 19.4 per cent.

Kalsi and Dhawan (2001) prepared guava powder by osmotic dehydration. Guava slices were blanched in boiling water for two minutes and immersed in 70°Brix sugar syrup over night followed by cabinet drying at 65°C. The recovery per cent was found to be 5-7 per cent.

Patil *et al.* (2002) dehydrated sapota slices cv. Kalipatti in a cabinet drier at 60°C and obtained a recovery percentage of 30.46 per cent. Acceptable quality instant mushroom soup powder was produced by Rakhi *et al.* (2002) in which mushroom was wet ground to slurry, spices and condiments were fried in oil and all the ingredients were mixed and cooked for three minutes at boiling temperature. The mushroom soup thus prepared was dehydrated at 60 ± 2°C in hot air cabinet for 12 hours. The dried soup was ground to powder and subsequently packed in high density food grade polyethylene bags.

When unripe edible pulp of bael fruit was air dried at 60°C, it took four hours to reduce the moisture content from 57.82 to 8.01 per cent to produce bael powder and the dehydration ratio was found to be 3.04. However fully ripe bael pulp could not be dried to the desired level even after 30 hours of drying (Srivastav *et al.*, 2002).

Bhaskar *et al.* (2003) reported that ripe banana was blanched, pulped, sulphited and dried in a cabinet drier for 11 hours at 60°C. The dried product with 6.78 per cent moisture was cooled at room temperature in a dessicator and ground to fine powder. The banana powder when packed in 150 gauge polyethylene gave a shelf life of 30 days under ambient conditions.

2.2 Additives used in fruit powders

Spray dried durian pulp gave a higher recovery when methyl cellulose (10 g/1000 g pulp) was used as additive compared to glyceryl monostearate. The use of milk was recommended for a milk-durian mixture because it gave a well homogenized final product (Bauchan, 1972). The hydrocolloid stabilizers such as carboxymethyl cellulose or other food grade gums added to the spray drying mix increased the intermolecular structuring of water, which reduced its rate of diffusion and evaporation during terminal stages of spray drying (Berlin *et al.*, 1973).

Arsdel (1973) reported that food grade silica gel could be utilized to prevent caking in spray dried tomato powder. Torrey (1974) opined that the amount of starch added to the pumpkin puree before drum drying should not exceed 30 per cent on dry weight basis.

Shahabuddin and Hawlader (1990) stated that magnesium stearate at one per cent level was used as anti-caking agent in pineapple powder. Sole (1996) reported that commercial banana powder contained silicon-di-oxide as flow agent.

Duck *et al.* (1997) prepared spray dried jujube powder by mixing concentrated, enzyme treated juice of jujube with carriers like maltose, dextrin and gum arabica. Young *et al.* (1998) found that two per cent sodium aluminium silicate was the best anti-caking agent for garlic powder compared to cellulose powder and calcium carbonate.

Lagunes *et al.* (1999) reported that avacado paste could be spray dried after adding 10 per cent monoacyl glyceride and 0.05 per cent tertiary butylated hydroxytoluene (TBHT). Cheman *et al.* (1999) found that glucose syrup solid was the most suitable encapsulating agent for spray drying durian juice flavour.

Addition of maltodextrins and starches to betacyanin extracts from amaranthus markedly reduced hygroscopicity and enhanced storage stability (Cai and Corke, 2000). Kee *et al.* (2000) evaluated various anticaking agents (corn starch, acetylated distarch adipate and α starch) for their effectiveness in onion powder. Results proved that waxy corn starch was the best option.

Cangrong *et al.* (2001) observed that spray drying of tomato paste containing 6.7 per cent maltodextrin, 3.3 per cent soluble starch and 0.04 per cent sodium hydrosulphite gave tomato powder of good colour and quality.

Hauser *et al.* (2002) opined that the commonly used anti-caking agent in food powders namely silica acid powder was not water-soluble and in general was not well perceived by the consumer. Jaya (2004) used tricalcium phosphate as anticaking agent in vacuum drying of mango pulp.

2.3 Packaging of fruit powders

Packaging of dehydrated fruit must protect the product against moisture, light, dust, microflora, foreign odour, insects and rhodents; provide strength and stability to maintain original product size, shape and appearance.

Talley *et al.* (1966) reported that drum dried pumpkin powder could be stored for at least one year under nitrogen without undergoing change in flavour. Addition of about 25 ppm BHA + 25 ppm BHT was in general effective against oxidation than nitrogen packing. But in the atmosphere of air, it acquired hay like off-flavour.

Nitrogen packing markedly increased shelf-life of cooked lima bean powder. Addition of three ppm Butylated Hydroxy Toluene (BHT) was beneficial in both air and nitrogen packs. The first flavour change in nitrogen packed, antioxidant treated powder of four per cent moisture was detected after 7.5 months at 38°C (Burr *et al.*, 1969).

Arsdel (1973) found that nitrogen or carbon-di-oxide packaging was best for spray dried tomato powder. Jayaraman *et al.* (1974) reported that fruit powder formulations when packed in an inner wrap of cellophane and an outer pouch of paper-aluminium foil-polyethylene laminate were found acceptable for more than six months at 37°C and for one year under ambient conditions.

Mango-milk powder with 2.5 per cent moisture when stored in tin plated hermetically sealed cans and gassed twice with nitrogen at an interval of 24 hours, remained acceptable for one year at room temperature. But free fat and acidity showed a progressive increase (Sharma *et al.*, 1974).

According to De (1976), spray dried channa containing 3.5 per cent moisture recorded an average shelf-life of two and four months under air and nitrogen packing respectively at room temperature (20 ± 2°C). Spray dried srikhand powder when packed in containers with nitrogen gas showed good flavour and reconstitution for about 45 days at room temperature (Mahajan *et al.*, 1979).

Malhotra and Mann (1989) reported that ready-to-reconstitute coffee powder could be stored for three months in metallised polyester LDPE laminate at 30

± 1°C. During that period, moisture content increased from 2.28 to 2.29 per cent and pH decreased from 6.45 to 6.37.

Lal *et al.* (1989) stated that freeze dried banana powder stored in CO_2 pack at 45°C showed less browning than those stored in air. Commercially, banana powder (two to four per cent moisture) is packed in polythene lined multi-layer kraft paper bags of 29 kg capacity or thermo sealed in vacuum sealed cans which can be kept for a year at 24-30°C without spoilage (Sole, 1996).

Loesecke (1998) reported that fading and off flavour development was lesser when dehydrated sweet potatoes were packed with nitrogen. He added that dehydrated products should be packed with residual oxygen less than two per cent. Sagar *et al.* (1999) observed that the nitrogen packed bags of 260 gauge aluminium laminated polyethylene were most suitable for retaining the quality and colour of dehydrated ripe mango slices.

Nitrogen packaging inhibited lipid oxidation in spray dried avacado powder (Lagunes *et al.*, 1999). Kumar and Sreenarayanan (2000) reported that onion flakes vacuum packed in 300 gauge polyethylene showed significantly lower non-enzymatic browning (NEB) during storage.

Gvozdenovic *et al.* (2000) investigated the colour stability of powdered orange. The product colour change depended on the barrier characteristics of the packaging material and its permeability to water vapour and oxygen. The permeability of light had no major influence on colour change. Vacuum packed orange powder retained their bright orange colour throughout the storage period.

Shah *et al.* (2000) reported that polymeric films with aluminium foil having adequate barrier protection against oxygen, water and light ingress are most suitable for packaging freeze dehydrated fruits.

2.4 Storage and quality of fruit powders

Shelf-life of dehydrated products depends upon factors such as temperature of storage, relative humidity, type of packaging material and the composition of the product. Upon storage, the powder undergoes physical, chemical and microbial changes causing deterioration and reduction in shelf-life of the product. Strolle and Cording (1965) reported that potato flakes with four per cent moisture deteriorated in one month but with 6.6 per cent moisture, remained acceptable for six months.

Losses of natural aroma while drying fruits amount to 63-87 per cent. It was therefore necessary to add back aroma components to the fruit powder. Manufacturers added encapsulated flavour to fruit powders to make up the loss of flavour during drying (Kitson and Sugisawa, 1974). Kjaergaard (1974) quoted that the powder particles should have the highest density of the solid part and lowest amount of occluded or entrapped air so as to have better shelf-life.

Lal *et al.* (1989) found that storage temperature had a significant effect on the colour (browning) of freeze dried banana powder. Browning of the product was more at 45°C storage temperature than at 30°C. Al-Kahtani and Hassan (1990) reported that moisture content, solubility and bulk density of spray dried roselle extract decreased with an increase in drying temperature.

One important parameter characterizing the temperature stability of fruit powders was the glass transition temperature (Tg). The glass transition was a physical change from the glassy to the liquid state that occurs in amorphous solids when they were heated. Fruit sugars and acids were low molecular weight entities having low Tg values. Due to low Tg value, fruit pulps gave sticky products on drying. In order to increase the Tg effectively, high molecular types like starch, maltodextrin were added to fruit pulp (Lloyd *et al.*, 1996).

Papadakis *et al.* (1998) observed that the solubility, bulk density and hygroscopicity of spray dried raisin extract concentrate increased as the moisture content decreased. Loesecke (1998) reported that non-enzymatic browning in dehydrated foods was due to Maillard reaction (i.e.) due to the interaction of the nitrogenous constituents with the reducing sugars and organic acids. The factors influencing browning were the pH, moisture, storage temperature and packaging atmosphere.

Tsami *et al.* (1999) compared the porosities of fruit powders obtained by different drying methods. They reported that freeze and vacuum dried powders had the highest porosities whilst microwave and conventionally dried products had the lowest porosities. Results suggest that bulk density and pore size of dried materials had significant effects on moisture sorption capacity.

Sagar *et al.* (2000) reported that ripe mango powder in 400 gauge low density polyethylene pouches could be stored for six months at 7°C and for four months at room temperature without loss of colour, flavour and texture. Low storage temperature induced higher retention of ascorbic acid and total carotenoids in the mango powder.

Onion powder could be stored upto six months in 200 gauge high density polyethylene (HDPE) pouches at 7°C compared to four months at ambient condition. For storage of the product having 3.85 per cent moisture, the optimum relative humidity (RH) was found to be 47.5 per cent and the critical and danger points as 9.14 per cent and 6.75 per cent moisture respectively (Sagar, 2001). Wauters *et al.* (2002) reported that storage of fruit powders at a lower temperature than Tg prevented caking and lumping.

The Tg value showed strong dependence on powder moisture content. As moisture content increased, the Tg value decreased. Elevation of the powder temperature above Tg promoted viscous flow and increased the potential of caking

(Hashimoto *et al.*, 2003). Singh *et al.* (2004) found that onion variety Agrifound white gave highest rehydration ratio (1:5.41) and lowest NEB (0.017) with regard to dehydration qualities.

Athanasia *et al.* (2004) opined that increased drying air temperature decreased the bulk density of spray dried tomato powder due to an increase in particle size and a greater tendency for the particles to be hollow. He added that the outlet air temperature of a spray drier was one of the key parameters affecting the powder properties.

Reineccius (2004) opined that dispersibility was influenced by particle size, bulk density and the carrier matrix used in spray dried food flavours. Spherical particles were desirable due to better aroma retention, higher bulk density and better flowability.

Jaya (2004) stated that some of the factors contributing to the quality of fruit powders are hygroscopicity, degree of caking, dispersibility, flowability, moisture content, sticky point (Tsp), surface caking (Tsc) and glass transition temperature (Tg) of dry powder. Drying of sugar rich foods such as fruit juices to powder was difficult mainly due to the low molecular weight sugars such as fructose, glucose, sucrose and acids like citric acid that were present in the fruit juice. These materials had low glass transition temperatures (Tg) that gave sticky product on drying instead of powder.

2.5 Banana juice

The traditional technology of banana juice extraction used in East Africa was studied by Kyamuhangine *et al.* (1998). Particular bananas referred to as 'Mbidde' were used by the farmers for juice extraction because of their unique ability to release juice. The process of juice extraction involved pressing, folding and turning the pulp mash mixed with spear grass over and over again until the juice started to flow.

Palmu *et al.* (1999) suggested pretreatment of banana juice with one per cent ascorbic acid and 0.15 per cent sodium meta-bi-sulphite to inhibit the polyphenol oxidase (PPO) activity. PPO was also removed by ultrafiltration of the juice using polysulphone membranes with a molecular weight cut-off of 20 kDa and a transmembrane pressure of 600 kPa.

Narayana *et al.* (2004) stated that banana nectar prepared with 30 per cent clarified banana juice was the best based on organoleptic quality. Bhaba Atomic Research Centre (BARC), Mumbai had developed a new variety of banana 'Basari 10 gy' which could yield juice without addition of external enzymes. One kilogram of Basari 10 gy could yield 600-700 ml of clarified juice (Deshpande, 2004).

2.6 Enzymatic extraction of fruit juices

Munyanganizi and Coppens (1976) compared two methods of extracting banana juice viz. enzyme treatment with Rapidase (0.01 - 0.05 per cent) and calcium oxide (CaO) treatment. The enzymic process gave a juice yield of 88 per cent which was dark brown with more flavour while the CaO treatment gave a juice yield of 82 per cent which was pale yellow with less flavour.

Jaleel *et al.* (1979) studied the enzymatic processing of banana on a pilot scale. Banana pulp was heated using tubular heat exchangers. An open type reaction vessel with provision for agitation was used for addition of pectinolytic enzyme. The juice was separated using plate and frame type filter press with hyglow supercel filter aids.

Viquez *et al.* (1981) found that treatment of banana pulp with ultrazym 0.025 per cent by weight at 45°C for two hours gave juice yields of more than 66 per cent while the untreated pulp gave juice yields of only 5-27 per cent. Yu and Wu (1987) obtained a juice yield of 69.2 per cent from banana pulp treated with 0.05 per cent (w/w) of Rohapect D5L at 45°C for two hours.

Addition of pectinol @ 0.5 per cent to the pulps of plum, peach and apricot increased the juice yield, decreased the apparent viscosity, improved the colour and clarity without affecting the flavour (Joshi *et al.*, 1991). Chan and Chiang (1992) found that treating guava puree with 1000 ppm pectinase at 50°C for three hours gave satisfactory clarification but caused severe losses in volatile components. Pre-treatment of pulp with 100 ppm pectinase for one hour followed by bentonite clarification was found better.

Pheantaveerat and Anprung (1993) compared commercially available pectinases, cellulases and amylases for the hydrolysis of ripe banana pulp. Juice yield of 73 per cent was obtained when banana pulp was incubated with 0.06 per cent cellulases and 0.05 per cent pectinases at 45°C for two hours. Results suggested that amylases were not effective in the production of banana juice. Singh *et al.* (1993) reported that banana pulp treated with pectinex ultra one per cent (v/w) concentration at 40°C for two hours yielded 67 per cent banana juice.

Kotecha *et al.* (1994) reported a juice recovery of 60-67 per cent in banana with pectinase at 0.2 per cent. Sims and Bates (1994) found that a combination of pectinase, cellulase and hemicellulase was the most effective of all enzyme systems in reducing viscosity and improving filterability of banana juice.

Shahadan and Abdullah (1995) found that the optimal juice extraction conditions in banana were 0.42 per cent pectinase enzyme, pulp pH of 3.4 and incubation at 35°C for four hours. Rajamala *et al.* (1995) reported maximum juice yield in banana with pectinase 1.5 per cent. Teotia *et al.* (1997) observed that 2.0 per cent (v/w) commercial pectinase gave maximum (91%) juice recovery in musk melon after three hours contact time at room temperature.

Chen and Lin (1997) studied the application of enzymes amylase and pectinase in clarification of banana juice. Optimum amylase treatment was with a concentration of 0.4 per cent at 55°C for 30 minutes while that of pectinase was 0.015 per cent at 45°C for 60 minutes.

Thakur *et al.* (1999) obtained higher serum yield in kinnow treated with 0.8 per cent pectinolytic enzyme at 40°C for four hours. Waskar and Garande (1999) found that treatment of ber pulp with 0.6 per cent pectinex 3XL or 0.4 per cent Trizyme P-50 gave higher recoveries of clarified juice.

Singh *et al.* (2000) reported that 30 minute liquefaction of mango pulp with 1.1 ml of pectinase enzyme per kilogram was optimal for recovery of clear mango juice following subsequent centrifugation of the serum.

Chopda and Barett (2001) obtained maximum juice yield in guava with 700 ppm Pectinex Ultra enzyme held at 50°C for 1.5 hours. Jackson and Badrie (2002) found that sensory quality was best for banana wine made from banana juice clarified using one per cent Pectolase. Devaraju *et al.* (2002) obtained clarified ber juice by treating ber pulp with pectinase @ 4 g/kg for 12-24 hours.

Kyamuhangire *et al.* (2002) compared the mechanical and enzymatic juice extraction in banana. In mechanical method, ripe banana pulp was mixed with polythene strips and worked with a dough mixer at room temperature for 20 minutes. Enzymatic extraction involved incubation of ripe pulp with pectinase enzyme for two hours at 50°C. Enzymatic method gave lower juice yield with higher total soluble solids (TSS) and acidity while the mechanical method gave higher juice yield with better flavour and overall acceptability. Gowda (2002) studied the enzymatic liquefaction of jackfruit pulp. Highest juice yield was observed with 0:12 per cent pectinex-ultra incubated at 45°C for three hours.

2.7 Blending of fruit juices

Blending of fruit juices offers the opportunity to adjust sugar/acid ratios and compensate for other imbalances in the juice. Defects in juice quality or nutritional attributes can be overcome by proper combination of juices. Kalra *et al.* (1991) reported that blending of fruit juices helped in improving nutritional status, reducing cost of production, masking the defects in juice quality (high acidity, poor taste, astringency and undesirable flavour) and led to new product development.

Mango pulp being a rich source of carotene could markedly upgrade the colour of other beverages from fruits such as pineapple and apple that did not have an attractive colour. Thus blending not only improved the quality and nutrition of basic material, but also offered scope for the development of newer products. Among the blended nectar of mango with pineapple, apple, orange and plum, ratios of 2:2, 3:1, 3:1 and 1:3 respectively gave the highest scores for sensory attributes (Sahni and Khurdiya, 1993).

Price *et al.* (1993) evaluated four fruit juice blends each with 60 per cent blue berry juice and 40 per cent from other sources for consumer preference. The Blue berry- Concord blend had the best flavour and 'first-choice' ratings. Tiwari (2000) studied the blending of 'Lucknow-49' guava and 'Solo' papaya pulp for preparation of RTS beverage. Sensory quality score was highest in 70:30 guava and papaya blend due to better consistency and flavour.

Nakadi *et al.* (2001) found that RTS beverage made with pomegranate and mango juice 60:40 blend was superior to other combinations because it had good colour, appearance, flavour, taste and overall acceptability.

Deka and Sethi (2001) prepared RTS spiced beverages from blended fruit juices of lime-aonla, mango-pineapple, grape-mango and grape-pineapple with addition of various aqueous spice extracts and commercial spice drops. The spiced lime-aonla (95:5) RTS beverage with aqueous spice extracts of curry leaf, cumin, cardamum, black pepper, ginger and mint was found best. Likewise, mango-pineapple (85:15) blend with cardamum spice drops was found best.

Deka *et al.* (2001) found that the scores for overall sensory quality were higher for the mango-pineapple and grape-pineapple blend and lower for lime-aonla and mango-grape blends. Bhupinder *et al.* (2003) reported that RTS beverage prepared from a blend of papaya with mango in the ratio 90:10 was found widely acceptable and preferred by the panelists. The inkling flavour of papaya was masked by the sweet flavour of mango in the blend.

2.8 Ready-To-Serve (RTS) beverage from fruits

Pandey and Singh (1999) evaluated the recipes, varietal suitability and storage stability of guava RTS beverage. The recipe containing 10 per cent pulp, 11 per cent TSS and 0.25 per cent acidity was found ideal. The RTS beverage from Lucknow 49 variety was better than Allahabad safeda, Apple colour and Sangam. Storage stability of the product was found to be four months at ambient temperature.

Tiwari and Dinesh (2001) reported that guava RTS beverage having 15 per cent pulp, 18°Brix and 0.3 per cent acidity could be stored for six months at room temperature without deterioration. Krishnaveni *et al.* (2001) studied the storage stability of jack fruit RTS beverage prepared with 10 per cent pulp, 18°Brix and 0.25 per cent acidity stored in coloured and colourless bottles. The retention of ascorbic acid and β-carotene contents were better in samples stored in green coloured bottles.

Pushpa *et al.* (2002) undertook a study to prepare RTS beverage from enzyme clarified juice of banana varieties, viz., Poovan, Karpooravalli, Rasthali, Virupakshi, Robusta, Red Banana and Nendran. Organoleptic evaluation revealed that the varieties Nendran, Rasthali and Virupakshi were highly acceptable.

Chitra and Manimegalai (2002) reported that banana RTS beverage could be stored safely upto 300 days under refrigeration temperature with minimum changes in its quality characteristics. Narayana *et al.* (2002) prepared banana RTS beverage from enzyme clarified juice of Poovan (Mysore) variety. The RTS with 15 per cent fruit juice, 0.3 per cent acidity and 13° Brix was stable for six months under ambient conditions.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Development of juice-based beverage and ripe-fruit powder from banana (*Musa* spp.)" was carried out at the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur and utilizing the facilities at Central Food Technological Research Institute (CFTRI), Mysore during the period 2001-2004.

The objectives of the study were to develop a drying and packaging regime for ripe banana powder and also to develop a Ready-To-Serve (RTS) beverage based on clarified banana juice.

The whole programme was divided into two major parts.

3.1 Development of technology for ripe banana powder

3.2 Development of technology for banana juice based beverage

3.1 DEVELOPMENT OF TECHNOLOGY FOR RIPE BANANA POWDER

3.1.1 Experiments on drying

The following methods of drying were adapted to find out the best drying technique for the production of ripe banana powder.

1) Spray drying
2) Drum drying
3) Cabinet drying

3.1.1.1 Spray drying

(a) Preparation of raw material

Fully ripe Robusta fruits procured from local market were peeled and pulped using a fruit pulper (Reylons Ltd., India) fitted with a sieve (Plate 1). To the sieved pulp, potassium meta-bi-sulphite (KMS) @ 0.1% and water @ 500 ml/kg were added.

Maltodextrin (20 Dextrose equivalent) and soluble starch procured from Rithi-Sithi Ltd., Bangalore were added to the diluted pulp in various proportions as given in the treatments. The prepared material was pasteurized at 80°C for 10 minutes and homogenized in a homogenizer (APV Gaulin, Gaulin Corporation, USA) without pressure initially and thereafter at 50 bar pressure for 30 minutes. This homogenized banana pulp having a TSS of 14.60°Brix, pH 4.48 and viscosity 3000 cps was used for spray drying. The flow chart for preparation of raw material is given in Fig. 1.

b) Spray drier

A laboratory spray drier (Bowen BLSA, New Jersey, USA) available in the main pilot plant of CFTRI, Mysore was used for the trials (Plate 1) with the following parameters.

Atomizer	-	Centrifugal disc type
Atomizer speed	-	20000 rpm
Outlet temperature	-	100°C
Pulp feed rate	-	50 ml/minute

c) Treatments

i) Inlet air temperatures used in spray drying

T_1 → 180° C

T_2 → 160° C

T_3 → 150° C

T_4 → 140° C

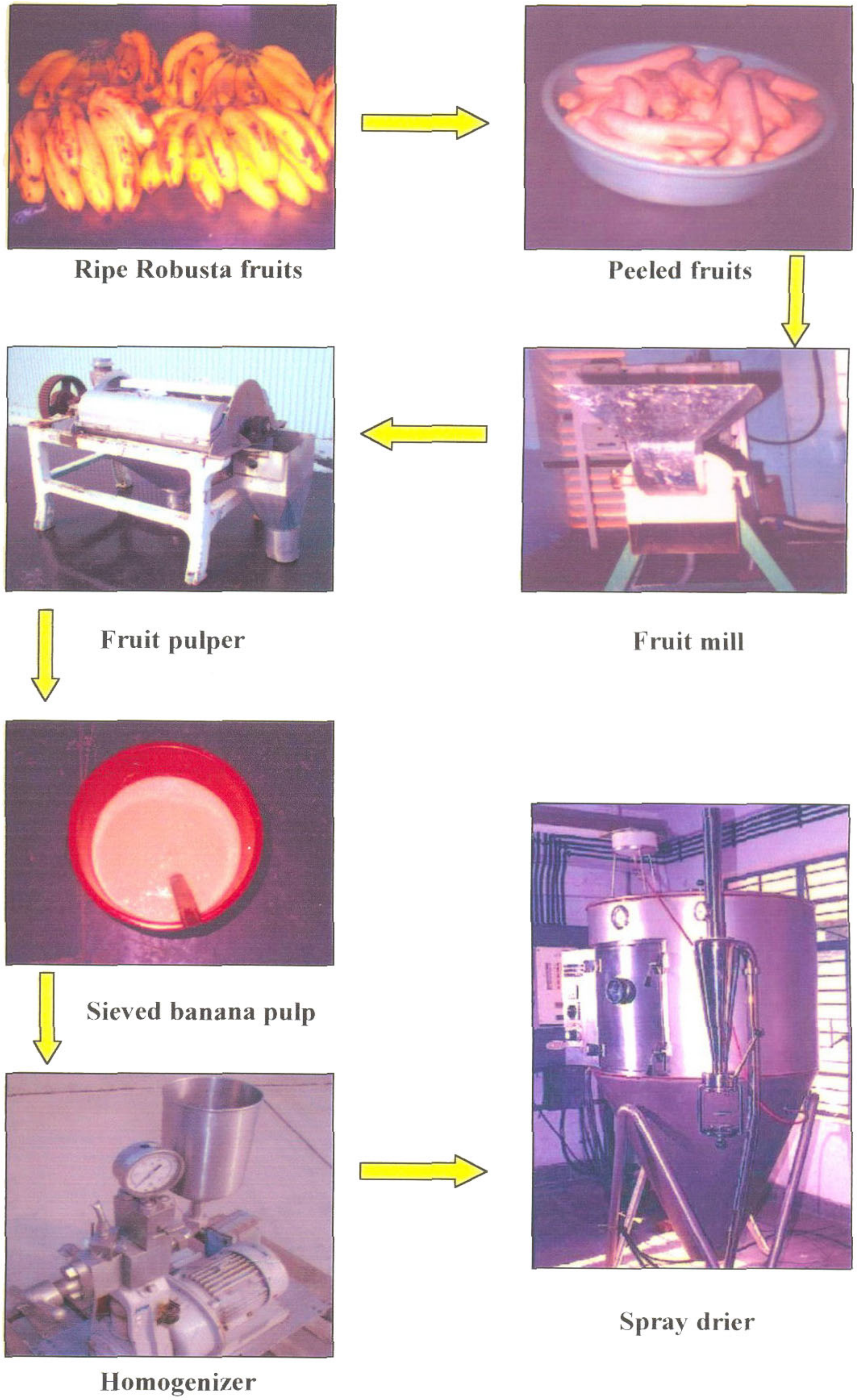
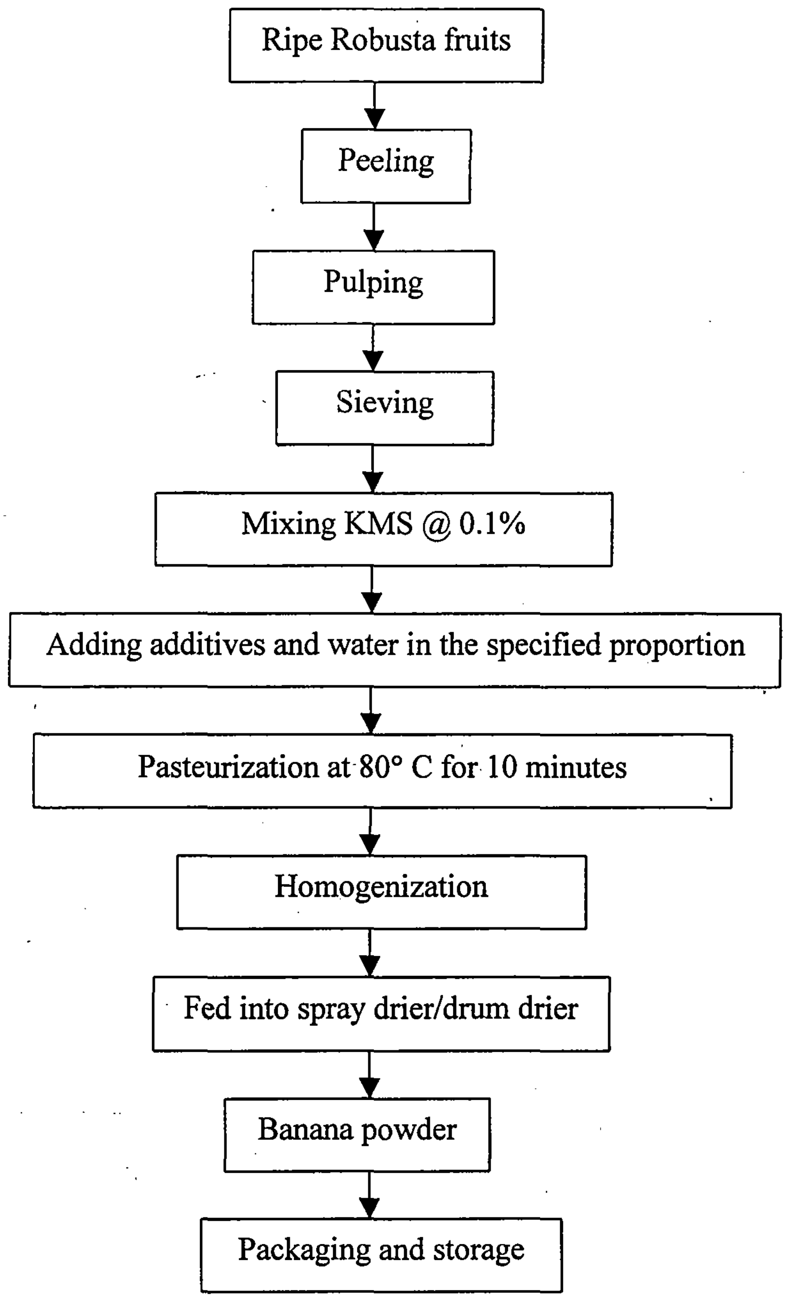


Plate 1. Schematic representation of steps involved in spray drying of banana pulp

Fig 1. Preparation of raw material for spray drying/drum drying of banana pulp



ii) **Additive levels (on wet basis) used in spray drying**

A_1 - Banana pulp + 5% Maltodextrin

A_2 - Banana pulp + 5% Soluble starch

A_3 - Banana pulp + 2.5% Maltodextrin + 2.5% Soluble starch

A_4 - Banana pulp + 3% Maltodextrin + 2% Soluble starch

A_5 - Banana pulp + 2% Maltodextrin + 3% Soluble starch

3.1.1.2 Drum drying

a) Preparation of raw material

Same as that for spray drying with modifications in the level of additive and water added. Soluble starch in various proportions as given in the treatments and water @ 100 ml/kg were added to banana pulp. The feed pulp had a TSS of 19.3°Brix, pH 4.77 and viscosity 5000 cps.

b) Drum drier

Double drum drier of M/s. Escherwyss, Germany having the following specifications was used for the trial (Plate 2).

Number of rollers	-	2
Heating surface	-	1.32 m²
Diameter	-	350 mm
Length	-	600 mm
Steam pressure	-	4 bar
Temperature	-	152°C
Speed	-	3 rpm

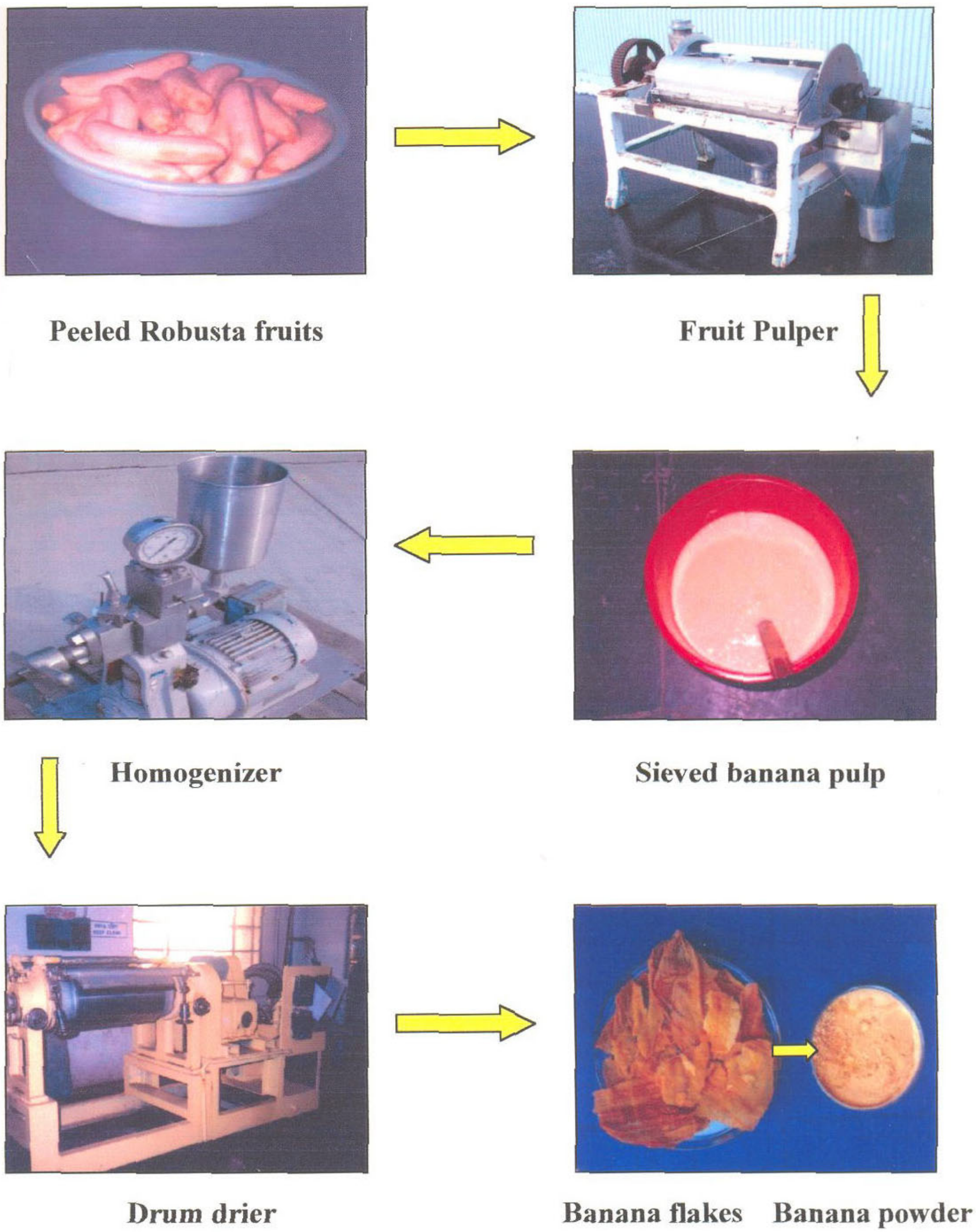


Plate 2. Schematic representation of steps involved in drum drying of banana pulp

c) **Treatments**

T_1 - Banana pulp + 1.0% Soluble starch

T_2 - Banana pulp + 1.5% Soluble starch

T_3 - Banana pulp + 2.0% Soluble starch

T_4 - Banana pulp + 2.5% Soluble starch

T_5 - Banana pulp + 3.0% Soluble starch

3.1.1.3 Cabinet drying

a) **Preparation of raw material**

Soluble starch at varied levels and KMS @ 0.1% were added to ripe Robusta pulp which was mixed thoroughly in a wet blender for five minutes, pasteurized and subjected to drying. The pulp was spread uniformly at one cm thickness over the stainless steel plates and dried at different temperatures.

b) **Cabinet drier**

A cabinet drier (Kilburn 0248, India) with inner dimension 0.9 x 1 x 0.61 m^3 and heating capacity 2.5 KW was used.

c) **Treatments**

i) **Drying temperatures used in cabinet drying**

$T_1 \rightarrow 60°$ C

$T_2 \rightarrow 70°$ C

$T_3 \rightarrow 80°$ C

$T_4 \rightarrow 90°$ C

ii) Additive levels (on wet basis) used in cabinet drying

A_1 - Banana pulp as such without additives

A_2 - Banana pulp + 1% Soluble starch

A_3 - Banana pulp + 2% Soluble starch

A_4 - Banana pulp + 3% Soluble starch

A_5 - Banana pulp + 4% Soluble starch

A_6 - Banana pulp + 5% Soluble starch

3.1.2 Experiments on packaging and storage of banana powder

Banana powder obtained by two drying methods (spray and drum drying) was packed in two different packaging materials employing four different packaging methods. These were then stored under ambient conditions.

a) Packaging materials

i) **Metallised polyester polyethylene laminated pouches**
Made of 12μm metallised polyester laminated with 40μm polyethylene purchased from Darsha Packaging, Mysore.

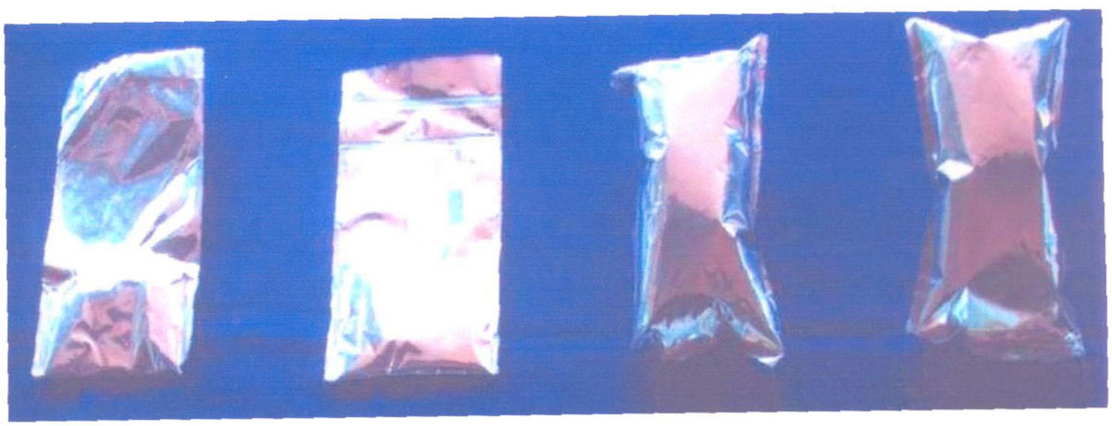
ii) **Aluminium foil laminated pouches**
Made of 7 μm aluminium foil laminated with 50μm polyethylene purchased from Flexi Packaging, Bangalore (Plate 3).

b) Packaging methods

i) Packed with vacuum
ii) Packed with nitrogen
iii) Packed with carbon-di-oxide
iv) Packed with air as control

Air pack Vacuum pack CO_2 pack Nitrogen pack

a) Aluminium foil laminated pouches



Vacuum pack Air pack CO_2 pack Nitrogen pack

b) Metallised polyester pouches

Plate 3. Packaging materials and methods used in the study

c) Packaging machine

A vacuum packaging machine Propack 400 VSG-Trolley model with gas flushing arrangement was used for packaging the banana powder (Plate 4).

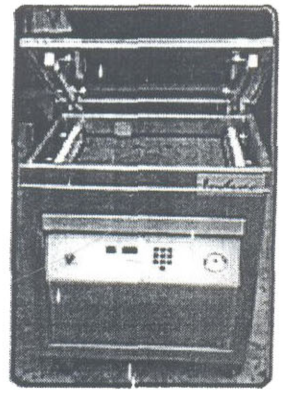


Plate 4. Vacuum packaging machine

3.1.3 OBSERVATIONS

3.1.3.1 Physical parameters

Moisture

Moisture content was measured using a vacuum oven (Hythermco 6002, New Jersey) operated at 70°C and 50±10 mm of Hg pressure for 16 hours (Ranganna, 1995).

Bulk density, Average particle density and Percentage volume occupied by powder particles

The method described by Beckett *et al.* (1962) was followed. In a 100 ml graduated cylinder, 50 ml hexane was taken and covered with an aluminium foil. The volume of hexane (V_1) and total weight (W_1) was recorded. Powder was then added slowly through a funnel into the cylinder to increase the volume by about 40 ml. The cylinder was then covered with aluminium foil and placed in a levelled and vibration free surface. After one hour, the volume of powder (V_3), hexane (V_2) and the total weight (W_2) were recorded. The calculation was done as given below.

$$\text{Bulk density (g ml}^{-1}\text{)} = \frac{W_2 - W_1}{V_3}$$

$$\text{Average particle density (g ml}^{-1}\text{)} = \frac{W_2 - W_1}{V_2 - V_1}$$

$$\% \text{ Volume occupied by the powder particles} = \frac{V_2 - V_1}{V_3}$$

Solubility per cent, Soluble and dispersed solids

In a 50 ml boiling tube, four gram banana powder and 32 ml warm water at 50±1°C were taken and shaken for 10 seconds. The tube was then placed in water bath at 50±1°C for five minutes. Again the tube was shaken well and two ml of homogenous mix was transferred to a dry tared aluminium dish (No.1). The tube was centrifuged for 10 minutes and two ml of the upper layer of the supernatant liquid was transferred to another aluminium dish (No.2). Both dishes were placed on a steam bath until apparently dry and then placed in air oven at 100°C for 90 minutes. The cooled dishes were weighted (BIS, 1981).

$$\text{Solubility per cent by weight} = \frac{W_4 \times W_1}{W_3 \times W_2} \times 100$$

Where

W_1	-	Weight of liquid in dish No.1
W_2	-	Weight of liquid in dish No.2
W_3	-	Weight of total solids in dish No.1
W_4	-	Weight of total solids in dish No.2

Dispersibility

Dispersibility is inversely related to sedimentation and was expressed in terms of sedimentation of per cent solids after 24 hours. For this 52 grams powder was mixed with 400 ml water in a mixie for 20 seconds, allowed to stand for five minutes and kept in beakers of 25 ml capacity. The supernatant fluid was taken at 0 and 24 hours to determine total solids (Sharma *et al.*, 1974).

Sinkability

Distilled water (3.5 ml) at 25°C was taken in a cuvette and 10 ml sample of the powder was dusted on the surface of water. The percentage transmission was continuously recorded for 6 minutes at 760 nm in spectrophotometer (Spectronic 20) at 2,4 and 6th minutes.

Powder recovery

The recovery of banana powder from pulp in different methods of drying was calculated on wet and dry basis.

$$\text{Powder recovery (\%) (Wet basis)} = \frac{\text{Weight of banana powder}}{\text{Weight of the wet pulp}} \times 100$$

$$\text{Powder recovery (\%) (Dry basis)} = \frac{\text{Weight of banana powder}}{\text{Weight of total solids in the pulp}} \times 100$$

Rehydration ratio

About 10 g of banana powder was boiled for five minutes with 100 ml distilled water. The contents were filtered using a coarse filter paper until the drip from the funnel has almost stopped. The rehydrated sample was weighed (Ranganna, 1995).

$$\text{Rehydration ratio} = \frac{\text{Weight of dry sample}}{\text{Drained weight of rehydrated sample}}$$

Additive

The additive percentage in the banana powder obtained from different methods of drying was calculated on wet and dry basis.

$$\text{Additive (\%) wet basis} = \frac{\text{Weight of additive added}}{\text{Weight of wet pulp}} \times 100$$

$$\text{Additive (\%) dry basis} = \frac{\text{Weight of additive added}}{\text{Weight of total solids in the pulp}} \times 100$$

Hunter colour values

Colour of the banana powder was estimated as Hunter value L, a and b using Hunter lab Colour Measuring System (Hunter Associates Laboratory, Virginia) as described by Phahar and Leung (1985). The 'L' value represents visual lightness and darkness, '+a' degree of redness, '-a' degree of greeness, '+b' degree of yellowness and '-b' degree of blueness of the powder.

Viscosity

Viscosity of the raw material was measured with a Brookfield Viscometer (Model LVT, Stoughton) using Spindles #2 and #3 (Chopda and Barett, 2001).

Microstructure

The powder was subjected to Scanning Electron Microscopy (SEM) (Plate 5) to study the internal structure as per the procedure outlined by Bhandari *et al.* (1984). The samples were applied to the stub coated with an adhesive. Excess and loosely attached particles were removed by blowing the stub with an inert gas or hair dryer. The mounted powder was sputter coated with gold of approximately 150A° thickness using Taab K 550 Sputter coater and examined under a Hitachi S 530 Scanning electron microscope at an accelerating voltage of 4 Kv for spray dried powder and 15 Kv for drum dried powder.

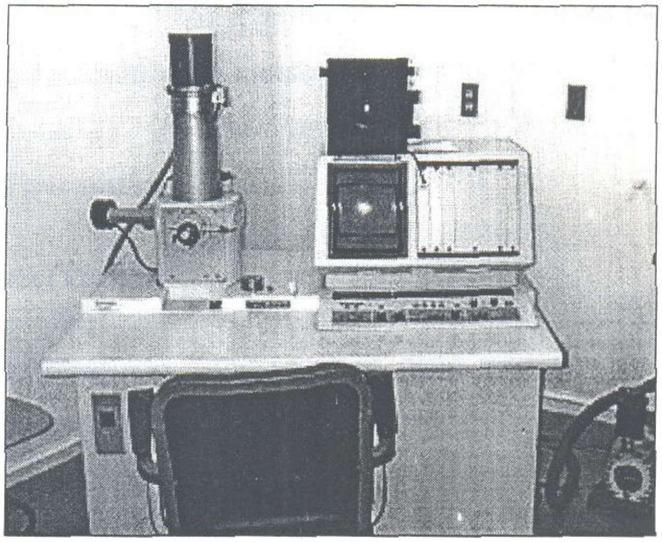


Plate 5. Scanning Electron Microscope

Moisture sorption behaviour

Moisture sorption studies were conducted by exposing banana powder (two grams) to different relative humidities (RH) ranging from 5 to 90 per cent created using sulphuric acid of various normalities. These atmospheric conditions were prepared by placing sulphuric acid of various normalities in the bottom part of the dessicators held at constant temperature (28±2°C) as described by Ranganna (1995).

Relative humidity (%)	Normality of sulphuric acid solution
5	22.0
15	18.0
25	15.8
35	13.9
45	12.3
65	9.2
85	5.2
95	2.3

The critical and danger points were evaluated according to the weight equilibrium method (Wink, 1946). Equilibrium moisture curves (sorption isotherms) were plotted to find the equilibrium moisture content.

3.1.3.2 Chemical parameters

Total Soluble Solids (TSS)

TSS was measured using an Erma hand refractometer and expressed as °Brix. Powder samples were diluted with distilled water in the ratio 1:5 to find the TSS (Chopda and Barett, 2001).

pH

Banana powder (20 g) was reconstituted with 100 ml distilled water as suggested by Chopda and Barett (2001) and pH was directly read using digital pH meter (ELICO 612, Hyderabad).

Non-enzymatic browning (NEB)

About five grams of banana powder was mixed with 100 ml of 60% Ethanol and kept overnight in dark after covering with aluminium foil. The mix was filtered and absorbance at 440 nm was recorded (Ranganna, 1995).

Acidity (%)

Acidity was determined by titration method using 0.1N NaOH (Ranganna, 1995). Five grams of banana powder was mixed with 20 ml distilled water and heated in a water bath for 10 minutes. The mix was filtered and titrated against 0.1N NaOH.

Sugars (%)

Reducing sugar and total sugar were estimated by Fehling's method (Ranganna, 1995). Two grams of banana powder was taken in a beaker. About 10 ml water was added and stirred well. To this, 5 ml of 10 per cent lead acetate was added and left for 15 minutes. Then 10 ml of 10 per cent potassium oxalate was added and left for 15 minutes. The solution was neutralized with 1N NaOH, made upto 100 ml and filtered. The filtrate was used for titration against Fehling's solution.

Starch (%)

Starch was estimated by the colorimetric method using anthrone reagent (Ranganna, 1995). Banana powder 0.5 gram was weighed and washed with 25 ml of hot 80 per cent ethyl alcohol three times. The residue was then washed with 52 per cent perchloric acid. The supernatant was made upto 100 ml. Pipetted out 5 ml of the solution, added 10 ml of anthrone reagent, heated for 10 minutes and the colour was read at 630 nm.

Protein (%)

Four grams of banana powder was taken in a kjeldahl flask. Concentrated H_2SO_4 25 ml was added for digestion. The cooled digest was distilled and titrated with 0.05 N HCl. Nitrogen content was estimated by the Kjeldahl method and protein content was worked out using the formula (Ranganna, 1995).

Protein (%) = Nitrogen (%) x 6.25

Total Ash (%)

Total ash was estimated by igniting five grams of banana powder in a silica dish on a bunsen burner (Ranganna, 1995).

Crude Fibre (%)

Crude fibre was estimated by acid digestion method (Ranganna, 1995). Two gram of banana powder was extracted with ether. The residue was digested with 200 ml of 0.255 N sulphuric acid solution. The residue from acid digestion was boiled with 200 ml of 0.313 N NaOH solution and filtered. Then the residue was washed with boiling water and alcohol and dried at 110°C to constant weight. The resultant residue was ignited in muffle furnace to find the crude fibre.

3.1.3.3 Gas Chromatography - Mass spectrometry (GC-MS) analysis

The basic instrument consists of a gas chromatograph (GC) with a quadrupole mass spectrometer (MS) as a detector. In the normal mode of operation, a sample consisting of a mixture of organic compounds that are volatile at a temperature of 275°C is introduced to the head of the column with a syringe. Helium serves as a carrier gas to move the sample through the column where the mixture is separated into individual components. As each component issues from the column, it is introduced to the mass spectrometer where a mass spectrum for that material is obtained and stored in a computer. Based on the mass spectrum, the compound is identified.

Qualitative analysis of the volatile compounds of banana powder was made using a gas chromatography (Plate 6) coupled to a mass spectrometer with the following specifications.

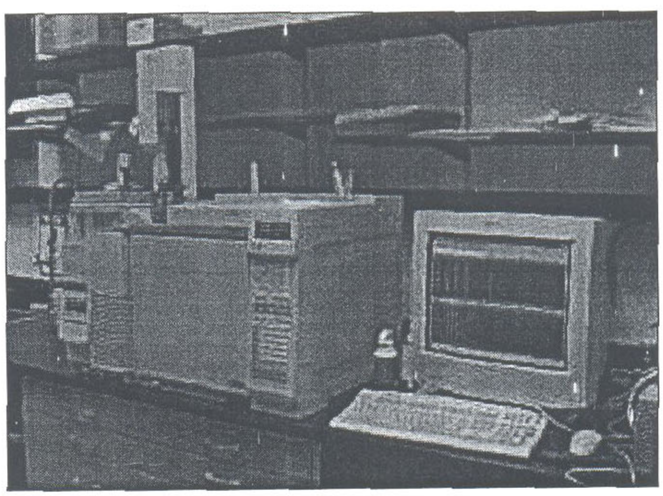


Plate 6. Gas chromatograph - Mass spectrometer

Gas chromatograph (GC)

Model	-	Varian GC Version 3800
Carrier gas	-	Helium (purity 99.996%)
Column type	-	Wall coated open tubular (WCOT) fused silica -DB 5

Column length	-	30 m
Film thickness	-	0.25 μm
Maximum allowed temperature	-	325°C
Volatile aromatic extract injected	-	one μl

Mass spectrometry (MS)

Model	-	Varian 1200 L single quadrupole MS
Scan rate	-	1250 μ/sec
Mass range	-	19-800 μ
Ionization mode	-	Electron ionization
Electron energy	-	70 eV
Scan mode	-	Centroid
Library	-	NIST 1998 software and NIST Chemistry webbook (http://webbook.nist.gov/chemistry/name-ser.html)

Extraction of volatile compounds

About 50 grams of banana powder or 120 grams of pulp (in the case of fresh banana) was blended in a mixie for one minute to get a homogenous paste. Volatile compounds were extracted with 80 ml of Methylene chloride by stirring for one hour with a magnetic stirrer. The resulting mixture was centrifuged at 5000 rpm for 10 minutes. The organic layer was dried with sodium sulphate and concentrated to 1 ml by keeping in the exhaust (Jordan *et al.*, 2001).

3.1.4 Organoleptic evaluation

Organoleptic scores for colour, flavour, texture and overall acceptability of the banana powder were recorded over a five point hedonic scale (Amerine *et al.*, 1965) by a panel of fifteen semi-trained evaluators at monthly intervals followed by statistical analysis. Average of five scores was taken as one replication. The score card for banana powder is given in Appendix-I.

3.1.5 Cost of production

Cost of production of five kilogram each of spray dried and drum dried banana powder were worked out. The following items of cost were considered for the estimation of cost of production.

i) Working capital

Working capital included the cost of raw materials viz., banana, additives, cost of fuel and labour involved for the production of five kilogram of the dried product.

ii) Interest on working capital

Interest on working capital was estimated at the rate of 12 per cent per annum and apportioned on the basis of working hours required for production of five kilogram of the product.

iii) Depreciation of machineries

Depreciation at the rate of 10 per cent per annum was calculated and apportioned on the basis of working hours of each machinery (Appendix-II).

iv) Interest on fixed capital

Interest on fixed capital, excluding land and building, was calculated at the rate of 12 per cent per annum and apportioned on the basis of working hours.

3.2 DEVELOPMENT OF TECHNOLOGY FOR BANANA JUICE BASED BEVERAGE

3.2.1 Experiment on enzyme aided banana juice extraction

Ripe banana fruits of different varieties purchased from local market were pulped and treated with commercial pectinase enzyme at two different incubation temperatures.

(a) Varieties

i) Robusta
ii) Poovan (Silk)
iii) Palayankodan (Mysore)
iv) Karpooravalli (Pisang Awak)

(b) Incubation time and temperature

i) Four hours at room temperature
ii) Two hours at 45°C

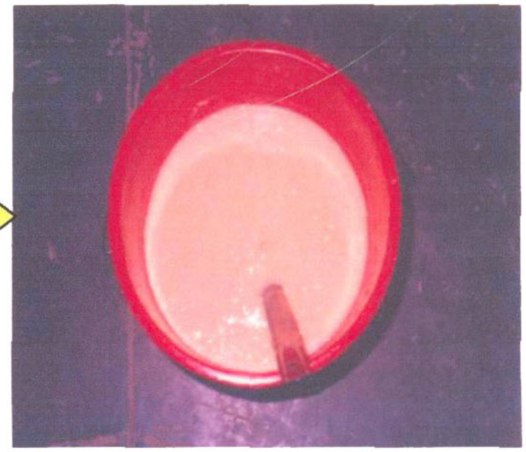
(c) Commercial pectinase enzyme

Pectinase CCM plus, an enzyme formulation derived from *Aspergillus niger* was purchased from Biocon India Ltd., Bangalore. It contained enzymes of different types like pectinases, cellulases, hemi-cellulases and amylases (Plate 7).

(d) Juice extraction

Fully ripe banana fruits were pulped in a mixie and KMS was added @ 0.1% to prevent browning. The pulp was pasteurized at 80°C for ten minutes. Pectinase CCM plus was added to the cooled pulp @ 5 ml per kilogram and mixed thoroughly. The treated pulp was kept undisturbed for a particular time as per treatments to facilitate juice separation. The banana juice was separated from the pomace by filtering in a muslin cloth. The turbid juice thus obtained was further clarified by overnight storage in the refrigerator followed by siphoning of the clear supernatant. The flow chart for enzymatic extraction is given in Fig. 2.

Ripe banana fruit



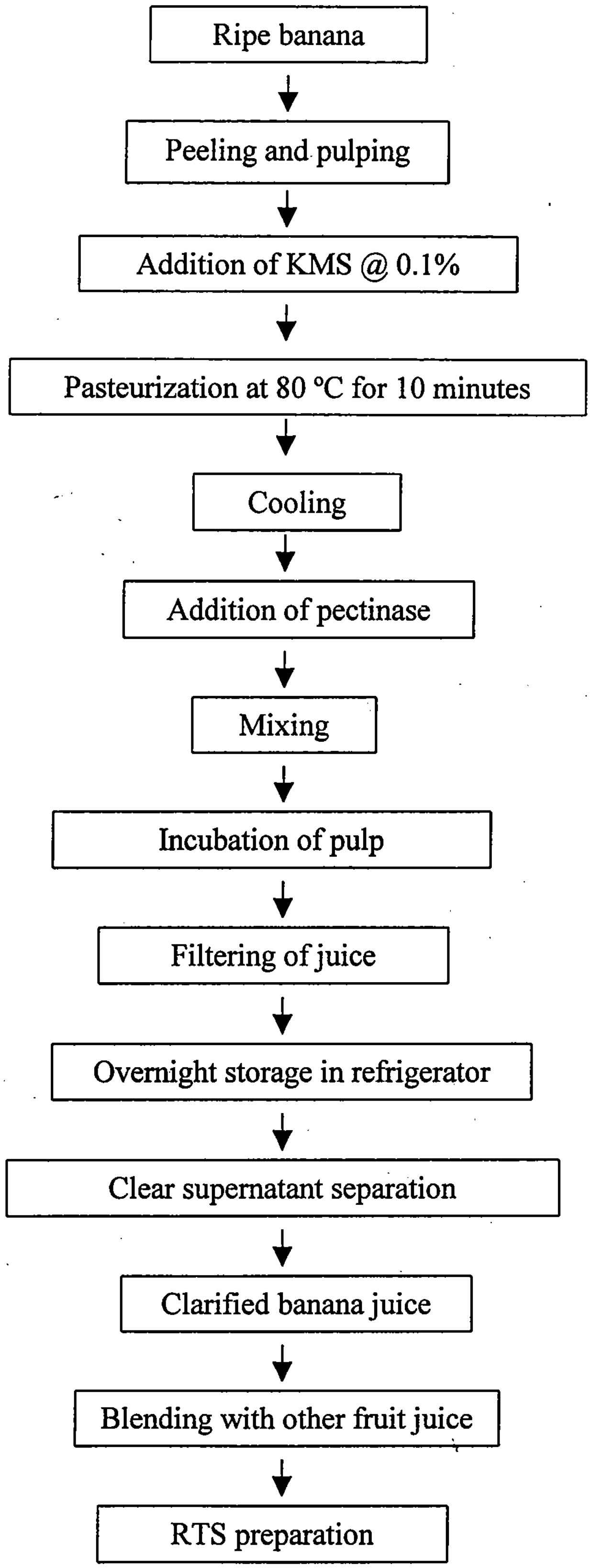
Ripe banana pulp

Commercial pectinase enzyme

Clarified banana juice

Plate 7. Schematic representation of steps involved in banana juice extraction

Fig. 2. Enzymatic juice separation from banana pulp



3.2.2 Experiments on blending and bottling of banana juice

The best quality juice obtained from Experiment 3.2.1 was blended with juice of four other tropical fruits at various proportions. The blended juice was used for the preparation of Ready-To-Serve (RTS) beverage as per Fruit Products Order (FPO) standard with TSS of 15°Brix, acidity 0.18% and 15% fruit juice.

(a) Tropical fruit juices used for blending

i) Pineapple
ii) Mango
iii) Guava
iii) Mandarin Orange

(b) Blending proportions

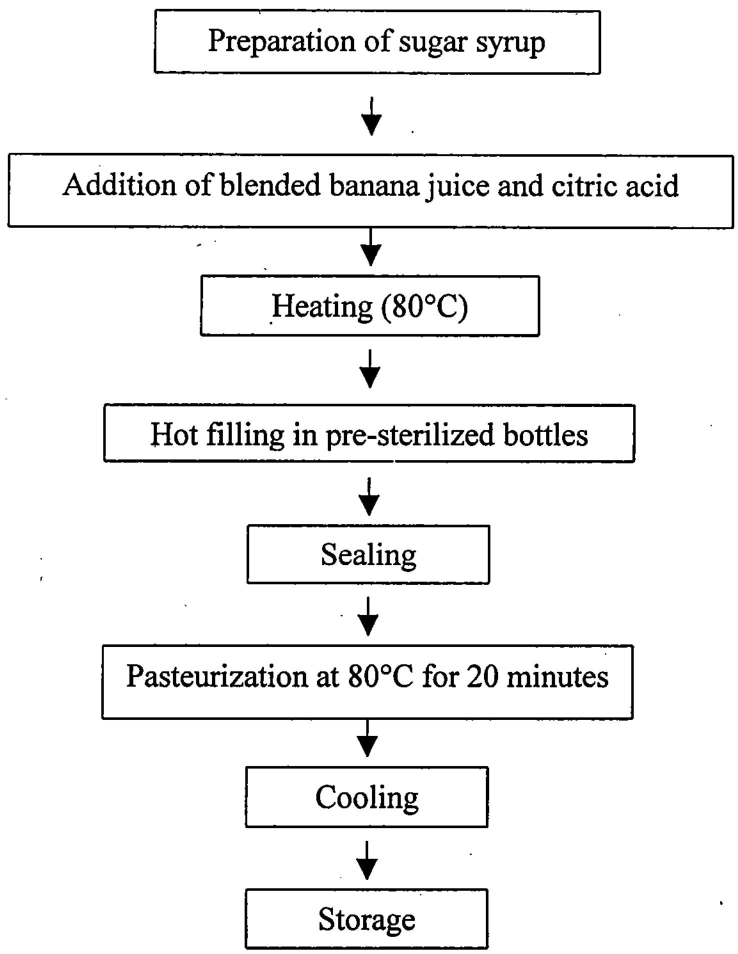
i) 50% banana juice + 50% other fruit juice
ii) 60% banana juice + 40% other fruit juice
iii) 75% banana juice + 25% other fruit juice
iv) 100% banana juice

The best blending proportion of banana juice with other fruit juices were further screened and the best blend was selected for bottling and storage under ambient conditions. Monthly observations were taken for six months.

(c) RTS preparation

Sugar was dissolved in required quantity of water and filtered to remove the impurities. The blended fruit juice and citric acid were mixed with the sugar syrup, heated to 80°C, hot filled in pre-sterilized bottles (200 ml capacity), sealed, pasteurized in boiling water for 20 minutes, cooled and stored at room temperature. The flow chart for RTS beverage preparation is given in Fig. 3.

Fig. 3. Preparation of RTS beverage from blended banana juice



3.2.3 OBSERVATIONS

3.2.3.1 Physical parameter

Juice recovery

The recovery of clear juice from enzyme treated banana pulp was calculated as follows:

$$\text{Juice recovery (\%)} = \frac{\text{Weight of clear juice}}{\text{Weight of enzyme treated fruit pulp}} \times 100$$

3.2.3.2 Chemical parameters

The TSS, pH, acidity, non-enzymatic browning (NEB), reducing and total sugars were estimated as per methods described under 3.1.3.2.

Cloud index

Cloud index of the RTS beverage indicating the colour stability was measured by taking the absorbance at 660 nm (Huggart *et al*., 1951).

3.2.4 Organoleptic evaluation

Organoleptic scores for colour, flavour, consistency, taste and overall acceptability of the chilled RTS juice were recorded as per the method described under 3.1.4. The score card for banana RTS beverage is given in Appendix-III.

3.2.5 Cost of production

Economics of production of 100 bottles of banana-mango RTS and mango RTS were worked out as per methods described under 3.1.5.

3.3 ENUMERATION OF FUNGUS AND BACTERIA

The quantitative assay of the microflora was carried out by serial dilution with Ringer's solutions and pour plate technique. Nutrient agar medium and potato dextrose agar medium were used for the enumeration of bacterial and fungal population respectively in the banana powder/RTS samples (Ranganna, 1995).

$$\text{No. of colony forming units (cfu) per gram of the sample} = \frac{\text{Mean number of cfu} \times \text{Dilution factor}}{\text{Weight of the sample in grams}}$$

3.4 STATISTICAL ANALYSIS

Data were analysed using M-Stat statistical software and subjected to analysis of variance at five per cent level of significance following Factorial Completely Randomized Design (Panse and Sukhatme, 1976). Comparison between spray dried and drum dried banana powder was done using two sample case 't' test. Significant differences between the means were estimated using Duncan's Multiple Range Test (DMRT).

Results

4. RESULTS

Various experiments were conducted to develop a juice-based beverage and ripe fruit powder from banana, the results of which are presented under the following two major headings viz.

1. Development of technology for ripe banana powder
2. Development of technology for banana juice based beverage

4.1 Development of technology for ripe banana powder

Experiments were conducted using spray, drum and cabinet driers to standardize the technology for production of ripe banana powder and the results are presented below. In all the drying experiments, deseeded ripe Robusta pulp was used, the average recovery of which was 57.5 per cent.

4.1.1 Experiments on spray drying

The inlet air temperature of the spray drier and the proportion of additives viz. maltodextrin and soluble starch added to the ripe banana pulp were varied to standardize the technology for producing spray dried banana powder (SDBP). In all the experiments, the outlet air temperature of the spray drier was kept at 100°C.

4.1.1.1 Effect of inlet air temperature

Table 4.1 shows the effect of inlet air temperature of spray drier on drying characteristics of banana pulp. At inlet air temperature of 180°C, the product was charred and removal of the powder was difficult. The product was free flowing with better recovery percentage at inlet temperatures of 160°C and 150°C. However, at inlet temperature of 140°C, the product was sticky with incomplete drying. Hence it was inferred that the ideal inlet air temperature was 150°C and for further spray drying experiments, 150°C inlet air temperature was maintained.

Table 4.1. Effect of inlet air temperature on spray dried banana powder

Treatment No.	Inlet air temperature °C	Product characteristics	Powder recovery (%) (Solid basis)	Remarks on drying characteristics
T_1	180	Charred	25.7^c	The dried powder was sticking firmly to the chamber, removal of powder was difficult
T_2	160	Free flowing	47.4^b	Complete drying but charred flavour
T_3	150	Free flowing	51.5^a	Complete drying with better flavour
T_4	140	Sticky	15.8^d	In complete drying, part of the pulp was remaining as such in the drying chamber

Values with different superscripts differ significantly at 5% level

4.1.1.2 Effect of additive proportions

The proportion of additives viz. maltodextrin and soluble starch added to the ripe Robusta pulp were varied maintaining the inlet air temperature at 150°C and outlet air temperature at 100°C in the spray drier. Table 4.2 gives the effect of additive proportions on quality of spray dried banana powder.

Table 4.2. Effect of additive proportions on quality of spray dried banana powder

Treatment No.	Maltodextrin to soluble starch (wet basis)	Product quality		
		Colour	Flavour	Flowability
A_1	5 : 0	Light brown	Charred	Good
A_2	0 : 5	Light brown	Charred	Slightly sticky
A_3	2.5 : 2.5	Light brown	Fruity	Good
A_4	3 : 2	Light brown	Fruity	Good
A_5	2 : 3	Off white	Banana like	Good

The five per cent additive on wet basis used in the present study corresponds to 25 per cent additive on solid basis. Among the various maltodextrin to soluble starch proportions, the proportion 2:3 (A_5) gave the best product quality with respect to colour, flavour and flowability.

The results of organoleptic evaluation of spray dried banana powder with varied additive proportions presented in Table 4.3 revealed that the proportion 2:3 (A_5) ranked best for all the quality parameters viz. colour, flavour, texture and overall acceptability.

Table 4.3. Effect of additive proportions on organoleptic quality of spray dried banana powder

Treatments	Sensory scores			
	Colour	Flavour	Texture	Overall acceptability
A_1	3.88^{b}	3.75^{b}	3.88^{ab}	3.83^{b}
A_2	3.63^{b}	3.75^{b}	3.13^{c}	3.50^{c}
A_3	3.88^{b}	3.75^{b}	3.88^{ab}	3.83^{b}
A_4	3.88^{b}	3.75^{b}	3.75^{b}	3.79^{b}
A_5	4.38^{a}	4.13^{a}	4.25^{a}	4.25^{a}

Values with different superscripts differ significantly at 5% level

4.1.2 Experiments on drum drying

The percentage of soluble starch added to the ripe Robusta pulp was varied maintaining the steam pressure at four bar (152°C) and drum speed at three revolutions per minute (rpm). Table 4.4 gives the effect of additive levels on quality of drum dried banana flakes. Treatment with 2.5 per cent soluble starch (T_4) gave the best quality flakes with respect to colour, flavour, moisture (1.19%) and recovery percentage (80.5%). When soluble starch was used at less than 2.5 per cent, the flakes obtained were moist, dark brown coloured, with charred flavour and the recovery was less.

Table 4.4. Effect of additive levels on the quality of drum dried banana flakes

Treat ment	% Soluble starch (Wet basis)	Flake characters			Remarks on dried flakes		
		Moisture (%)	NEB (OD at 420 nm)	Powder recovery % (Dry basis)	Colour	Flavour	Texture
T_1	1.0	3.20^a	0.563^a	60.4^c	Dark brown	Charred	Flexible
T_2	1.5	2.86^b	0.520^a	60.9^c	Dark brown	Charred	Slightly flexible
T_3	2.0	2.55^b	0.453^b	71.3^b	Dark brown	Fruity	Slightly flexible
T_4	2.5	1.19^c	0.360^c	80.5^a	Light brown	Banana like	Crisp
T_5	3.0	1.17^c	0.368^c	81.0^a	Light brown	Fruity	Crisp

Values with different superscripts differ significantly at 5% level

The organoleptic scores of drum dried banana powder with varied additive levels given in Table 4.5 indicated that powder obtained with 2.5 per cent soluble starch was judged best by the panel.

Table 4.5. Effect of additive levels on organoleptic quality of drum dried banana powder

Treatments	Sensory scores			
	Colour	Flavour	Texture	Overall acceptability
T_1	2.75^d	2.25^c	2.13^e	2.38^e
T_2	3.13^c	2.75^c	2.75^d	2.87^d
T_3	3.38^c	3.50^b	3.25^c	3.38^e
T_4	4.63^a	4.38^a	4.50^a	4.50^a
T_5	4.00^b	4.13^a	4.10^b	4.00^b

Values with different superscripts differ significantly at 5% level

4.1.3 Experiments on cabinet drying

Experiments were conducted with varied drying temperatures and additive levels to standardize technology for production of cabinet dried ripe banana powder.

4.1.3.1 Effect of drying temperature

The Robusta pulp without additive was dried in a cabinet drier at 60°C, 70°C, 80°C and 90°C. The effect of drying temperature is given in Table 4.6. Though the drying time decreased with increasing drying temperature, the dried product remained as a flexible sheet that could not be powdered. Therefore, it is inferred that ripe banana pulp seems difficult to be dried and powdered using an ordinary cabinet drier.

Table 4.6. Effect of drying temperature on cabinet drying of banana pulp

Sl. No.	Drying temperature (°C)	Drying time (hours)	Product moisture (%)	Remarks on dried product
1	60	32	7.5	Flexible, non-crispy sheet and could not be powdered
2	70	28	7.2	"
3	80	24	7.2	"
4.	90	21	7.0	"

Values are the average of three replications

4.1.3.2 Effect of additive levels

Varied levels of soluble starch were added to ripe Robusta pulp and dried at 80°C. The result given in Table 4.7 revealed that immaterial of the levels of soluble starch added, the Robusta pulp could not be dried properly in a cabinet drier. The dried product resembled sticky fruit leather which could be rolled but not crisp enough to be powdered.

Table 4.7. Effect of additive levels on cabinet drying of banana pulp

Treatment No.	% Soluble starch	Drying time (hours)	Product moisture (%)	Remarks on dried product
T_1	0	24	7.2	Flexible, non-crispy sheet and could not be powdered
T_2	1	22	7.0	”
T_3	2	22	7.0	”
T_4	3	20	6.9	”
T_5	4	20	6.8	“
T_6	5	19	6.8	“

Values are the average of three replications

4.1.4 Comparison of spray dried and drum dried banana powder

In order to find the best drying technology to obtain quality banana powder, the physico-chemical, organoleptic characters and cost of production of spray and drum dried banana powder were compared.

4.1.4.1 Physical characteristics

The physical characteristics of drum and spray dried banana powder are given in Table 4.8.

Moisture

The spray dried and drum dried banana powder possessed moisture content of 1.09 per cent and 1.19 per cent respectively which did not differ significantly.

Bulk density (BD), Average particle density (APD) and Percentage volume occupied by powder particles (PVPP)

The bulk density of drum dried (0.72 g ml^{-1}) and spray dried (0.70 g ml^{-1}) banana powder did not differ significantly. Similarly, the APD and PVPP of the drum dried and spray dried powder were on par with each other indicating the physical similarity of the powders.

Solubility

The spray and drum dried powder recorded values of 92.4 per cent and 89.80 per cent respectively for solubility and were on par to each other. Higher the solubility better is the product as it is one of the characteristic features for instant powders.

Table 4.8. Physical characteristics of drum and spray dried banana powder

Characters		**Drum dried**	**Spray dried**
Moisture (%)		1.19	1.09
Bulk density (g ml^{-1})		0.72	0.70
Average particle density (g ml^{-1})		1.54	1.42
% Volume occupied by powder particles		48.08	46.92
Solubility (%)		89.80	92.40
Soluble solids (%)		70.53	74.65
Dispersed solids (%)		24.47	22.35
Dispersibility (%)		96.23	98.64
Sinkability (% T)	2 min	96.60	95.40
	4 min	97.40	96.80
	6 min	98.00	97.20
Powder recovery ((%)	Dry basis	82.00^a	51.00^b
	Wet basis	20.4^a	12.8^b
Additive (%)	Dry basis	12.5^b	25.0^a
	Wet basis	2.5^b	5.0^a
Rehydration ratio		4.67	4.85

Values with different superscripts differ significantly at 5% level

Soluble solids and dispersed solids

No significant difference existed between the spray and drum dried banana powder. The values for soluble solids were 70.53 per cent and 74.65 per cent while that for dispersed solids were 24.47 per cent and 22.55 per cent respectively for drum and spray dried banana powder.

Dispersibility

No significant difference was noticed in dispersibility between the spray dried (98.64%) and drum dried (96.23%) banana powder. It was observed that both powders recorded a higher dispersibility values which is an indication of least sedimentation.

Sinkability

Sinkability, an index of sedimentation rate was on par for drum dried and spray dried banana powder. At 6th minute, the drum dried powder recorded sinkability value of 98 while the spray dried powder showed 97.2.

Powder recovery

The drum dried powder recorded the highest powder recovery of 20.4 per cent on wet basis and 82.0 per cent on dry basis compared to spray dried powder (12.8% on wet basis and 51.0% on dry basis). This indicated that the drying loss was lesser in drum drying process.

Additive level

The additive percentage in the finished products when worked out on dry basis was more in spray dried powder (25.0%) than in drum dried powder (12.5%). This indicated the presence of more banana solids in drum dried powder.

Rehydration ratio

No significant difference was observed in the rehydration ratios of the drum dried and spray dried powder which were 4.67 and 4.85 respectively.

4.1.4.2 Hunter colour values

The colour of the powders when estimated using Hunter lab colour measuring system revealed that spray dried product showed higher 'L' value (73.20) compared to drum dried powder (60.63). Higher 'L' value reflected the visual lightness of the spray dried powder compared to the darker drum dried powder (Table 4.9).

Table 4.9. Hunter colour values of drum and spray dried banana powder

Characters	Drum dried	Spray dried
Hunter value 'L'	60.63^{b}	73.20^{a}
Hunter value 'a'	5.45^{a}	0.64^{b}
Hunter value 'b'	15.96^{a}	10.75^{b}

Values with different superscripts differ significantly at 5% level

Spray dried powder recorded lower 'a' and 'b' hunter values compared to drum dried powder. Lower 'a' and 'b' hunter values indicated that the spray dried powder had lesser 'redness' and 'yellowness' respectively when compared to more intense red and yellow colour of drum dried powder. Visually, the spray dried powder was off-white in colour compared to the yellowish colour of drum dried powder. The hunter results corraborate well with the visual colour of the powders (Plate 8).

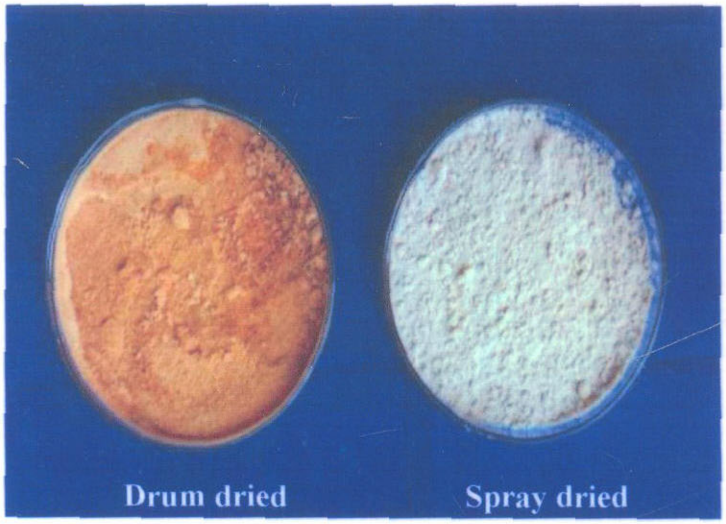
4.1.4.3 Micro structure

Micro structure of the powders when observed under scanning electron microscope revealed that spray dried particles possessed a slightly distorted spherical shape with few shallow depressions on the smooth surface. The diameter of the particles ranged from 11-35 µm. The drum dried particles appeared larger measuring 20-47 µm in diameter. They were elongated oblong particles with few protuberances on the rough surface. In both the powders, non-uniform distribution of the particles was observed and the particles remained in clusters (Plate 9).

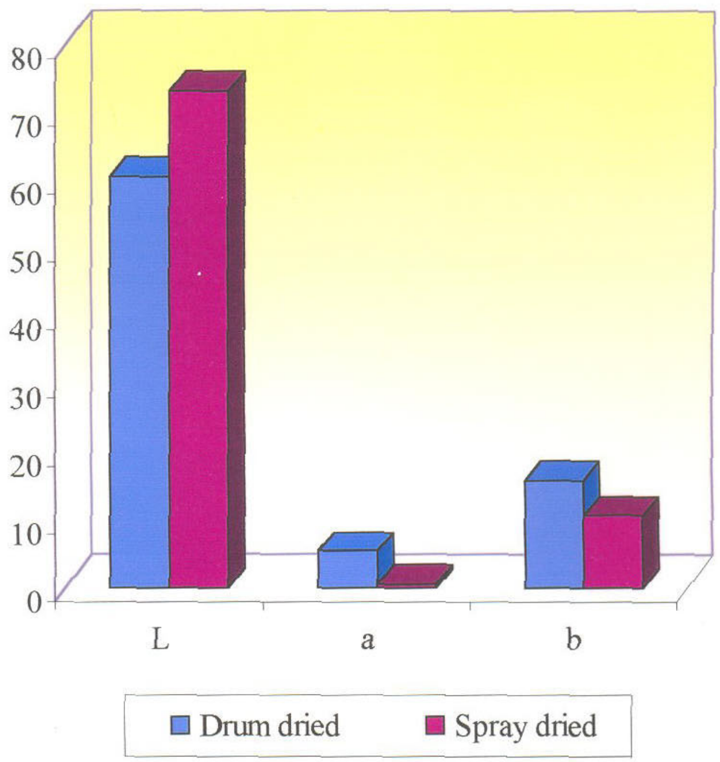
4.1.4.4 Moisture sorption behaviour

Drum dried banana powder

The moisture sorption behaviour of drum dried banana powder at ambient temperature on exposure to different relative humidities between 8 and 94 per cent is



a) Banana powder



b) Hunter colour values of banana powder

L - visual lightness; a - redness; b - yellowness

Plate 8. Banana powder - Colour comparison

Drum dried | **Spray dried**

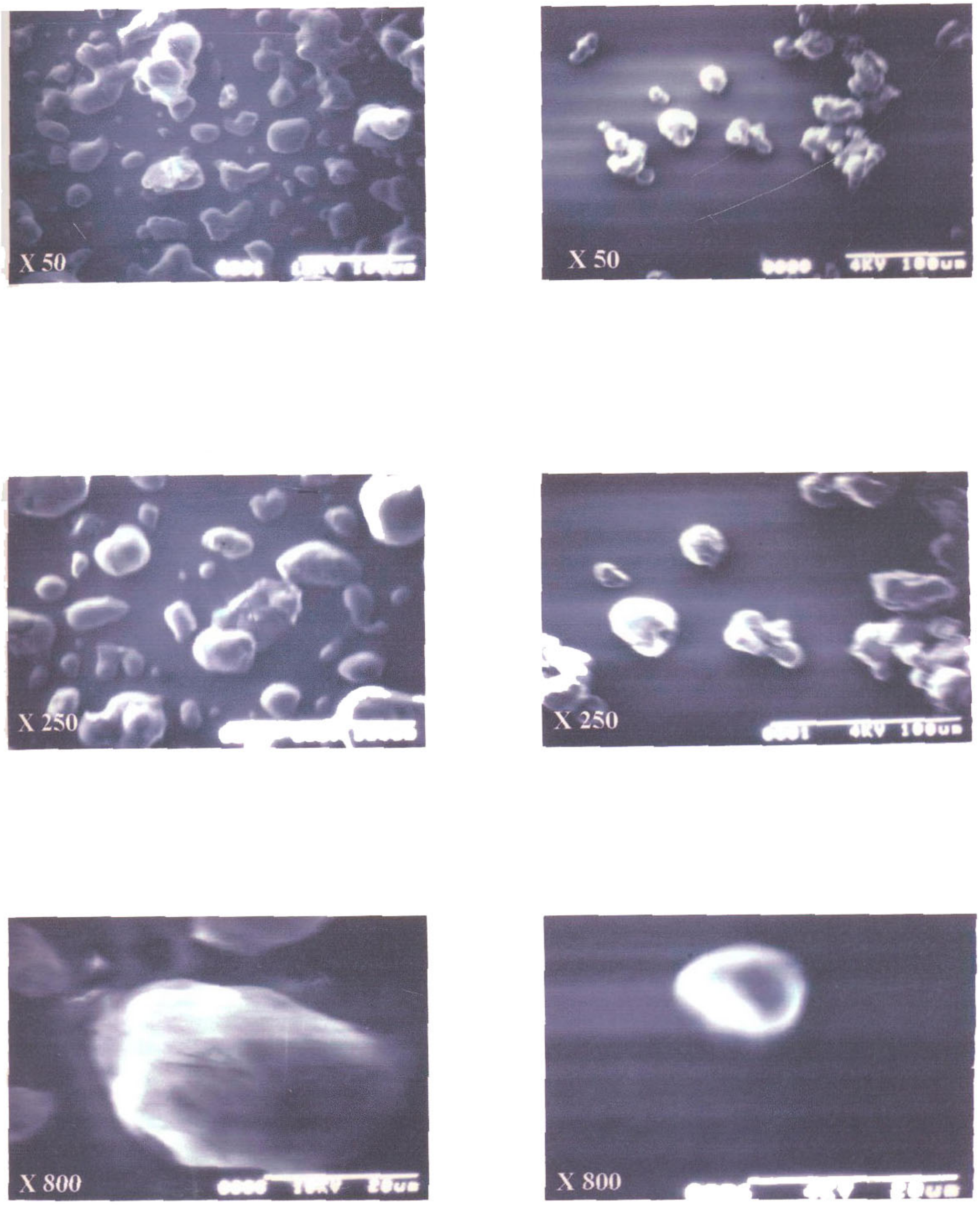
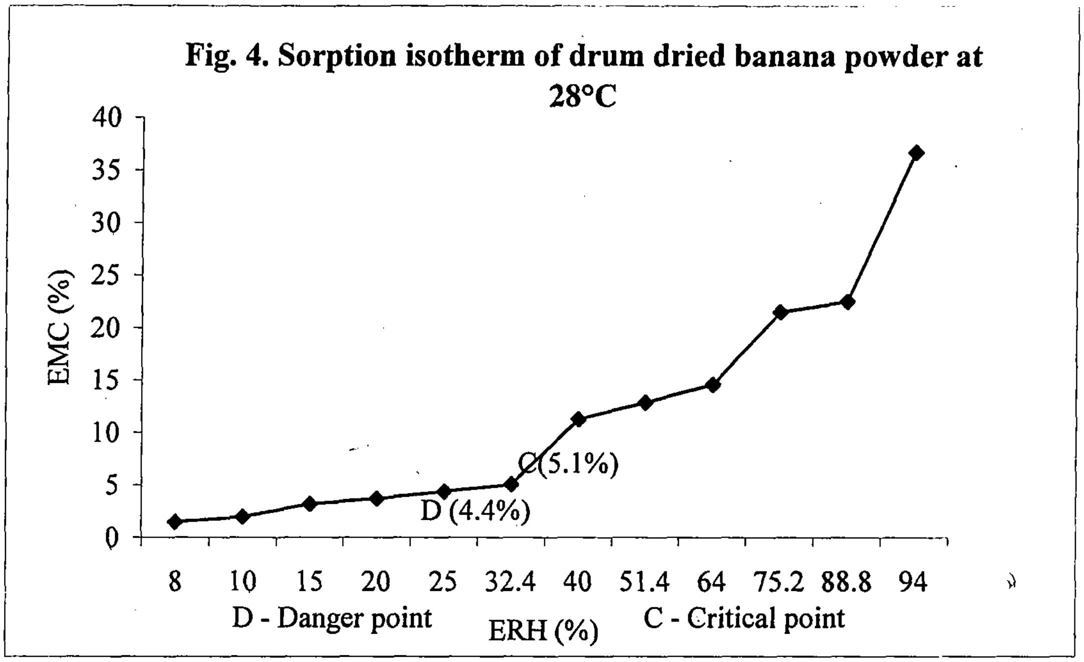


Plate 9. Microstructure of banana powder under different magnifications

given in Table 4.10. The product remained free flowing at less than 30 per cent relative humidity beyond which caking and colour deterioration were observed. Critical point (C), the stage at which product just becomes lumpy was found to be 5.10 per cent equilibrium moisture content (30% ERH) and danger point, the point which is five per cent lower ERH than critical point was found to be 4.40 per cent equilibrium moisture (25% ERH). The sorption isotherm showed a sigmoidal pattern (Fig. 4).

Table 4.10. Equilibrium Relative Humidity (ERH) data for drum-dried banana powder at room temperature (28°C)

Equilibrium Relative Humidity (ERH %)	Equilibrium Moisture Content (EMC %)	Physical observation
8	1.50	Product free flowing, colour and flavour not affected
10	2.01	”
15	3.22	”
20	3.75	”
25	4.40	”
32.4	5.37	Slight caking and colour change started after eight days
40	11.30	Slight caking started after five days and the colour turned to brownish
51.4	12.90	Fully caked, brown colour
64	14.67	Fully caked, deep brown colour, off-flavour developed
75.2	21.57	Fully caked, deep brown, wet mould appeared after 27 days
88.5	22.60	Fully caked, dark brown, wet, mould appeared after 20 days
94.0	36.80	Fully caked, blackish brown, wet, mould appeared after 11 days



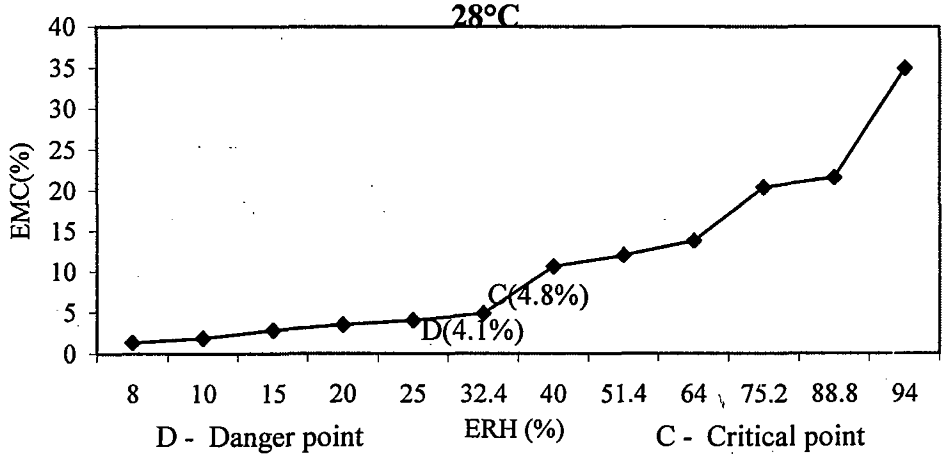
Spray dried banana powder

Equilibrium Relative Humidity (ERH) data for spray dried banana powder given in Table 4.11 indicated that the powder remained free flowing at less than 28 per cent relative humidity beyond which caking, colour and flavour deterioration and mould growth were witnessed. Equilibrium moisture curves showed that the critical point was at 28 per cent ERH pertaining to 4.8 per cent equilibrium moisture content and danger point was 23 per cent ERH pertaining to 4.1 per cent equilibrium moisture. A sigmoidal isotherm pattern was observed for the powder (Fig. 5).

Table 4.11. Equilibrium Relative Humidity (ERH) data for spray dried banana powder at room temperature (28°C)

Equilibrium Relative Humidity (ERH %)	Equilibrium Moisture Content (EMC %)	Physical observation
8	1.38	Product free flowing, colour and flavour not affected
10	1.90	”
15	2.85	”
20	3.52	”
25	4.28	”
32.4	5.10	Slight caking and colour charge started after four days
40	10.65	Fully caked, sticky and the colour formed to slightly brown
51.4	12.03	Fully caked, brown colour
64	13.83	Fully caked, deep brown colour, off flavour developed
75.2	20.42	Fully caked, deep brown, wet mould appeared after 13 days
88.5	21.61	Fully caked, dark brown, wet mould appeared after 10 days
94.0	34.97	Fully caked, blackish brown, wet, mould appeared after seven days

Fig. 5. Sorption isotherm of spray dried banana powder at 28°C



4.1.4.5 Chemical characteristics

The chemical characteristics of drum and spray dried powder are given in Table 4.12. The total soluble solids (TSS) and pH of the reconstituted powder were higher for drum dried powder compared to spray dried powder. The non-enzymatic browning of the spray dried product was lower (0.069) than that of drum dried product (0.360). The drum dried powder showed higher values for reducing sugars (24.68%), total sugars (55.37%), starch (22.17%) and crude fibre (2.22%) while the spray dried powder showed higher values for acidity (2.11%), protein (2.65%) and total ash (3.22%).

Table 4.12. Chemical characteristics of drum and spray dried banana powder

Characters	Drum dried	Spray dried
TSS (°Brix)	13.40[a]	11.93[b]
pH	4.843[a]	4.484[b]
Browning (OD at 420 nm)	0.360[a]	0.069[b]
Acidity (%)	1.95[b]	2.11[a]
Reducing sugar (%)	24.68[a]	18.91[b]
Total sugar (%)	55.37[a]	49.25[b]
Starch (%)	22.17[a]	17.21[b]
Protein (%)	2.18[b]	2.65[a]
Total ash (%)	2.62[b]	3.22[a]
Crude fibre (%)	2.22[a]	1.79[b]

Values with different superscripts differ significantly at 5% level

4.1.4.6 Gas chromatography - Mass spectrometry

GC-MS analysis

One microlitre of volatile extract when injected into a GC-MS gave the following aroma profile (Table 4.13) for fresh Robusta pulp, spray dried and drum dried banana powder. The compounds identified were predominantly alcohols and their esters (Fig. 6, 7 and 8).

Fig. 6. GC-MS of fresh ripe Robusta banana

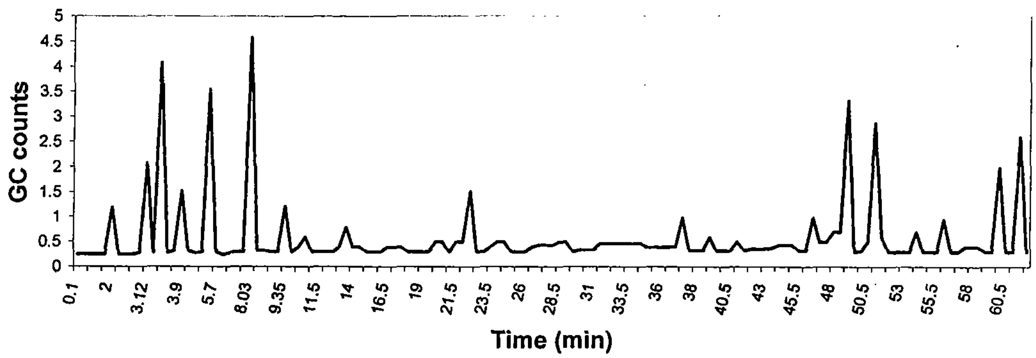


Fig. 7. GC-MS of Drum dried banana powder

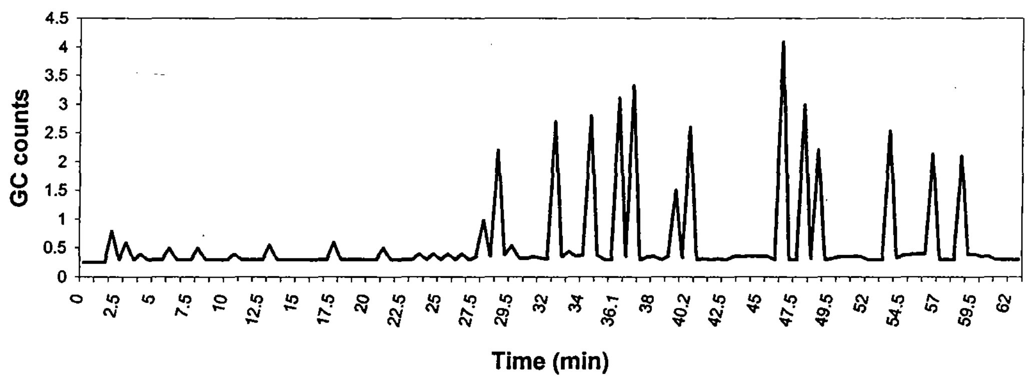


Fig. 8. GC-MS of Spray dried banana powder

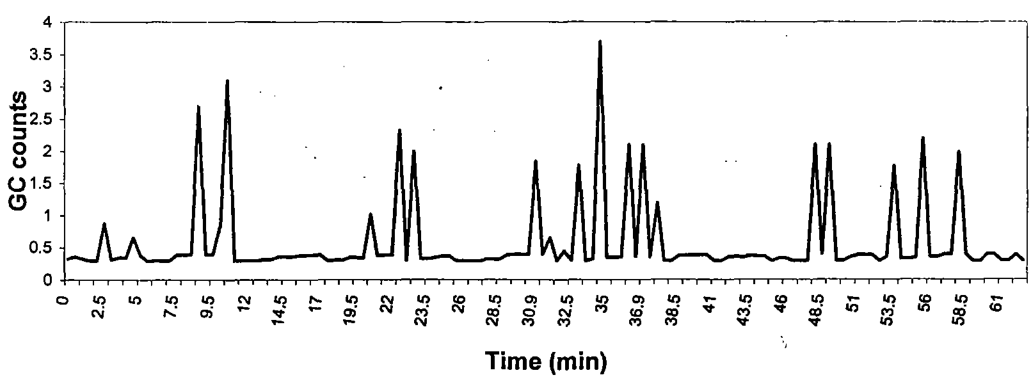


Table 4.13. Volatile compounds identified in fresh banana fruit, spray dried and drum dried banana powder

No	Compounds	Retention time (min)	Molecular weight	Product		
				Fresh fruit	Spray dried powder	Drum dried powder
1	2 pentanol	3.12	88.15	✓	x	x
2	3 hydroxy 2 butanone	3.27	88.11	✓	x	x
3	3 methyl 1 butanol	3.90	88.15	✓	x	x
4	Hexanal	5.54	100.16	✓	x	x
5	E2 hexenal	8.03	98.14	✓	x	x
6	Ethyl hexanoate	8.92	144.21	x	✓	x
7	Iso amyl acetate	9.35	130.18	✓	x	x
8	2 Heptanol	10.51	116.21	x	✓	x
9	Iso amyl butyrate	22.29	158.24	✓	✓	✓
10	Cyclohexanol	22.58	100.16	x	✓	x
11	Furfural	30.87	96.08	x	✓	x
12	Diethyl succinate	32.93	174.19	x	✓	✓
13	2 phenyl ethanol	34.50	122.16	x	✓	✓
14	Furaneol	36.10	160.10	x	✓	✓
15	Ethyl cinnamate	36.85	176.21	x	✓	✓

✓ - detected
x - not detected≠

Isoamyl butyrate was the only common compound detected in all the samples viz. fresh fruit, spray and drum dried banana powder. Except isoamyl butyrate, none of the compounds detected in fresh fruit were found in spray or drum dried powder indicating that fresh banana aroma was lost during the drying process and some other compounds formed during the dehydration process were responsible for the flavour. These compounds like diethyl succinate, 2 phenyl ethanol, Furaneol and ethyl cinnamate detected in both spray and drum dried powder were responsible for the caramelised fruity odour of the powders. Cyclohexanol and furfural detected in spray dried powder were not detected in drum dried powder.

About nine aroma compounds were detected in spray dried powder while only five were detected in drum dried powder indicating the higher flavour recovery in spray drying process. The molecular weight of detected compounds was in the range of 88-158 in fresh banana, 116-176 in spray dried powder and 174-176 in drum dried powder. Higher molecular weight aroma compounds with higher boiling points were detected in spray and drum dried powder compared to fresh banana.

4.1.4.7 Organoleptic evaluation

Organoleptic characters of drum dried and spray dried banana powder given in Table 4.14 indicated that except for colour, the spray and drum dried powder were on par with each other. Colour wise, spray dried powder rated superior though the overall acceptability was same.

Table 4.14. Organoleptic characters of drum and spray dried banana powder

Characters	Drum dried	Spray dried
Colour	4.17[b]	4.83[a]
Flavour	4.65	4.67
Texture	4.70	4.83
Overall acceptability	4.70	4.78

Values with different superscripts differ significantly at 5% level

4.1.4.8 Cost of production

The cost of production for 100 grams of spray and drum dried banana powder worked out to be Rs.26.61 and Rs.18.66 respectively (Table 4.15). Among the different components of total cost, raw material alone accounted for 70.35 per cent and 62.29 per cent of total cost of spray and drum dried powder respectively. The cost of production was 42.6 per cent higher for spray dried powder compared to drum dried powder.

Table 4.16 shows the cost of raw material for the production of 5 kg spray and drum dried banana powder. The cost of raw material was 67.7 per cent higher for spray dried powder (Rs.906.00) compared to drum dried powder (Rs.540.12).

Table 4.15. Comparative cost of production of spray and drum dried banana powder

Sl. No.	Item	Spray dried (Rs.)	Drum dried (Rs.)
1	Working capital (for 5 kg banana powder)		
	a) Raw material	906.00	540.12
	b) Fuel	186.00	177.00
	c) Labour	150.00	150.00
	Total	1242.00	867.12
2	Interest on working capital @ 12%	0.41	0.29
3	Depreciation of machineries @ 10%	20.67	10.40
4	Interest on fixed cost @ 12%	24.81	12.47
5	Cost of production of 5 kg banana powder	1287.89	890.28
6	Cost of 100 gram banana powder	25.76	17.81
7	Cost of packaging	0.85	0.85
8	Cost of unit pack (100 g)	26.61	18.66

Table 4.16. Cost of raw material for the production of 5 kg spray and drum dried banana powder

Drying method	Raw material	Quantity for 5 kg powder (kg)	Rate (Rs./kg)	Cost	
				(Rs.)	(%)
Spray drying	Robusta	68.00	12.00	816.00	90.07
	Additives	2.00	45.00	90.00	9.93
			Total	906.00	100.00
Drum drying	Robusta	42.61	12.00	511.32	94.67
	Additives	0.64	45.00	28.80	5.33
			Total	540.12	100.00

4.1.5 Storage studies

The drum dried and spray dried banana powder were packed in two types of packaging material viz. metallised polyester pouches and aluminium foil laminated pouches with four methods of packaging viz. nitrogen, carbon-di-oxide, vacuum and air (control). The physical, chemical and microbial changes during storage of banana powder under ambient conditions are presented hereunder.

4.1.5.1 Effect of packaging material on shelf-life of banana powder

The packaging material showed a pronounced effect on the shelf life of drum and spray dried banana powder (Table 4.17). Irrespective of the drying method and packaging technique, banana powder packed in aluminium foil laminated pouches showed a shelf-life of more than a year while those packed in metallised polyester laminated pouches could be stored only for three months under ambient conditions (26-30°C). Aluminium foil packed powders remained free flowing with minimum browning even after one year while the metallised polyester packed powders showed caking, discolouration and loss of flavour beyond three months of storage under ambient conditions (Plate 10 and 11). Therefore, it is confirmed that aluminium foil laminated pouches are needed for such hygroscopic product.

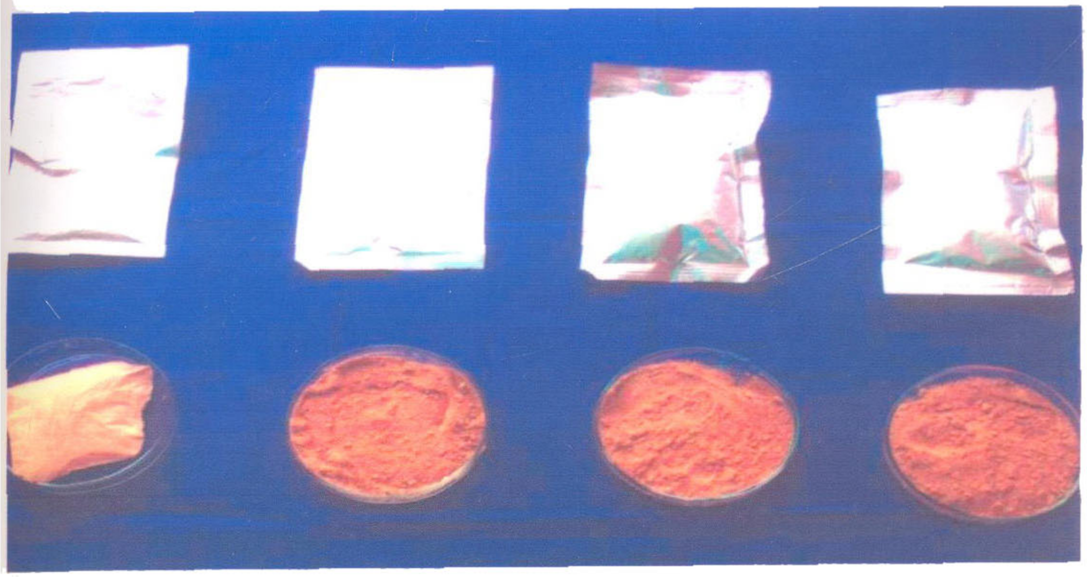
Table 4.17. Effect of packaging material on shelf life of banana powder at room temperature

Packaging material	Banana powder	Shelf life	Observations at the end of shelf-life
Metallised polyester pouches	Drum dried	3 months	Caked and discoloured
	Spray dried	3 months	Caked and discoloured
Aluminium foil laminated pouches	Drum dried	12 months	Free flowing with minimum loss of colour and flavour
	Spray dried	12 months	Free flowing with minimum loss of colour and flavour

4.1.5.2 Effect of packaging methods on quality of drum and spray dried banana powder during storage

The changes in physico-chemical characters, hunter colour values, microbial status and organoleptic characters during storage of banana powder are presented hereunder.

Vacuum pack | Air pack | CO_2 pack | Nitrogen pack



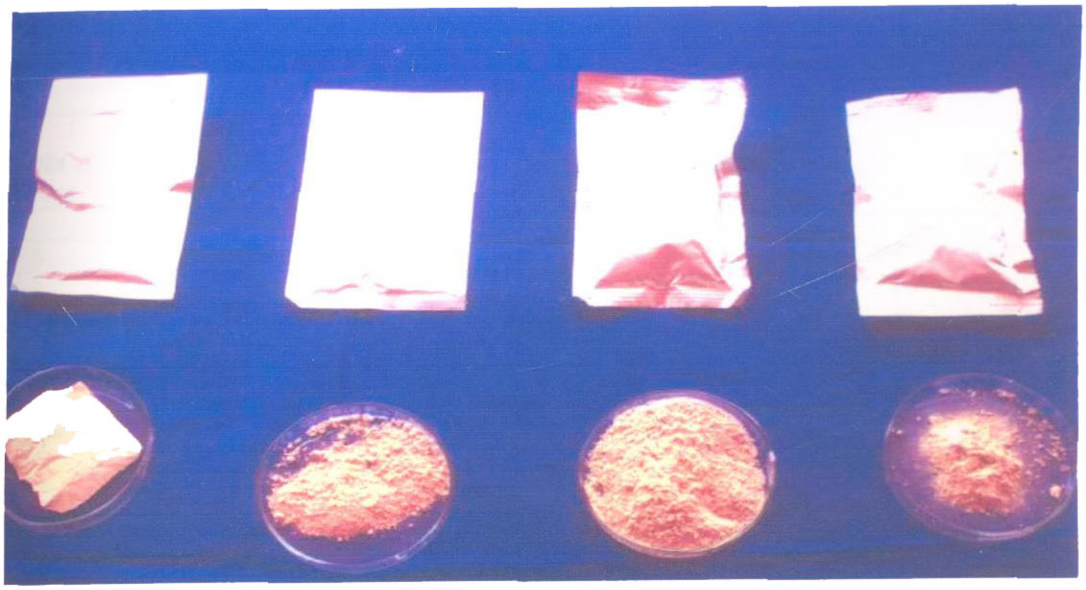
a) In aluminium foil laminated packs after 12 months of storage showing free flowing nature

Vacuum pack | Air pack | CO_2 pack | Nitrogen pack

b) In metallised polyester packs after three months of storage showing caking

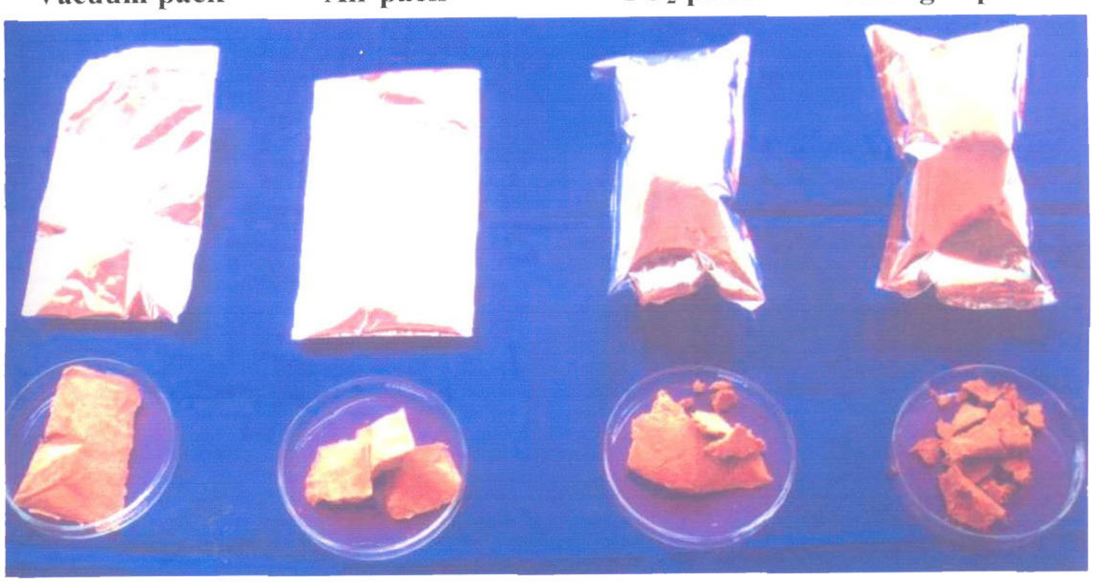
Plate 10. Packaged drum dried banana powder after storage

Vacuum pack Air pack CO_2 pack Nitrogen pack



a) In aluminium foil laminated packs after 12 months of storage showing free flowing nature

Vacuum pack Air pack CO_2 pack Nitrogen pack



b) In metallised polyester packs after three months of storage showing caking

Plate 11. Packaged spray dried banana powder after storage

Table 4.18. Physico-chemical changes during storage of drum dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Moisture (%)					
0	1.19^{NS}	1.19^{NS}	1.19^{NS}	1.19^{NS}	1.19^{e}
2	1.33^{NS}	1.30^{NS}	1.25^{NS}	1.22^{NS}	1.28^{de}
4	1.47^{NS}	1.42^{NS}	1.25^{NS}	1.22^{NS}	1.34^{cd}
6	1.52^{NS}	1.49^{NS}	1.27^{NS}	1.22^{NS}	1.38^{bcd}
8	1.68^{NS}	1.55^{NS}	1.27^{NS}	1.23^{NS}	1.43^{abc}
10	1.71^{NS}	1.60^{NS}	1.28^{NS}	1.23^{NS}	1.48^{ab}
12	1.81^{NS}	1.66^{NS}	1.30^{NS}	1.24^{NS}	1.50^{a}
Mean	1.53^{A}	1.46^{A}	1.26^{B}	1.22^{B}	
Non-enzymatic browning(OD at 420 nm)					
0	0.360^{i}	0.360^{i}	0.360^{i}	0.360^{i}	0.360^{e}
2	0.39^{ghi}	0.367^{hi}	0.360^{i}	0.360^{i}	0.371^{de}
4	0.424^{fgh}	0.418^{fghi}	0.385^{ghi}	0.360^{i}	0.397^{d}
6	0.532^{d}	0.524^{de}	0.402^{ghi}	0.385^{ghi}	0.461^{c}
8	0.682^{b}	0.585^{c}	0.444^{fg}	0.402^{ghi}	0.528^{b}
10	0.715^{ab}	0.603_{c}	0.467^{f}	0.421^{fgh}	0.552^{ab}
12	0.764^{a}	0.611^{c}	0.476^{ef}	0.444^{fg}	0.574^{a}
Mean	0.554^{A}	0.496^{B}	0.413^{C}	0.390^{D}	
Acidity (%)					
0	1.95^{NS}	1.95^{NS}	1.95^{NS}	1.95^{NS}	1.95^{a}
2	1.82^{NS}	1.85^{NS}	1.90^{NS}	1.80^{NS}	1.84^{b}
4	1.75^{NS}	1.82^{NS}	1.87^{NS}	1.71^{NS}	1.79^{bc}
6	1.70^{NS}	1.75^{NS}	1.80^{NS}	1.67^{NS}	1.73^{cd}
8	1.63^{NS}	1.68^{NS}	1.73^{NS}	1.55^{NS}	1.65^{d}
10	1.52^{NS}	1.60^{NS}	1.70^{NS}	1.28^{NS}	1.53^{e}
12	1.47^{NS}	1.54^{NS}	1.65^{NS}	1.20^{NS}	1.47^{e}
Mean	1.69^{B}	1.74^{AB}	1.80^{A}	1.59^{C}	
Reducing sugar (%)					
0	24.68^{n}	24.68^{n}	24.68^{n}	24.68^{n}	24.68^{g}
2	24.71^{n}	24.68^{n}	25.24^{kl}	24.93^{mn}	24.89^{f}
4	25.44^{jk}	25.11^{lm}	26.12^{g}	25.85^{hi}	25.63^{e}
6	25.93^{gh}	25.62^{ij}	26.98^{e}	26.12^{g}	26.16^{d}
8	26.88^{e}	26.08^{gh}	27.83^{d}	27.03^{e}	26.95^{c}
10	27.91^{d}	26.54^{f}	28.62^{b}	28.19^{c}	27.82^{b}
12	28.33^{c}	26.82^{e}	29.04^{a}	28.90^{a}	28.27^{a}
Mean	26.27^{C}	26.65^{D}	26.93^{A}	26.53^{B}	
Total sugar (%)					
0	55.37^{n}	55.37^{n}	55.37^{n}	55.37^{n}	55.37^{g}
2	56.55^{m}	56.97^{m}	57.12^{lm}	56.83^{m}	56.87^{f}
4	57.63^{kl}	58.25^{ij}	58.63^{hi}	58.07^{jk}	58.16^{e}
6	58.65^{hi}	59.03^{gh}	59.34^{g}	58.98^{gh}	59.00^{d}
8	59.07^{gh}	60.25^{f}	60.83^{e}	60.02^{f}	60.04^{c}
10	59.10^{gh}	61.33^{de}	61.84^{cd}	60.99^{e}	60.82^{b}
12	59.13^{gh}	62.41^{b}	62.99^{a}	61.98^{bc}	61.63^{a}
Mean	57.93^{C}	59.09^{B}	59.45^{A}	58.89^{B}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.19. Physico-chemical changes during storage of drum dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Moisture (%)					
0	1.19^{l}	1.19^{l}	1.19^{l}	1.19^{l}	1.19^{d}
1	4.04^{g}	3.94^{h}	3.74^{i}	2.36^{k}	3.52^{c}
2	5.75^{c}	5.11^{e}	4.95^{f}	3.12^{j}	4.73^{b}
3	6.59^{a}	5.85^{b}	5.62^{d}	3.82^{i}	5.47^{a}
Mean	4.39^{A}	4.03^{B}	3.88^{C}	2.62^{D}	
Non-enzymatic browning(OD at 420 nm)					
0	0.360^{j}	0.360^{j}	0.360^{j}	0.360^{j}	0.360^{d}
1	0.486^{f}	0.462^{g}	0.432^{h}	0.409^{i}	0.447^{c}
2	0.573^{c}	0.550^{d}	0.522^{e}	0.513^{e}	0.540^{b}
3	0.619^{a}	0.592^{b}	0.577^{bc}	0.565^{cd}	0.588^{a}
Mean	0.510^{A}	0.491^{B}	0.473^{C}	0.462^{D}	
Acidity (%)					
0	1.95^{a}	1.95^{a}	1.95^{a}	1.95^{a}	1.95^{a}
1	1.80^{bcd}	1.85^{abc}	1.90^{ab}	1.78^{bcd}	1.83^{b}
2	1.68^{de}	1.80^{bcd}	1.86^{abc}	1.63^{ef}	1.74^{c}
3	1.55^{fg}	1.73^{cde}	1.81^{bcd}	1.47^{g}	1.64^{d}
Mean	1.74^{B}	1.83^{A}	1.88^{A}	1.71^{B}	
Reducing sugar (%)					
0	24.68^{g}	24.68^{g}	24.68^{g}	24.68^{g}	24.68^{d}
1	24.97^{ef}	24.75^{fg}	25.61^{d}	25.20^{e}	25.13^{c}
2	25.01^{ef}	24.98^{ef}	26.52^{b}	25.94^{c}	25.61^{b}
3	25.17^{e}	25.11^{e}	27.05^{a}	26.57^{b}	25.95^{a}
Mean	24.96^{C}	24.88^{C}	25.97^{A}	25.57^{B}	
Total sugar (%)					
0	55.37^{j}	55.37^{j}	55.37^{j}	55.37^{j}	55.37^{d}
1	55.81^{i}	56.81^{e}	56.95^{e}	56.63^{f}	56.58^{c}
2	56.25^{h}	57.50^{c}	57.63^{c}	57.14^{d}	57.13^{b}
3	56.43^{g}	58.36^{b}	58.87^{a}	57.62^{c}	57.82^{a}
Mean	55.99^{D}	57.01^{B}	57.21^{A}	56.68^{C}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.20. Physico-chemical changes during storage of spray dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Moisture (%)					
0	1.09^{l}	1.09^{l}	1.09^{l}	1.09^{l}	1.09^{g}
2	1.53^{hi}	1.33^{jk}	1.28^{k}	1.18^{kl}	1.33^{f}
4	1.71^{gh}	1.65^{ghi}	1.50^{ij}	1.32^{jk}	1.55^{e}
6	1.95^{de}	1.83^{efg}	1.75^{fg}	1.64^{ghi}	1.79^{d}
8	2.10^{bcd}	2.06^{cd}	1.93^{def}	1.81^{efg}	1.98^{c}
10	2.28^{ab}	2.18^{abc}	2.10^{bcd}	2.08^{cd}	2.16^{b}
12	2.34^{a}	2.29^{ab}	2.22^{abc}	2.18^{abc}	2.26^{a}
Mean	1.86^{A}	1.78^{B}	1.70^{C}	1.62^{D}	
Non enzymatic browning(OD at 420 nm)					
0	0.069^{o}	0.069^{o}	0.069^{o}	0.069^{o}	0.069^{f}
2	0.099^{jkl}	0.081^{lmno}	0.073^{mno}	0.068^{o}	0.080^{e}
4	0.124^{gh}	0.113^{hij}	0.103^{ijk}	0.071^{no}	0.103^{d}
6	0.168^{d}	0.124^{gh}	0.109^{hij}	0.079^{mno}	0.120^{c}
8	0.095^{c}	0.136^{fg}	0.112^{hij}	0.085^{klmno}	0.132^{b}
10	0.220^{b}	0.149^{ef}	0.115^{hij}	0.088^{klmn}	0.132^{b}
12	0.238^{a}	0.156^{de}	0.118^{hi}	0.090^{klm}	0.150^{a}
Mean	0.159^{A}	0.118^{B}	0.100^{C}	0.079^{D}	
Acidity (%)					
0	2.11^{NS}	2.11^{NS}	2.11^{NS}	2.11^{NS}	2.11^{a}
2	2.05^{NS}	2.09^{NS}	2.11^{NS}	2.00^{NS}	2.06^{ab}
4	1.98^{NS}	2.03^{NS}	2.07^{NS}	1.85^{NS}	1.98^{b}
6	1.83^{NS}	1.92^{NS}	1.98^{NS}	1.72^{NS}	1.86^{c}
8	1.79^{NS}	1.85^{NS}	1.92^{NS}	1.68^{NS}	1.81^{c}
10	1.70^{NS}	1.63^{NS}	1.70^{NS}	1.60^{NS}	1.66^{d}
12	1.67^{NS}	1.72^{NS}	1.76^{NS}	1.58^{NS}	1.68^{d}
Mean	1.88^{B}	1.91^{AB}	1.95^{A}	1.79^{C}	
Reducing sugar (%)					
0	18.91^{NS}	18.19^{NS}	18.91^{NS}	18.91^{NS}	18.91^{e}
2	19.00^{NS}	18.95^{NS}	19.45^{NS}	19.01^{NS}	19.10^{e}
4	19.91^{NS}	19.83^{NS}	20.06^{NS}	19.97^{NS}	19.94^{d}
6	20.58^{NS}	20.45^{NS}	20.98^{NS}	20.63^{NS}	20.66^{c}
8	20.99^{NS}	20.88^{NS}	21.33^{NS}	21.07^{NS}	21.07^{b}
10	21.03^{NS}	20.95^{NS}	21.85^{NS}	21.22^{NS}	21.26^{ab}
12	21.26^{NS}	21.03^{NS}	22.08^{NS}	21.54^{NS}	21.48^{a}
Mean	20.24^{B}	20.14^{B}	20.67^{A}	20.34^{B}	
Total sugar (%)					
0	49.25^{m}	49.25^{m}	49.25^{m}	49.25^{m}	49.25^{g}
2	50.17^{l}	51.07^{k}	51.32^{k}	50.75^{k}	50.83^{f}
4	52.00^{j}	53.25^{i}	53.85^{gh}	52.25^{j}	52.84^{e}
6	53.50^{hi}	54.11^{gh}	54.91^{ef}	53.98^{gh}	54.13^{d}
8	54.06^{gh}	54.98^{ef}	55.58^{d}	54.21^{g}	54.71^{c}
10	54.25^{g}	55.61^{d}	56.91^{b}	54.97^{ef}	55.44^{b}
12	54.40^{fg}	56.33^{c}	57.87^{a}	55.16^{de}	55.94^{a}
Mean	52.52^{D}	53.51^{B}	54.24^{A}	52.94^{C}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.21. Physico-chemical changes during storage of spray dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Moisture (%)					
0	1.09^{i}	1.09^{i}	1.09^{i}	1.09^{i}	1.09^{d}
1	3.98^{f}	3.86^{f}	3.51^{g}	2.94^{h}	3.57^{c}
2	6.65^{b}	5.92^{c}	5.05^{d}	4.26^{e}	5.47^{b}
3	7.33^{a}	6.65^{b}	5.99^{c}	5.15^{d}	6.28^{a}
Mean	4.76^{A}	4.38^{B}	3.91^{C}	3.36^{D}	
Non-enzymatic browning(OD at 420 nm)					
0	0.069^{g}	0.069^{g}	0.069^{g}	0.069^{g}	0.069^{d}
1	0.120^{ef}	0.099^{ef}	0.092^{f}	0.087^{f}	0.095^{c}
2	0.158^{b}	0.133^{c}	0.115^{de}	0.099^{ef}	0.126^{b}
3	0.197^{a}	0.160^{b}	0.143^{bc}	0.130^{cd}	0.157^{a}
Mean	0.131^{A}	0.115^{B}	0.105^{C}	0.096^{C}	
Acidity (%)					
0	2.11^{a}	2.11^{a}	2.11^{a}	2.11^{a}	2.11^{a}
1	1.98^{bc}	2.01^{b}	2.03^{b}	1.91^{cd}	1.98^{b}
2	1.85^{d}	1.87^{d}	1.92^{cd}	1.75^{e}	1.85^{c}
3	1.60^{f}	1.61^{f}	1.63^{f}	1.40^{g}	1.56^{d}
Mean	1.89^{B}	1.90^{AB}	1.92^{A}	1.79^{C}	
Reducing sugar (%)					
0	18.91^{i}	18.91^{i}	18.91^{i}	18.91^{i}	18.91^{d}
1	19.01^{hi}	18.96^{hi}	19.36^{de}	19.10^{gh}	19.11^{c}
2	19.27^{ef}	19.09^{gh}	20.25^{b}	19.50^{cd}	19.53^{b}
3	19.50^{cd}	19.19^{fg}	20.81^{a}	19.62^{c}	19.78^{a}
Mean	19.17^{C}	19.04^{D}	19.83^{A}	19.28^{B}	
Total sugar (%)					
0	49.25^{k}	49.25^{k}	49.25^{k}	49.25^{k}	49.25^{d}
1	50.93^{j}	51.50^{h}	51.72^{g}	51.25^{i}	51.35^{c}
2	52.85^{f}	53.25^{e}	53.81^{d}	53.07^{e}	53.24^{b}
3	53.86^{cd}	54.90^{b}	55.76^{a}	54.04^{c}	54.64^{a}
Mean	51.72^{D}	52.23^{B}	52.64^{A}	51.90^{C}	

* Values with different superscripts differ significantly at 5% level
NS - Non significant

Changes in physico-chemical characters

The physico-chemical changes during storage of drum dried and spray dried banana powder are given in Table 4.18, 4.19, 4.20 and 4.21. Irrespective of the treatments, the moisture, non-enzymatic browning, reducing sugar and total sugar of the banana powder progressively increased throughout the storage period whereas the acidity of the powder decreased.

Comparing the different packaging methods, irrespective of method of drying or packaging material, vacuum packed samples recorded the lowest moisture and non-enzymatic browning while, air packed samples showed the highest values. Maximum acidity was noted in nitrogen packs and minimum in vacuum packs. Reducing and total sugars were maximum in nitrogen packs and minimum in airpacks.

Changes in Hunter colour values

Irrespective of the treatments, the hunter colour value 'L' (visual lightness) decreased during storage while the hunter value 'a' (redness) and 'b' (yellowness) progressively increased throughout the storage period (Tables 4.22, 4.23, 4.24 and 4.25).

Among the packaging methods, vacuum packed samples recorded the highest 'L' value and lowest 'a' and 'b' values while the air packed samples (control) recorded the lowest 'L' value and highest 'a' and 'b' values.

The overall inference from the hunter readings showed that minimum colour loss occurred in vacuum packed powder and maximum in control (air pack). The hunter results also matched with that of non-enzymatic browning.

Table 4.22. Changes in Hunter colour values during storage of drum dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Hunter value 'L'					
0	60.63 NS	60.63 NS	60.63 NS	60.63 NS	60.63 a
2	59.69 NS	59.86 NS	59.95 NS	60.01 NS	59.88 b
4	59.25 NS	59.51 NS	59.63 NS	59.85 NS	59.56 c
6	58.66 NS	58.93 NS	59.07 NS	59.25 NS	58.98 d
8	58.83 NS	58.67 NS	58.84 NS	59.07 NS	58.85 d
10	58.07 NS	58.31 NS	58.66 NS	58.98 NS	58.51 e
12	57.40 NS	57.91 NS	58.38 NS	58.96 NS	58.16 f
Mean	58.93 C	59.12 BC	59.31 AB	59.54 A	
Hunter value 'a'					
0	5.45 NS	5.45 NS	5.45 NS	5.45 NS	5.45 d
2	5.93 NS	5.89 NS	5.73 NS	5.69 NS	5.81 c
4	6.21 NS	6.17 NS	6.07 NS	6.01 NS	6.12 b
6	6.44 NS	6.31 NS	6.21 NS	6.13 NS	6.27 ab
8	6.57 NS	6.40 NS	6.32 NS	6.21 NS	6.38 ab
10	6.61 NS	6.48 NS	6.40 NS	6.38 NS	6.47 a
12	6.70 NS	6.56 NS	6.51 NS	6.45 NS	6.56 a
Mean	6.27 NS	6.18 NS	6.10 NS	6.05 NS	
Hunter value 'b'					
0	15.96 NS	15.96 NS	15.96 NS	15.96 NS	15.96 g
2	17.85 NS	17.63 NS	17.54 NS	17.41 NS	17.61 f
4	18.71 NS	18.50 NS	18.31 NS	18.19 NS	18.43 e
6	19.63 NS	19.42 NS	19.35 NS	19.21 NS	19.40 d
8	20.41 NS	20.21 NS	20.07 NS	20.01 NS	20.18 c
10	21.11 NS	20.97 NS	20.83 NS	20.53 NS	20.86 b
12	21.37 NS	21.08 NS	20.91 NS	20.76 NS	21.03 a
Mean	19.29 A	19.11 B	19.00 C	18.87 D	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.23. Changes in Hunter colour values during storage of drum dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Hunter value 'L'					
0	60.63^{a}	60.63^{a}	60.63^{a}	60.63^{a}	60.63^{a}
1	53.10^{f}	55.80^{d}	56.50^{c}	57.71^{b}	55.78^{b}
2	46.95^{h}	53.63^{ef}	54.11^{e}	55.25^{d}	52.49^{c}
3	38.59^{j}	42.16^{i}	50.25^{g}	53.07^{f}	46.02^{d}
Mean	49.82^{D}	53.05^{C}	55.37^{B}	56.66^{A}	
Hunter value 'a'					
0	5.45^{f}	5.45^{f}	5.45^{f}	5.45^{f}	5.45^{c}
1	5.71^{cde}	5.60^{def}	5.54^{ef}	5.52^{ef}	5.59^{b}
2	5.90^{b}	5.73^{bcd}	5.58^{def}	5.54^{ef}	5.69^{a}
3	6.08^{a}	5.81^{bc}	5.60^{def}	5.56^{def}	5.76^{a}
Mean	5.79^{A}	5.65^{B}	5.54^{C}	5.52^{C}	
Hunter value 'b'					
0	15.96^{i}	15.96^{i}	15.96^{i}	15.96^{i}	16.96^{d}
1	16.41^{efg}	16.36^{fg}	16.25^{gh}	16.14^{hi}	16.29^{c}
2	16.88^{ab}	16.60^{cde}	16.51^{def}	16.44^{defg}	16.61^{b}
3	16.96^{a}	16.71^{bc}	16.63^{cd}	16.50^{def}	16.70^{a}
Mean	16.66^{A}	16.41^{B}	16.34^{BC}	16.26^{C}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.24. Changes in Hunter colour values during storage of spray dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Hunter value 'L'					
0	73.20^{a}	73.20^{a}	73.20^{a}	73.20^{a}	73.20^{a}
2	72.52^{defg}	72.81^{bcd}	72.95^{abc}	73.01^{ab}	72.82^{b}
4	72.27^{fgh}	72.67^{bcde}	72.81^{bcd}	72.95^{abc}	72.68^{b}
6	71.83^{jkl}	72.21^{ghi}	72.44^{efg}	72.61^{cdef}	72.28^{c}
8	71.21^{mn}	71.89^{ijk}	72.02^{hij}	72.18^{ghij}	71.83^{d}
10	70.65^{o}	71.03^{n}	71.53^{lm}	71.55^{klm}	71.19^{e}
12	69.82^{p}	70.43^{o}	71.09^{n}	71.38^{mn}	70.68^{f}
Mean	71.64^{C}	72.03^{B}	72.29^{A}	72.41^{A}	
Hunter value 'a'					
0	0.64^{NS}	0.64^{NS}	0.64^{NS}	0.64^{NS}	0.64^{NS}
2	0.71^{NS}	0.68^{NS}	0.65^{NS}	0.64^{NS}	0.67^{NS}
4	0.77^{NS}	0.74^{NS}	0.72^{NS}	0.70^{NS}	0.73^{NS}
6	0.81^{NS}	0.79^{NS}	0.75^{NS}	0.73^{NS}	0.77^{NS}
8	0.86^{NS}	0.82^{NS}	0.80^{NS}	0.78^{NS}	0.82^{NS}
10	0.88^{NS}	0.84^{NS}	0.81^{NS}	0.78^{NS}	0.83^{NS}
12	0.90^{NS}	0.85^{NS}	0.81^{NS}	0.79^{NS}	0.84^{NS}
Mean	0.80^{NS}	0.77^{NS}	0.74^{NS}	0.72^{NS}	
Hunter value 'b'					
0	10.75^{p}	10.75^{p}	10.75^{p}	10.75^{p}	10.75^{g}
2	11.90^{lm}	11.73^{mn}	11.50^{no}	11.32^{o}	11.61^{f}
4	12.81^{fgh}	12.50^{hij}	11.83^{lm}	11.75^{lmn}	12.22^{e}
6	13.15^{de}	12.77^{fgh}	12.25^{jk}	12.05^{kl}	12.56^{d}
8	13.45^{bc}	13.08^{def}	12.51^{hij}	12.37^{ij}	12.85^{c}
10	13.71^{ab}	13.61^{bc}	12.92^{ef}	12.60^{ghi}	13.21^{b}
12	13.96^{a}	13.92^{a}	13.37^{cd}	12.86^{efg}	13.53^{a}
Mean	12.81^{A}	12.62^{B}	12.16^{C}	11.96^{D}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.25. Changes in Hunter colour values during storage of spray dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	**CO_2 pack**	**Nitrogen pack**	**Vacuum pack**	**Mean**
Hunter value 'L'					
0	73.20^{a}	73.20^{a}	73.20^{a}	73.20^{a}	73.20^{a}
1	64.22^{e}	65.71^{d}	66.25^{c}	67.38^{b}	65.89^{b}
2	58.50^{j}	60.33^{h}	62.38^{g}	63.81^{f}	61.26^{c}
3	51.28^{l}	54.60^{k}	58.61^{j}	59.37^{i}	55.97^{d}
Mean	61.80^{D}	63.46^{C}	65.11^{D}	65.94^{A}	
Hunter value 'a'					
0	0.64^{h}	0.64^{h}	0.64^{h}	0.64^{h}	0.64^{d}
1	0.98^{g}	0.95^{g}	0.91^{g}	0.89^{g}	0.93^{c}
2	1.65^{c}	1.48^{d}	1.30^{ef}	1.15^{f}	1.40^{b}
3	2.10^{a}	1.84^{b}	1.58^{cd}	1.43^{de}	1.74^{a}
Mean	1.34^{A}	1.23^{B}	1.11^{C}	1.03^{D}	
Hunter value 'b'					
0	10.75^{k}	10.75^{k}	10.75^{k}	10.75^{k}	10.75^{d}
1	11.90^{de}	11.41^{hi}	11.28^{i}	11.03^{j}	11.43^{c}
2	12.81^{b}	12.08^{d}	11.77^{ef}	11.50^{gh}	12.04^{b}
3	13.38^{a}	12.50^{c}	11.83^{de}	11.69^{fg}	12.38^{a}
Mean	12.21^{A}	11.68^{B}	11.43^{C}	11.24^{D}	

* Values with different superscripts differ significantly at 5% level
NS - Non significant

Changes in microbial status

The microbial changes during storage of banana powder are given in Tables 4.26, 4.27, 4.28 and 4.29. The bacterial and fungal counts during storage of banana powder in aluminium foil pouches remained well within the limits prescribed by ICMSF (1986) even after one year of storage under ambient conditions. But the banana powder packed in metallised polyester pouches showed bacterial counts (10.25 - 15.33 x 10^3 cfu/g) above prescribed limit (10 x 10^3 cfu/g) at the end of three months, indicating that the packaging material was not ideal for long term storage of banana powder.

Among the packaging methods, the vacuum packed samples recorded the lowest bacterial and fungal counts while the control (air pack) recorded the highest counts in both packaging materials.

Table 4.26. Microbiological changes during storage of drum dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Bacterial count (x10^3 cfu/g)					
0	0.67^{p}	0.67^{p}	0.67^{p}	0.67^{p}	0.67^{g}
2	2.17^{m}	1.50^{no}	1.83^{mno}	1.33^{o}	1.71^{f}
4	3.33^{ijk}	2.83^{kl}	3.17^{jkl}	2.00^{mn}	2.83^{e}
6	4.08^{gh}	3.33^{ijk}	3.58^{hij}	2.75^{l}	3.44^{d}
8	5.08^{cde}	4.33^{fg}	4.67^{ef}	3.17^{jkl}	4.31^{c}
10	5.92^{b}	4.92^{de}	5.17^{cde}	3.50^{ij}	4.88^{b}
12	6.50^{a}	5.33^{cd}	5.50^{bc}	3.83^{ghi}	5.29^{a}
Mean	3.96^{A}	3.27^{C}	3.51^{B}	2.46^{D}	
Fungal count (x10^2 cfu/g)					
0	0.33^{o}	0.33^{o}	0.33^{o}	0.33^{o}	0.33^{g}
2	1.67^{kl}	1.17^{mn}	1.33^{lm}	0.83^{n}	1.25^{f}
4	2.83^{gh}	2.17^{ij}	2.33^{i}	1.83^{jk}	2.29^{e}
6	4.17^{e}	3.33^{f}	3.50^{f}	2.50^{hi}	3.38^{d}
8	5.83^{c}	4.33^{e}	4.50^{e}	3.17^{fg}	4.46^{c}
10	6.83^{b}	5.67^{cd}	5.83^{c}	4.50^{e}	5.71^{b}
12	7.83^{a}	6.92^{b}	7.00^{b}	5.33^{d}	6.77^{a}
Mean	4.21^{A}	3.42^{B}	3.55^{B}	2.64^{C}	

* Values with different superscripts differ significantly at 5% level

Table 4.27. Microbiological changes during storage of drum dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Bacterial count (x10^3 cfu/g)					
0	0.67^{i}	0.67^{i}	0.67^{i}	0.67^{i}	0.67^{d}
1	3.42^{g}	3.00^{g}	3.50^{g}	2.42^{h}	3.08^{c}
2	6.92^{d}	5.00^{e}	6.42^{d}	4.33^{f}	5.67^{b}
3	12.50^{a}	9.58^{b}	10.08^{b}	8.33^{c}	10.13^{a}
Mean	5.88^{A}	4.56^{C}	5.17^{B}	3.94^{D}	
Fungal count (x10^2 cfu/g)					
0	0.33^{i}	0.33^{i}	0.33^{i}	0.33^{i}	0.33^{d}
1	3.17^{f}	2.50^{g}	2.67^{g}	2.00^{h}	2.58^{c}
2	7.07^{c}	6.33^{d}	6.50^{d}	5.17^{e}	6.27^{b}
3	8.70^{a}	7.50^{b}	7.83^{b}	6.50^{d}	7.63^{a}
Mean	4.82^{A}	4.17^{B}	4.33^{B}	3.50^{C}	

* Values with different superscripts differ significantly at 5% level

Table 4.28. Microbiological changes during storage of spray dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Bacterial count ($x10^3$ cfu/g)					
0	0.33^{p}	0.33^{p}	0.33^{p}	0.33^{p}	0.33^{g}
2	2.17^{n}	1.58^{o}	1.67^{o}	1.42^{o}	1.71^{f}
4	3.58^{jkl}	3.08^{lm}	3.25^{klm}	2.33^{n}	3.06^{e}
6	4.83^{def}	3.92^{hij}	4.17^{ghi}	2.92^{m}	3.96^{d}
8	6.17^{c}	4.58^{efg}	4.92^{de}	3.67^{ijk}	4.83^{c}
10	7.33^{b}	5.67^{c}	6.17^{c}	4.33^{fgh}	5.88^{b}
12	8.33^{a}	6.83^{b}	7.25^{b}	5.17^{d}	6.90^{a}
Mean	4.68^{A}	3.71^{C}	3.96^{B}	2.88^{D}	
Fungal count ($x10^2$ cfu/g)					
0	0.00^{p}	0.00^{p}	0.00^{p}	0.00^{p}	0.00^{g}
2	1.83^{lm}	1.17^{n}	1.50^{mn}	0.67^{o}	1.29^{f}
4	3.33^{ij}	2.83^{k}	3.00^{jk}	2.17^{l}	2.83^{e}
6	4.67^{g}	3.33^{ij}	3.67^{i}	2.83^{k}	3.63^{d}
8	6.17^{e}	4.83^{fg}	5.17^{f}	4.17^{h}	5.08^{c}
10	7.33^{b}	6.33^{de}	6.67^{cd}	4.83^{fg}	6.29^{b}
12	8.67^{a}	7.08^{bc}	7.50^{b}	6.00^{e}	7.31^{a}
Mean	4.57^{A}	3.66^{C}	3.93^{B}	2.95^{D}	

* Values with different superscripts differ significantly at 5% level

Table 4.29. Microbiological changes during storage of spray dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Bacterial count (x10^3 cfu/g)					
0	0.33^{j}	0.33^{j}	0.33^{j}	0.33^{j}	0.33^{d}
1	4.42^{h}	4.00^{h}	4.42^{h}	2.83^{i}	3.92^{c}
2	8.00^{e}	7.08^{f}	7.33^{f}	6.33^{g}	7.19^{b}
3	15.33^{a}	12.58^{c}	13.58^{b}	10.25^{d}	12.94^{a}
Mean	7.02^{A}	6.00^{C}	6.42^{B}	4.94^{D}	
Fungal count (x10^2 cfu/g)					
0	0.00^{k}	0.00^{k}	0.00^{k}	0.00^{k}	0.00^{d}
1	3.33^{g}	2.67^{i}	3.00^{h}	2.33^{j}	2.83^{c}
2	7.93^{c}	7.08^{e}	7.42^{d}	5.83^{f}	7.07^{b}
3	9.50^{a}	8.83^{b}	9.00^{b}	7.33^{de}	8.67^{a}
Mean	5.19^{A}	4.65^{C}	4.85^{B}	3.88^{D}	

* Values with different superscripts differ significantly at 5% level

Changes in organoleptic characters

The changes in organoleptic characters during storage of banana powder are given in Tables 4.30, 4.31, 4.32 and 4.33. The banana powder packed in metallised polyester pouches remained organoleptically acceptable only for three months whereas those packed in aluminium foil laminated pouches remained acceptable for one year. Among the packaging methods, vacuum packed samples showed highest scores for colour and flavour. Texture and overall acceptability scores were maximum for nitrogen packed samples.

Table 4.30. Changes in organoleptic characters during storage of drum dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Colour					
0	4.17^{NS}	4.17^{NS}	4.17^{NS}	4.17^{NS}	4.17^{a}
2	4.17^{NS}	4.17^{NS}	4.17^{NS}	4.17^{NS}	4.17^{a}
4	4.00^{NS}	4.00^{NS}	4.00^{NS}	4.17^{NS}	4.04^{ab}
6	3.83^{NS}	4.00^{NS}	4.00^{NS}	4.17^{NS}	4.00^{abc}
8	3.67^{NS}	3.83^{NS}	4.00^{NS}	4.17^{NS}	3.92^{bcd}
10	3.50^{NS}	3.67^{NS}	3.83^{NS}	4.17^{NS}	3.79^{cd}
12	3.33^{NS}	3.67^{NS}	3.83^{NS}	4.17^{NS}	3.75^{d}
Mean	3.81^{C}	3.93^{BC}	4.00^{B}	4.17^{A}	
Flavour					
0	4.33^{NS}	4.33^{NS}	4.33^{NS}	4.33^{NS}	4.33^{a}
2	4.17^{NS}	4.17^{NS}	4.33^{NS}	4.33^{NS}	4.25^{a}
4	4.17^{NS}	4.00^{NS}	4.17^{NS}	4.17^{NS}	4.13^{ab}
6	3.83^{NS}	3.83^{NS}	4.00^{NS}	4.17^{NS}	3.96^{b}
8	3.33^{NS}	3.67^{NS}	3.83^{NS}	4.00^{NS}	3.71^{c}
10	3.33^{NS}	3.67^{NS}	3.67^{NS}	4.00^{NS}	3.67^{c}
12	3.17^{NS}	3.50^{NS}	3.67^{NS}	4.00^{NS}	3.58^{c}
Mean	3.76^{C}	3.88^{BC}	4.00^{AB}	4.14^{A}	
Texture					
0	4.67^{a}	4.67^{a}	4.67^{a}	4.67^{a}	4.67^{a}
2	4.33^{abc}	4.33^{abc}	4.50^{ab}	2.67^{f}	3.96^{b}
4	4.17^{abcd}	4.17^{abcd}	4.33^{abc}	2.67^{f}	3.83^{bc}
6	3.83^{cde}	4.00^{bcd}	4.17^{abcd}	2.50^{fg}	3.63^{cd}
8	3.67^{de}	3.83^{cde}	4.17^{abcd}	2.33^{fg}	3.50^{de}
10	3.33^{e}	3.67^{de}	4.17^{abcd}	2.17^{g}	3.33^{e}
12	3.33^{e}	3.67^{de}	4.17^{abcd}	2.17^{g}	3.33^{e}
Mean	3.91^{B}	4.05^{B}	4.31^{A}	2.74^{C}	
Overall acceptability					
0	4.39^{NS}	4.39^{NS}	4.39^{NS}	4.39^{NS}	4.39^{a}
2	4.22^{NS}	4.22^{NS}	4.33^{NS}	3.72^{NS}	4.13^{ab}
4	4.11^{NS}	4.06^{NS}	4.17^{NS}	3.67^{NS}	4.00^{abc}
6	3.83^{NS}	3.94^{NS}	4.06^{NS}	3.61^{NS}	3.86^{bcd}
8	3.56^{NS}	3.78^{NS}	4.00^{NS}	3.50^{NS}	3.71^{bcd}
10	3.39^{NS}	3.67^{NS}	3.89^{NS}	3.45^{NS}	3.60^{cd}
12	3.28^{NS}	3.61^{NS}	3.89^{NS}	3.45^{NS}	3.56^{d}
Mean	3.83^{AB}	3.95^{AB}	4.10^{A}	3.68^{B}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.31. Changes in organoleptic characters during storage of drum dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Colour					
0	4.17[a]	4.17[a]	4.17[a]	4.17[a]	4.17[a]
1	3.83[a]	4.00[a]	4.17[a]	4.17[a]	4.04[a]
2	2.83[b]	3.83[a]	4.00[a]	4.17[a]	3.71[b]
3	2.67[b]	3.67[a]	3.83[a]	4.00[a]	3.54[b]
Mean	3.38[B]	3.82[A]	4.04[A]	4.13[A]	
Flavour					
0	4.33[NS]	4.33 [NS]	4.33 [NS]	4.33 [NS]	4.33[a]
1	3.83 [NS]	4.00 [NS]	4.17 [NS]	4.17 [NS]	4.04[b]
2	3.33 [NS]	3.83 [NS]	3.83 [NS]	4.00 [NS]	3.75[c]
3	3.17 [NS]	3.67 [NS]	3.83 [NS]	4.00 [NS]	3.67[c]
Mean	3.67[B]	3.96[A]	4.04[A]	4.13[A]	
Texture					
0	4.67[a]	4.67[a]	4.67[a]	4.67[a]	4.67[a]
1	3.83[cd]	4.17[bc]	4.33[ab]	2.17[f]	3.63[b]
2	3.67[de]	4.00[bcd]	4.17[bc]	2.00[f]	3.46[bc]
3	3.33[e]	3.83[cd]	4.00[bcd]	1.83[f]	3.25[c]
Mean	3.88[B]	4.17[A]	4.29[A]	2.67[C]	
Overall acceptability					
0	4.39[NS]	4.39 [NS]	4.39 [NS]	4.39 [NS]	4.39[a]
1	3.83 [NS]	4.06 [NS]	4.22 [NS]	3.50 [NS]	3.90[b]
2	3.28 [NS]	3.89 [NS]	4.00 [NS]	3.39 [NS]	3.64[b]
3	3.06 [NS]	3.72 [NS]	3.89 [NS]	3.28 [NS]	3.49[b]
Mean	3.64 [NS]	4.01 [NS]	4.13 [NS]	3.64 [NS]	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

Table 4.32. Changes in organoleptic characters during storage of spray dried banana powder in aluminium foil pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Colour					
0	4.83 NS	4.83 NS	4.83 NS	4.83 NS	4.83 a
2	4.67 NS	4.83 NS	4.83 NS	4.83 NS	4.79 ab
4	4.33 NS	4.67 NS	4.67 NS	4.67 NS	4.42 bc
6	4.17 NS	4.33 NS	4.50 NS	4.67 NS	4.42 cd
8	3.83 NS	4.17 NS	4.33 NS	4.50 NS	4.21 cd
10	3.67 NS	3.83 NS	4.17 NS	4.33 NS	4.00 ef
12	3.50 NS	3.67 NS	4.17 NS	4.33 NS	3.92 f
Mean	4.14 C	4.33 B	4.50 AB	4.60 A	
Flavour					
0	4.67 NS	4.67 NS	4.67 NS	4.67 NS	4.67 a
2	4.50 NS	4.50 NS	4.50 NS	4.67 NS	4.54 ab
4	4.33 NS	4.33 NS	4.33 NS	4.50 NS	4.38 ab
6	4.17 NS	4.17 NS	4.33 NS	4.33 NS	4.25 bc
8	3.67 NS	3.83 NS	4.17 NS	4.33 NS	4.00 cd
10	3.33 NS	3.67 NS	3.67 NS	4.17 NS	3.71 d
12	3.17 NS	3.67 NS	3.67 NS	4.17 NS	3.67 d
Mean	3.98 B	4.12 B	4.18 AB	4.41 A	
Texture					
0	4.83 a	4.83 a	4.83 a	4.83 a	4.83 a
2	4.33 abcd	4.50 abc	4.67 ab	2.67 f	4.04 b
4	4.17 abcd	4.33 abcd	4.50 abc	2.67 f	3.92 bc
6	4.00 bcd	4.17 abcd	4.33 abcd	2.33 fg	3.75 bcd
8	3.83 cde	4.17 abcd	4.33 abcd	2.33 fg	3.67 cde
10	3.67 de	4.00 bcd	4.33 abcd	2.17 fg	3.54 de
12	3.33 e	4.00 bcd	4.33 abcd	2.00 g	3.42 e
Mean	4.02 B	4.29 A	4.48 A	2.74 C	
Overall acceptability					
0	4.78 NS	4.78 NS	4.78 NS	4.78 NS	4.78 a
2	4.50 NS	4.61 NS	4.67 NS	4.06 NS	4.46 ab
4	4.28 NS	4.44 NS	4.50 NS	3.95 NS	4.29 ab
6	4.11 NS	4.22 NS	4.39 NS	3.83 NS	4.14 bc
8	3.78 NS	4.06 NS	4.28 NS	3.72 NS	3.96 bc
10	3.56 NS	3.83 NS	4.06 NS	3.56 NS	3.75 c
12	3.33 NS	3.78 NS	4.06 NS	3.50 NS	3.67 c
Mean	4.05 AB	4.25 AB	4.39 A	3.91 B	

* Values with different superscripts differ significantly at 5% level
NS – Non significant

Table 4.33. Changes in organoleptic characters during storage of spray dried banana powder in metallised polyester pouches

Months of storage	Packaging methods				
	Air pack	CO_2 pack	Nitrogen pack	Vacuum pack	Mean
Colour					
0	4.83[a]	4.83[a]	4.83[a]	4.83[a]	4.83[a]
1	3.83[cde]	4.17[bcd]	4.33[abc]	4.67[ab]	4.25[b]
2	2.67[f]	3.67[de]	4.17[bcd]	4.50[ab]	3.75[c]
3	2.33[f]	3.50[e]	3.83[cde]	4.33[abc]	3.50[d]
Mean	3.42[D]	4.04[C]	4.29[B]	4.58[A]	
Flavour					
0	4.67[NS]	4.67[NS]	4.67[NS]	4.67[NS]	4.67[a]
1	3.83[NS]	4.17[NS]	4.33[NS]	4.50[NS]	4.21[b]
2	3.67[NS]	4.00[NS]	4.17[NS]	4.33[NS]	4.04[b]
3	3.50[NS]	3.83[NS]	4.00[NS]	4.33[NS]	3.92[b]
Mean	3.92[B]	4.17[AB]	4.29[A]	4.46[A]	
Texture					
0	4.83[a]	4.83[a]	4.83[a]	4.83[a]	4.83[a]
1	4.00[cde]	4.17[bcd]	4.50[ab]	2.33[g]	3.75[b]
2	3.67[e]	3.83[de]	4.33[bc]	2.17[g]	3.50[c]
3	3.17[f]	3.83[de]	4.17[bcd]	2.00[g]	3.29[c]
Mean	3.92[C]	4.17[B]	4.46[A]	2.83[D]	
Overall acceptability					
0	4.78[NS]	4.78[NS]	4.78[NS]	4.78[NS]	4.78[a]
1	3.89[NS]	4.17[NS]	4.39[NS]	3.83[NS]	4.07[b]
2	3.34[NS]	3.83[NS]	4.22[NS]	3.67[NS]	3.77[b]
3	3.00[NS]	3.72[NS]	4.00[NS]	3.55[NS]	3.58[b]
Mean	3.75[NS]	4.13[NS]	4.34[NS]	3.96[NS]	

* Values with different superscripts differ significantly at 5% level
NS - Non significant

4.2 DEVELOPMENT OF TECHNOLOGY FOR BANANA JUICE BASED BEVERAGE

Experiments were carried out on enzyme aided banana juice extraction with different varieties, blending of clarified banana juice with other fruit juices and storage stability of banana juice based beverage.

4.2.1 Experiment on enzyme aided banana juice extraction

The pulp of four varieties of banana viz. Robusta, Poovan, Palayankodan and Karpooravalli were treated with commercial pectinase enzyme and incubated at two temperatures viz. 50°C and room temperature (28°C). The results are presented here under.

Physico-chemical characters of banana juice

The physico-chemical characters of enzyme clarified banana juice are given in Table 4.34. Among the four banana varieties, Palayankodan recorded the maximum juice recovery of 74.46 per cent while Karpooravalli recorded the lowest (60.60 per cent). Total soluble solids (29.09°Brix), reducing sugar (20.75%) and total sugars (25.38%) were maximum in clarified Karpooravalli juice and minimum in Robusta juice.

Acidity was maximum (0.792%) in Palayankodan juice and minimum (0.511%) in Poovan juice. Robusta juice recorded the lowest (0.052) non-enzymatic browning (NEB) value while Poovan juice recorded the highest NEB value (0.178) indicating the light yellow colour of Robusta juice compared to the golden yellow colour of Poovan juice (Plate 12).

Among the incubation temperatures, the juice recovery was more at room temperature (70.06%) than at 50°C (67.58%). The incubation temperatures of the enzyme treated ripe pulp affected the quality of clarified juice significantly. TSS,

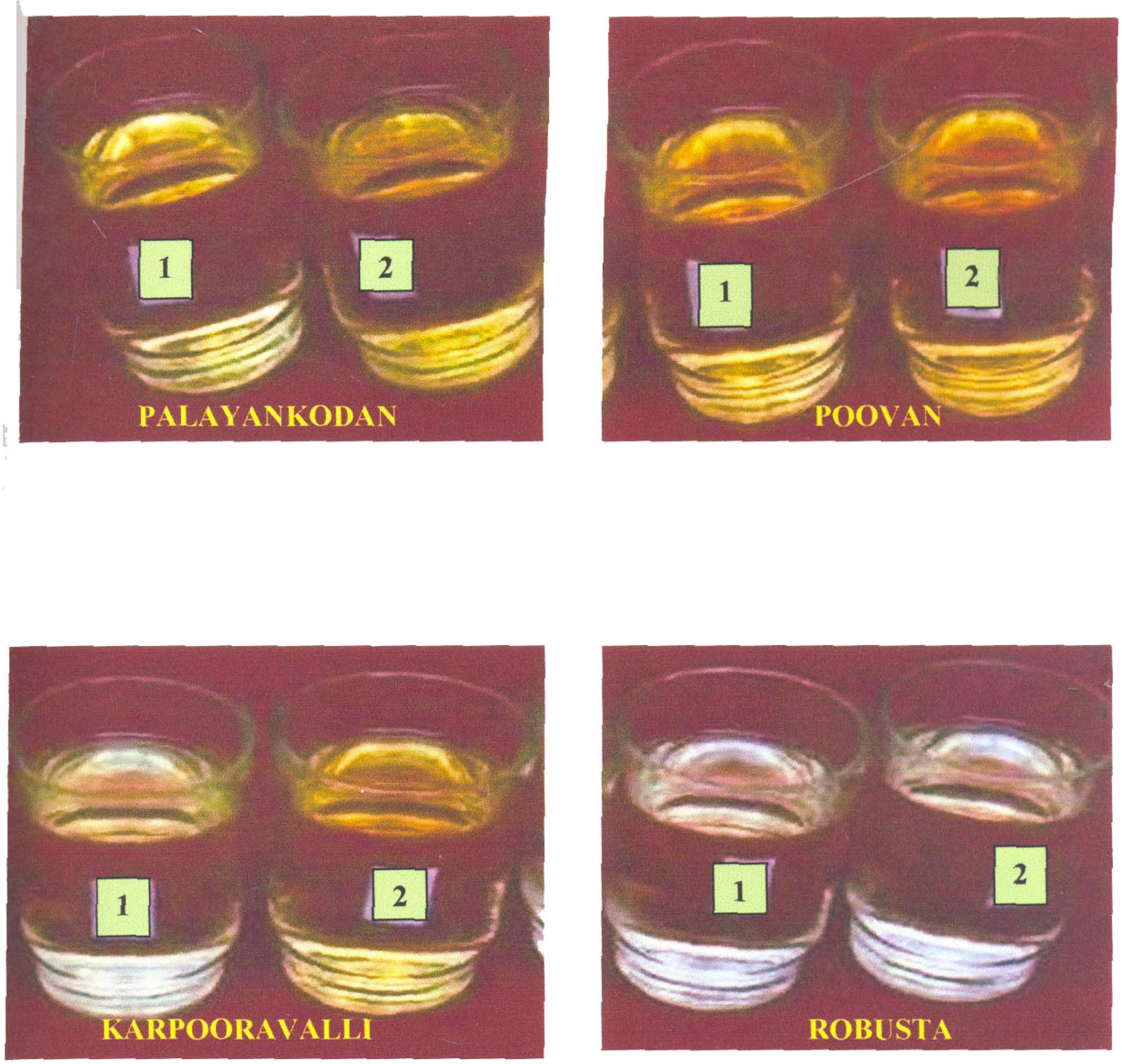


Plate 12. Clarified banana juice from different varieties under different incubation time and temperature

1) Incubated at room temperature for four hours
2) Incubated at 50°C for two hours

acidity, NEB and total sugars were higher when incubated at 50°C. The lesser NEB of juice incubated at room temperature indicated the lighter colour of the juice. Considering the results of juice recovery percentage and colour of juice, the juice recovered from pulp incubated at room temperature for four hours was found superior.

Table 4.34. Physico-chemical characters of enzyme clarified banana juice

Varieties	Treatments T1	Treatments T2	Mean	Treatments T1	Treatments T2	Mean
	Juice recovery (%)			**TSS(° Brix)**		
Robusta	69.03^{e}	70.70^{d}	69.86^{b}	22.03^{f}	22.23^{e}	22.13^{c}
Palayankodan	73.90^{b}	75.03^{a}	74.46^{a}	23.38^{d}	23.80^{c}	23.59^{b}
Karpooravalli	59.78^{h}	61.43^{g}	60.60^{c}	28.50^{a}	27.65^{b}	28.09^{a}
Poovan	67.60^{f}	73.10^{c}	70.35^{b}	23.75^{c}	23.45^{d}	23.60^{b}
Mean	67.58^{B}	70.06^{A}		24.41^{A}	24.28^{B}	
	Acidity(%)			**pH**		
Robusta	0.718^{d}	0.740^{c}	0.729^{b}	4.24^{NS}	4.24^{NS}	4.24^{NS}
Palayankodan	0.806^{a}	0.778^{b}	0.792^{a}	3.94^{NS}	5.44^{NS}	4.69^{NS}
Karpooravalli	0.536^{e}	0.524^{e}	0.530^{c}	3.99^{NS}	4.00^{NS}	3.99^{NS}
Poovan	0.524^{e}	0.499^{f}	0.511^{d}	4.12^{NS}	4.10^{NS}	4.10^{NS}
Mean	0.646^{A}	0.635^{B}		4.07^{NS}	4.44^{NS}	
	Reducing sugars(%)			**Total sugars(%)**		
Robusta	11.89^{h}	12.62^{g}	12.25^{d}	20.28^{e}	20.19^{e}	20.24^{c}
Palayankodan	15.37^{d}	18.86^{b}	17.11^{b}	21.23^{d}	22.57^{c}	21.90^{b}
Karpooravalli	23.47^{a}	18.02^{c}	20.75^{a}	26.35^{a}	24.41^{b}	25.38^{a}
Poovan	14.00^{f}	14.71^{e}	14.36^{c}	21.33^{d}	19.70^{e}	20.47^{c}
Mean	16.18^{NS}	16.05^{NS}		22.27^{A}	21.72^{B}	

Varieties	Non-enzymatic browning(OD at 420nm) Treatments T1	T2	Mean
Robusta	0.057^{f}	0.046^{f}	0.052^{d}
Palayankodan	0.127^{d}	0.123^{d}	0.125^{c}
Karpooravalli	0.216^{a}	0.105^{e}	0.160^{b}
Poovan	0.197^{b}	0.160^{c}	0.178^{a}
Mean	0.149^{A}	0.108^{B}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

T1 - Pulp incubated at 50°C for two hours

T2 - Pulp incubated at room temperature for four hours

Organoleptic characters of banana juice

The organoleptic characters of enzyme clarified banana juice are presented in Table 4.35. Among the varieties, the colour and flavour scores did not vary significantly but the scores for acidity, taste and overall acceptability varied significantly. Robusta juice recorded the highest score for taste (4.42) and overall acceptability (3.77) while Palayankodan juice recorded the least scores. Considering the organoleptic superiority of Robusta juice over other variety juices, it was selected for further blending and bottling studies. Among the two incubation temperatures, there was no significant variation in the organoleptic scores.

Table 4.35. Organoleptic characters of enzyme clarified banana juice

Varieties	Colour			Flavour		
	Treatments		Mean	Treatments		Mean
	T1	T2		T1	T2	
Robusta	3.92 NS	3.84 NS	3.88 NS	3.54 NS	3.16 NS	3.35 NS
Palayankodan	3.83 NS	4.08 NS	3.96 NS	3.50 NS	2.75 NS	3.13 NS
Karpooravalli	3.59 NS	3.84 NS	3.71 NS	3.67 NS	3.17 NS	3.42 NS
Poovan	3.17 NS	3.58 NS	3.38 NS	3.08 NS	3.00 NS	3.04 NS
Mean	3.63 NS	3.83 NS		3.45 NS	3.02 NS	
	Acidity			**Taste**		
Robusta	3.50 NS	3.33 NS	3.42 ^{a}	4.50 NS	4.33 NS	4.42 ^{a}
Palayankodan	2.75 NS	2.58 NS	2.57 ^{b}	2.59 NS	2.25 NS	2.42 ^{d}
Karpooravalli	3.25 NS	3.58 NS	3.42 ^{a}	3.59 NS	3.83 NS	3.71 ^{b}
Poovan	2.84 NS	3.17 NS	3.00 ^{ab}	3.00 NS	2.92 NS	2.96 ^{c}
Mean	3.08 NS	3.17 NS		3.42 NS	3.33 NS	

Varieties	Overall acceptability		
	Treatments		Mean
	T1	T2	
Robusta	3.87 NS	3.67 NS	3.77 ^{a}
Palayankodan	3.17 NS	2.92 NS	3.04 ^{c}
Karpooravalli	3.53 NS	3.61 NS	3.57 ^{ab}
Poovan	3.03 NS	3.17 NS	3.10 ^{bc}
Mean	3.40 NS	3.34 NS	

* Values with different superscripts differ significantly at 5% level
NS - Non significant
T1 - Pulp incubated at 50°C for two hours
T2 - Pulp incubated at room temperature for four hours

4.2.2 Experiment for selection of best blending proportion of banana juice

Clarified Robusta juice obtained from Experiment 4.2.1 was blended with juices of other fruits at various proportions. The RTS (Ready-To-Serve) beverage prepared without addition of synthetic colour and essence from such blended juices were evaluated for their bio-chemical and organoleptic characters.

Table 4.36. Bio-chemical characters of banana RTS blended in various proportions

Treatments	TSS (°Brix)	Acidity (%)	pH	Cloud index (OD at 660nm)	Reducing sugar (%)	Total sugar (%)
Banana-Pineapple RTS beverage						
50:50 Banana + Pineapple	14.40^{b}	0.175	3.755^{c}	0.156^{a}	1.89^{d}	12.97^{b}
60:40 Banana + Pineapple	14.40^{b}	0.180	3.775^{c}	0.132^{b}	2.11^{c}	13.09^{b}
75:25 Banana + Pineapple	14.60^{a}	0.180	3.830^{b}	0.104^{c}	2.26^{b}	13.33^{b}
100:0 Banana + Pineapple	14.30^{c}	0.175	3.935^{a}	0.064^{d}	2.77^{a}	13.75^{a}
Mean	14.43	0.178	3.824	0.112	2.21	13.28
Banana-Mango RTS beverage						
50:50 Banana + Mango	15.00^{a}	0.191	3.772^{d}	1.722^{a}	1.57^{d}	14.33^{b}
60:40 Banana + Mango	14.98^{a}	0.192	3.805^{c}	1.461^{b}	2.22^{c}	14.44^{b}
75:25 Banana + Mango	15.20^{a}	0.191	3.857^{b}	1.083^{c}	2.46^{b}	14.59^{a}
100:0 Banana + Mango	14.40^{b}	0.192	3.975^{a}	0.065^{d}	2.84^{a}	13.55^{c}
Mean	14.89	0.191	3.852	1.083	2.27	14.23
Banana-Orange RTS beverage						
50:50 Banana + Orange	15.02^{a}	0.180	3.801^{d}	0.421^{a}	1.77^{d}	14.05^{c}
60:40 Banana + Orange	15.02^{a}	0.185	3.829^{c}	0.375^{b}	2.08^{c}	14.24^{b}
75:25 Banana + Orange	14.60^{b}	0.180	3.844^{b}	0.263^{c}	2.33^{b}	14.42^{a}
100:0 Banana + Orange	14.60^{b}	0.180	3.862^{a}	0.064^{d}	2.77^{a}	13.85^{d}
Mean	14.81	0.181	3.834	0.280	2.24	14.14
Banana-Guava RTS beverage						
50:50 Banana + Guava	14.40	0.210^{a}	3.676^{d}	0.085^{a}	1.93^{d}	12.97^{d}
60:40 Banana + Guava	14.40	0.200^{b}	3.731^{c}	0.076^{b}	2.01^{c}	13.25^{c}
75:25 Banana + Guava	14.20	0.195^{c}	3.803^{b}	0.069^{c}	2.15^{b}	13.34^{b}
100:0 Banana + Guava	14.37	0.183^{d}	3.862^{a}	0.062^{d}	2.77^{a}	13.75^{a}
Mean	14.34	0.197	3.768	0.073	2.22	13.33

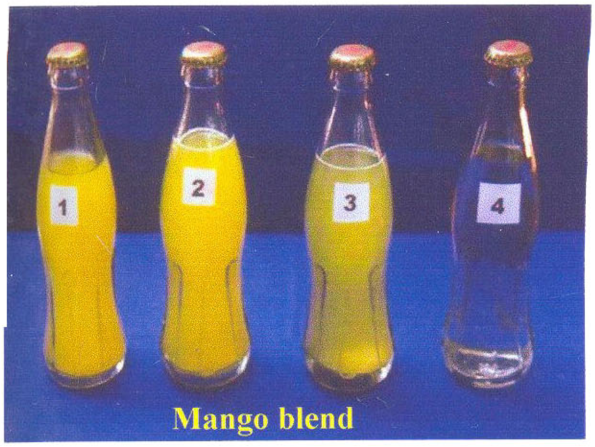
Values with different superscripts differ significantly at 5% level

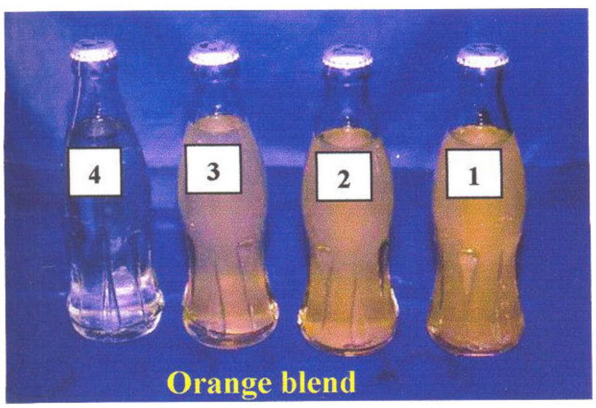
The blended banana RTS beverage had TSS (Total Soluble Solids) in the range of 14.2-15.2°Brix, acidity 0.175%-0.210%, reducing sugar 1.58%-2.85% and total sugar in the range of 12.97%-14.59% (Table 4.36). Among the various fruit blends viz., Pineapple, Mango, Mandarin Orange and Guava, the banana-mango blended RTS beverage gave the maximum cloud index (1.083) while the banana-guava RTS beverage gave the least mean colour index (0.073) indicating the attractive orange yellow colour of the banana-mango RTS beverage (Plate 13).

Table 4.37. Organoleptic characters of banana RTS blended in various proportions

Treatments	Organoleptic scores				
	Colour	Flavour	Taste	Consistency	Overall Acceptability
Banana-Pineapple RTS					
50:50 Banana + Pineapple	3.75	3.87	4.75^{a}	3.87	4.06^{a}
60:40 Banana + Pineapple	4.12	3.75	4.00^{b}	4.00	3.97^{b}
75:25 Banana + Pineapple	3.87	3.75	3.62^{b}	3.75	3.75^{b}
100:0 Banana + Pineapple	3.87	3.50	3.25^{b}	3.62	3.56^{b}
Mean	3.90	3.71	3.90	3.81	3.83
Banana-Mango RTS					
50:50 Banana + Mango	4.00	3.25	4.75^{a}	3.75	3.94^{a}
60:40 Banana + Mango	3.75	3.25	3.87^{b}	3.62	3.62^{b}
75:25 Banana + Mango	3.12	3.50	3.62^{b}	3.50	3.44^{b}
100:0 Banana + Mango	3.00	3.50	3.37^{b}	2.75	3.16^{b}
Mean	3.46	3.37	3.90	3.40	3.52
Banana-Orange RTS					
50:50 Banana + Orange	3.50^{a}	3.25	4.75^{a}	3.75	3.81^{a}
60:40 Banana + Orange	3.37^{a}	3.50	3.50^{b}	3.50	3.47^{b}
75:25 Banana + Orange	2.62^{b}	2.87	3.25^{b}	3.25	3.00^{b}
100:0 Banana + Orange	2.25^{b}	3.12	2.87^{b}	3.25	2.87^{b}
Mean	2.93	3.18	3.59	3.43	3.28
Banana-Guava RTS					
50:50 Banana + Guava	3.12	4.25^{a}	4.37^{a}	3.37	3.78^{a}
60:40 Banana + Guava	3.12	3.75^{b}	4.00^{a}	3.37	3.56^{b}
75:25 Banana + Guava	3.12	3.62^{b}	3.62^{a}	3.37	3.43^{b}
100:0 Banana + Guava	3.12	3.00^{c}	2.87^{b}	3.37	3.09^{c}
Mean	3.12	3.65	3.71	3.37	3.46

Values with different superscripts differ significantly at 5% level





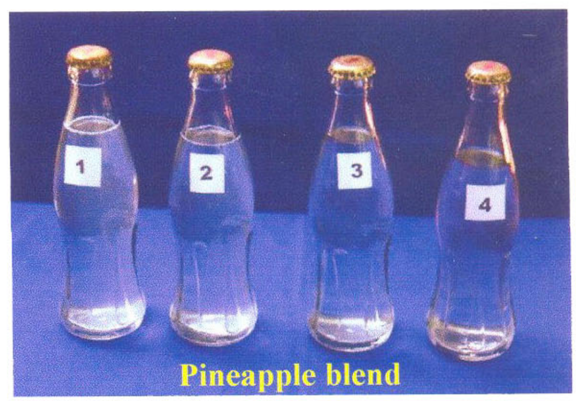


Plate 13. Blended banana Ready-To-Serve beverage with other fruit juices

1 -- 50:50 banana : other fruit blend
2 -- 60:40 banana : other fruit blend
3 -- 75:25 banana : other fruit blend
4 -- 100:0 banana : other fruit blend

Organoleptic characters of blended banana RTS given in Table 4.37 indicated that among the various blending proportions, the 50:50 blend of banana with other fruit juice gave the highest scores for taste and overall acceptability. Therefore, the 50:50 blending proportion in each fruit was selected as standard proportion for further studies.

4.2.3 Experiment for selection of best fruit blend with banana juice

The best blending proportion of 50:50 (banana:other fruit juice) selected through Experiment 4.2.2 was further evaluated to find the best fruit that can be blended with banana juice. Fruit juices of pineapple, orange, guava and mango were blended with banana juice in the ratio 50:50 and the blended juices were used for RTS preparation with added synthetic colour and banana essence.

Among the various fruit blends, the banana-mango RTS showed the highest values for total soluble solids (TSS), reducing sugars, total sugars and colour readings (Table 4.38). Organoleptic evaluation of the blended RTS (Table 4.39) revealed that the banana-mango RTS recorded the maximum scores for colour (4.75), taste (4.71), flavour (4.08), consistency (4.25) and overall acceptability (4.45). Therefore, the banana-mango RTS was selected for further bottling and storage studies (Plate 14).

Table 4.38. Bio-chemical characters of banana RTS blended with various fruit juices

Characters	T1	T2	T3	T4	T5
TSS(° Brix)	14.55^{b}	14.45^{b}	14.55^{b}	14.80^{a}	14.50^{b}
Acidity (%)	0.211^{b}	0.218^{a}	0.218^{a}	0.218^{a}	0.208^{b}
pH	3.848^{d}	3.863^{c}	3.871^{b}	3.839^{e}	4.090^{a}
Colour at 420 nm	0.081^{c}	0.175^{b}	0.078^{c}	0.699^{a}	0.021^{d}
Reducing sugar (%)	2.95^{b}	2.88^{c}	2.95^{b}	3.10^{a}	2.93^{b}
Total sugar (%)	13.62^{b}	13.40^{c}	13.62^{b}	13.79^{a}	13.39^{c}

* Values with different superscripts differ significantly at 5% level
T1 – RTS from 50% banana juice and 50% Pineapple juice blend
T2 – RTS from 50% banana juice and 50% Orange juice blend
T3 - RTS from 50% banana juice and 50% Guava juice blend
T4 - RTS from 50% banana juice and 50% Mango juice blend
T5 – RTS from 100% banana juice (Control)

Plate 14. Banana-mango Ready-To-Serve beverage selected as the best by taste panel

Table 4.39. Organoleptic characters of banana RTS blended with various fruit juices

Characters	T1	T2	T3	T4	T5
Colour	3.71^{b}	3.50^{b}	3.79^{b}	4.75^{a}	3.46^{b}
Taste	3.79^{b}	3.50^{b}	3.38^{b}	4.71^{a}	3.04^{b}
Flavour	3.71^{ab}	3.67^{ab}	3.38^{bc}	4.08^{a}	3.00^{c}
Consistency	3.33^{b}	3.50^{b}	3.38^{b}	4.25^{a}	3.42^{b}
Overall acceptability	3.64^{b}	3.54^{bc}	3.48^{bc}	4.45^{a}	3.23^{c}

* Values with different superscripts differ significantly at 5% level

T1 – RTS from 50% banana juice and 50% Pineapple juice blend
T2 – RTS from 50% banana juice and 50% Orange juice blend
T3 - RTS from 50% banana juice and 50% Guava juice blend
T4 - RTS from 50% banana juice and 50% Mango juice blend
T5 – RTS from 100% banana juice (Control)

4.2.4 Storage studies on banana-mango RTS beverage

The storage stability of banana-mango RTS under ambient conditions was studied for a period of six months. The monthly changes in bio-chemical, microbial and organoleptic characters are given in Tables 4.40, 4.41 and 4.42 respectively.

Storage study of banana-mango RTS revealed that the total soluble solids (TSS), acidity, cloud index and reducing sugar progressively increased during storage while the total sugars decreased (Table 4.40). The colour of the RTS as indicated by the mean cloud index was higher (0.932) in banana-mango RTS compared to control (banana RTS) indicating the dominance of orange colour of mango in the blend of banana.

Table 4.40. Bio-chemical changes during storage of banana-mango RTS under ambient conditions

Treat-ments	Months of storage							
	0	1	2	3	4	5	6	Mean
				TSS (°Brix)				
T_1	14.80^{NS}	14.81^{NS}	14.90^{NS}	14.92^{NS}	15.00^{NS}	15.00^{NS}	15.00^{NS}	14.92^{a}
T_2	14.50^{NS}	14.53^{NS}	14.60^{NS}	14.61^{NS}	14.70^{NS}	14.70^{NS}	14.80^{NS}	14.64^{b}
Mean	14.65^{D}	14.67^{CD}	14.75^{BCD}	14.77^{BC}	14.85^{AB}	14.85^{AB}	14.90^{A}	
				Acidity (%)				
T_1	0.22^{NS}	0.22^{NS}	0.22^{NS}	0.23^{NS}	0.24^{NS}	0.24^{NS}	0.24^{NS}	0.23^{a}
T_2	0.21^{NS}	0.21^{NS}	0.21^{NS}	0.22^{NS}	0.22^{NS}	0.22^{NS}	0.22^{NS}	0.21^{b}
Mean	0.21^{C}	0.21^{C}	0.22^{BC}	0.22^{ABC}	0.23^{AB}	0.23^{AB}	0.23^{A}	
				pH				
T_1	3.839^{NS}	3.800^{NS}	3.798^{NS}	3.765^{NS}	3.745^{NS}	3.696^{NS}	3.695^{NS}	3.756^{b}
T_2	4.090^{NS}	4.030^{NS}	3.980^{NS}	3.970^{NS}	3.960^{NS}	3.955^{NS}	3.940^{NS}	3.989^{a}
Mean	3.965^{NS}	3.915^{NS}	3.889^{NS}	3.868^{NS}	3.852^{NS}	3.825^{NS}	3.796^{NS}	
				Cloud index (OD at 660 nm)				
T_1	0.699^{d}	0.710^{d}	0.823^{c}	0.915^{bc}	0.998^{c}	1.150^{a}	1.230^{a}	0.932^{a}
T_2	0.021^{e}	0.025^{e}	0.029^{e}	0.031^{e}	0.033^{e}	0.034^{e}	0.036^{e}	0.030^{b}
Mean	0.360^{D}	0.367^{D}	0.426^{CD}	0.473^{BC}	0.516^{B}	0.592^{A}	0.633^{A}	
				Reducing sugar (%)				
T_1	3.10^{i}	3.85^{h}	4.27^{g}	5.01^{e}	5.97^{c}	6.25^{b}	6.67^{a}	5.02^{a}
T_2	2.93^{j}	3.23^{i}	3.98^{h}	4.71^{f}	5.25^{d}	5.98^{c}	6.17^{b}	4.61^{b}
Mean	3.02^{G}	3.54^{F}	4.13^{E}	4.86^{D}	5.61^{C}	6.12^{B}	6.42^{A}	
				Total sugar (%)				
T_1	13.79^{NS}	13.50^{NS}	13.17^{NS}	13.01^{NS}	12.90^{NS}	12.62^{NS}	12.31^{NS}	13.04^{a}
T_2	13.39^{NS}	13.19^{NS}	13.00^{NS}	12.88^{NS}	12.63^{NS}	12.25^{NS}	11.99^{NS}	12.76^{b}
Mean	13.69^{A}	13.35^{B}	13.09^{C}	12.95^{D}	12.77^{E}	12.44^{F}	12.15^{G}	

* Values with different superscripts differ significantly at 5% level

NS - Non significant

T_1 - 50% banana juice + 50% mango juice based RTS beverage

T_2 - 100% banana juice based RTS beverage

The bacterial and fungal counts remained well within the prescribed limits in ICMSF (1986) throughout six months of storage indicating the microbial safety of the beverage (Table 4.41). Organoleptic evaluation of the banana-mango RTS revealed that the beverage was organoleptically acceptable even after six months of storage at room temperature (Table 4.42). The banana-mango RTS was organoleptically superior to control as evidenced by higher mean scores for colour (4.54), flavour (4.03), taste (4.34), consistency (4.14) and overall acceptability (4.26).

Table 4.41. Changes in microbial status during storage of banana-mango RTS under ambient conditions

Treat-ments	Months of storage							
	0	1	2	3	4	5	6	Mean
Bacterial count (x10^3 cfu/ml)								
T_1	0.00^h	1.17^{fg}	1.50^f	2.17^e	3.33^c	4.57^b	6.23^a	2.71^a
T_2	0.00^h	1.00^g	1.00^g	1.33^{fg}	2.00^e	2.83^d	3.67^c	1.69^b
Mean	0.00^F	1.08^E	1.25^E	1.75^D	2.67^C	3.70^B	4.95^A	
Fungal count (x10^2 cfu/ml)								
T_1	0.00^{NS}	0.00^{NS}	1.00^{NS}	1.33^{NS}	2.17^{NS}	2.67^{NS}	3.00^{NS}	1.45^a
T_2	0.00^{NS}	0.33^{NS}	0.67^{NS}	1.17^{NS}	1.83^{NS}	2.17^{NS}	2.33^{NS}	1.21^b
Mean	0.00^E	0.17^E	0.83^D	1.25^C	2.00^B	2.42^A	2.67^A	

* Values with different superscripts differ significantly at 5% level
NS - Non significant
T_1 - 50% banana juice + 50% mango juice based RTS beverage
T_2 - 100% banana juice based RTS beverage

Table 4.42. Changes in organoleptic characters during storage of banana-mango RTS beverage under ambient conditions

Treat-ments	Months of storage							
	0	1	2	3	4	5	6	Mean
				Colour				
T_1	4.75^{a}	4.75^{a}	4.75^{a}	4.50^{b}	4.50^{b}	4.25^{c}	4.25^{c}	4.54^{a}
T_2	3.46^{d}	3.46^{d}	3.40^{d}	3.40^{d}	3.40^{d}	3.40^{d}	3.40^{d}	3.42^{b}
Mean	4.11^{A}	4.11^{A}	4.08^{A}	3.95^{B}	3.95^{B}	3.83^{C}	3.83^{C}	
				Flavour				
T_1	4.08^{NS}	4.08^{NS}	4.08^{NS}	4.00^{NS}	4.00^{NS}	4.00^{NS}	4.00^{NS}	4.03^{a}
T_2	3.00^{NS}	3.00^{NS}	3.00^{NS}	3.00^{NS}	3.00^{NS}	3.00^{NS}	3.00^{NS}	3.00^{b}
Mean	3.54^{NS}	3.54^{NS}	3.54^{NS}	3.50^{NS}	3.50^{NS}	3.50^{NS}	3.50^{NS}	
				Taste				
T_1	4.71^{a}	4.65^{ab}	4.50^{b}	4.25^{c}	4.25^{c}	4.00^{d}	4.00^{d}	4.34^{a}
T_2	3.04^{e}	3.00^{e}	3.00^{e}	3.00^{e}	3.00^{e}	3.00^{e}	3.00^{e}	3.01^{b}
Mean	3.88^{A}	3.88^{AB}	3.75^{B}	3.63^{C}	3.63^{C}	3.50^{D}	3.50^{D}	
				Consistency				
T_1	4.25^{a}	4.25^{a}	4.25^{a}	4.10^{b}	4.10^{b}	4.00^{b}	4.00^{b}	4.14^{a}
T_2	3.42^{c}	3.40^{c}	3.45^{c}	3.45^{c}	3.50^{c}	3.50^{c}	3.50^{c}	3.45^{b}
Mean	3.84^{NS}	3.83^{NS}	3.85^{NS}	3.78^{NS}	3.80^{NS}	3.75^{NS}	3.75^{NS}	
				Overall acceptability				
T_1	4.45^{NS}	4.43^{NS}	4.40^{NS}	4.21^{NS}	4.21^{NS}	4.06^{NS}	4.06^{NS}	4.26^{a}
T_2	3.23^{NS}	3.22^{NS}	3.21^{NS}	3.21^{NS}	3.23^{NS}	3.23^{NS}	3.23^{NS}	3.22^{b}
Mean	3.84^{NS}	3.82^{NS}	3.80^{NS}	3.71^{NS}	3.72^{NS}	3.64^{NS}	3.64^{NS}	

* Values with different superscripts differ significantly at 5% level
NS - Non significant
T_1 - 50% banana juice + 50% mango juice based RTS beverage
T_2 - 100% banana juice based RTS beverage

4.2.5 Cost of production

Table 4.43 shows the cost of production of 100 bottles of banana-mango blended RTS beverage. The cost per bottle (200 ml) worked out to be Rs.3.84 for banana-mango RTS and Rs.4.23 for pure mango RTS. (Appendix IV)

Table 4.43. Cost of production of 100 bottles (200 ml/bottle) of banana-mango blended Ready-To-Serve (RTS) beverage

Sl. No.	Item	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Raw material			
	a) Robusta fruit	3.58 kg	12/kg	42.96
	b) Mango fruit	5.03 kg	20/kg	100.60
	c) Sugar	2.19 kg	16/kg	35.04
	d) Citric acid	19.31 g	150/kg	2.90
	e)Potassium meta-bi-sulphite (KMS)	2.13 g	180/500 g	0.77
	f) Synthetic yellow food colour	2.00 g	45/100 g	0.90
	g) Banana essence	12.5 ml	200/500 ml	5.00
	h) Commercial pectinase enzyme	10.75 ml	2000/lit	21.50
II	Fuel		75 p/kg of beverage	15.00
III	Labour			
	a) Skilled labour	4 h	200/8 h	100.00
	b) Attendant (women)	4 h	100/8 h	50.00
			Total	374.67
IV	Interest on working capital @ 12%			0.12
V	Interest on fixed capital @ 12%			1.04
VI	Depreciation of machineries and accessories @ 10%			0.87
VII	Total cost of production			376.70
VIII	Processing loss (2%)			2 bottles
IX	Actual quantity of beverage			98 bottles
X	**Cost per bottle (200 ml)**			**3.84**

Discussion

5. DISCUSSION

Banana as a dessert fruit is very popular because of its ready availability, affordability, non-seasonal nature, nutritional and medicinal qualities. But the fruit being highly perishable suffers from postharvest losses to the extent of 40 per cent. These post harvest losses can be minimized by developing value added products from banana. Owing to their concentrated form, longer shelf-life and demand in the food industry, these banana based value added products are becoming popular now-a-days.

Though India is the largest producer of banana in the world, its share in world trade of fresh and processed banana is negligible. The demand for banana-based products like aseptic banana puree, banana flakes, powder and juice-based beverage are high in European countries. Despite the demand, India is yet to excel in the export market owing to several reasons. Lack of infrastructure, failure to abide by the quality standards and poor awareness about the scientific packaging techniques among exporters are posing a hindrance to export of fresh and processed banana from India.

Development of new value added products from banana and popularizing them for export is the need of the hour for India. This strategy can put India in the world map as a leading producer and exporter of banana. The project "Development of juice-based beverage and ripe-fruit powder from banana (*Musa* spp.)" was proposed and taken up in this background with the objective to develop a drying and packaging technology for obtaining quality banana powder and to develop a Ready-To-Serve beverage based on clarified banana juice. The project results are discussed hereunder.

5.1 DEVELOPMENT OF TECHNOLOGY FOR RIPE BANANA POWDER

Experiments were conducted on spray, drum and cabinet drying of ripe banana pulp with varied drying temperatures and additive levels to standardize the technology for obtaining quality banana powder. The results of the experiments are discussed below.

5.1.1 Experiments on spray drying

The inlet air temperature of the spray drier and the ratios of additives viz., maltodextrin and soluble starch added to the ripe banana pulp were varied to standardize the technology for producing spray dried banana powder (SDBP).

Of the various inlet air temperatures tried viz., 140 to 180°C, the best product quality with regard to colour, flowability and higher powder recovery was obtained at an inlet air temperature of 150-160°C. This showed that 160°C is the highest inlet temperature in consistent with the product safety. Laxminarayana *et al.* (1997) also used an inlet air temperature of 160°C and outlet air temperature of 95°C to spray dry a mix of ripe banana pulp and condensed milk to obtain banana milk shake powder.

In the present spray drying experiment, it was found that above inlet air temperature of 160°C, the banana powder obtained was charred with burnt flavour and removal of powder from the chamber wall was difficult (wall deposition). It is a well-known fact that higher the inlet temperature of the spray drier, the more rapid the drying rate. But above certain temperature, the product becomes charred and devoid of any flavour.

Sticky point temperature (Tsp) is the temperature at which caking of powder is instantaneous. Tsp is directly proportional to Tg (glass transition temperature). Tg is the temperature at which there is physical change from the hard, solid glassy state to the soft, rubbery liquid state that occurs in amorphous solids when they were heated. Hashimoto *et al.* (2003) reported that elevation of the powder temperature above Tg and Tsp promoted viscous flow and increased the potential of caking.

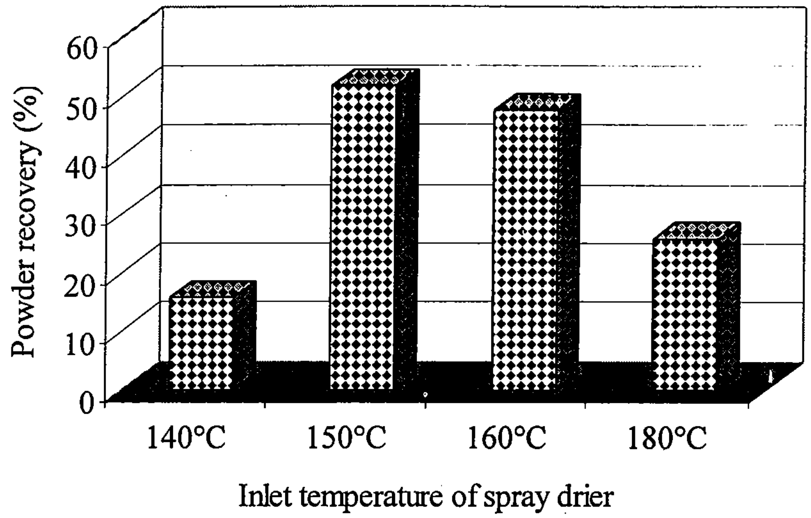


Fig. 9. Effect of inlet air temperature on recovery of spray dried banana powder

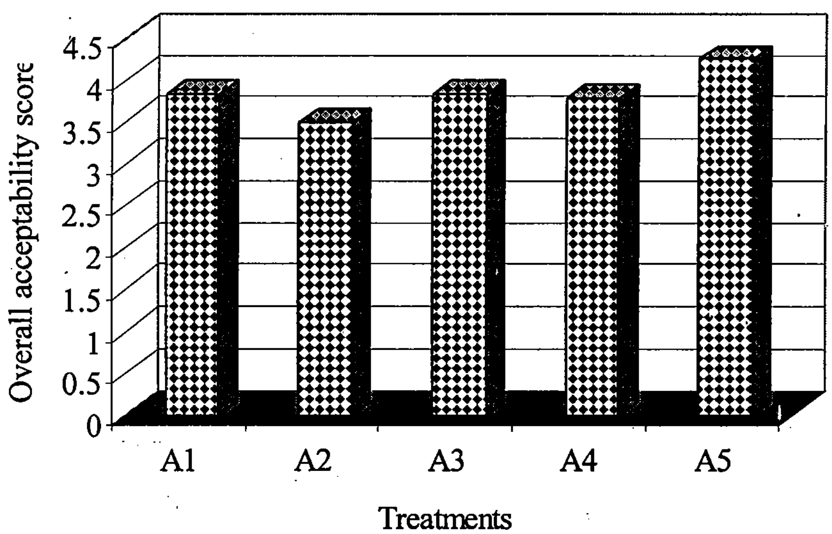


Fig. 10. Effect of additive proportions on overall acceptability of spray dried banana powder

In the present spray drying experiment, inlet air temperature above 160°C promoted wall deposition indicating that the chamber wall temperature and product temperature was evidently above the Tg and Tsp value of the powder. Brennan *et al.* (1971) reported that problems of wall deposition while spray drying were found to be minimized when the chamber wall was cooled to below the sticky point temperature (Tsp) of the product.

Spray drying, being an energy intensive process, the best way to control energy usage is raising the inlet temperature as high as possible, keeping outlet temperature as low as possible, taking full advantage of the energy introduced. The potential of discolouration and high moisture content of final powder should be taken into consideration while fixing the inlet air temperature in a spray drier.

In the present spray drying experiment, inlet air temperature below 150°C showed incomplete drying. The pulp did not dry fully and was sticking to the chamber wall. This was because of the slow evaporation rates insufficient to quickly dehydrate the product quickly. Moreover, the moisture in the incompletely dried pulp decreased the Tg and Tsp values of the semidried pulp. Water is the major component responsible for depressing the Tg of food materials as water has a very low Tg value of -135°C (Johari *et al.*, 1987). Roos and Karel (1991) reported that Tg value of a product decreased as moisture increased.

Brennan *et al.* (1971) reported about the heavy wall deposit and poor powder recovery (1-2%) when concentrated orange juice was spray dried at lower inlet air temperature of 130-140°C. As already discussed, elevation of the chamber temperature above Tg promoted wall deposition and caking. In the present study, inlet air temperature of 140°C was above the low Tg and Tsp of the semi dried moist pulp resulting in wall deposition. Bhandari *et al.* (1997) also reported that the product temperature and chamber wall temperature of spray drier should not cross 10-20°C above Tg of the product.

Based on the above discussion, it is concluded that inlet temperatures of 150°C-160°C is ideal for spray drying of banana pulp, which gave a product of acceptable flavour, better recovery and good free flowing properties.

In the experiment to standardize the proportion of additives viz., maltodextrin and soluble starch added to the Robusta pulp before spray drying, it was found that the proportion 2:3 (maltodextrin:soluble starch) gave the best product quality with regard to colour, flavour, flowability and organoleptic characters. Maltodextrin and soluble starch, which were used as spray drying aids, increased the Tg value (glass transition temperature) and improved powder flowability.

Fruit sugars and acids have low molecular weights and low Tg values. Due to low Tg value, fruit pulps give sticky products on drying. In order to increase the Tg effectively, high molecular materials like starch, maltodextin, corn syrup etc. are added to fruit pulp prior to drying (Lloyd *et al.*, 1996).

Based on the Tg values of sugars and acids present in the fruit pulp, the requirement of maltodextrin is calculated. Tg value is determined by a method called Differential Scanning Calorimetry. Since the facility was not available, in the present study, the additive level of 25% on dry basis (5% on wet basis) was fixed based on the spray drying results of related fruit crops.

Bhandari *et al.* (1993) used 35% maltodextrin (6 DE) for spray drying black currant pulp while Borges *et al.* (2002) used 20-30 per cent maltodextrin for spray drying pineapple and passion fruit juices. Cangrong *et al.* (2001) used a combination of maltodextrin and soluble starch in the ratio 3:2 for spray drying tomato paste. The present research finding of 25 per cent additive level (on dry basis) comprising of maltodextrin and soluble starch in the ratio 2:3 for spray drying ripe banana pulp is in concurrence with the findings in related fruit crops.

Maltodextrins, which are partially hydrolyzed starch, is a non-sweet nutritive saccharide polymer that consists of D-glucose units linked primarily by ∝ (1→4) bonds and has a DE (Dextrose Equivalent) of less than 20. These are used as carrier or bulk agents, texture provider, spray-drying aid, fat replacer, film former, freeze control agent, to prevent crystallization and to supply nutritional value. Orally consumed maltodextrins are partially hydrolyzed by salivary ∝-amylase and further hydrolyzed by pancreatic ∝-amylase to lower saccharides and well absorbed in the human body (Marchal *et al.*, 1999).

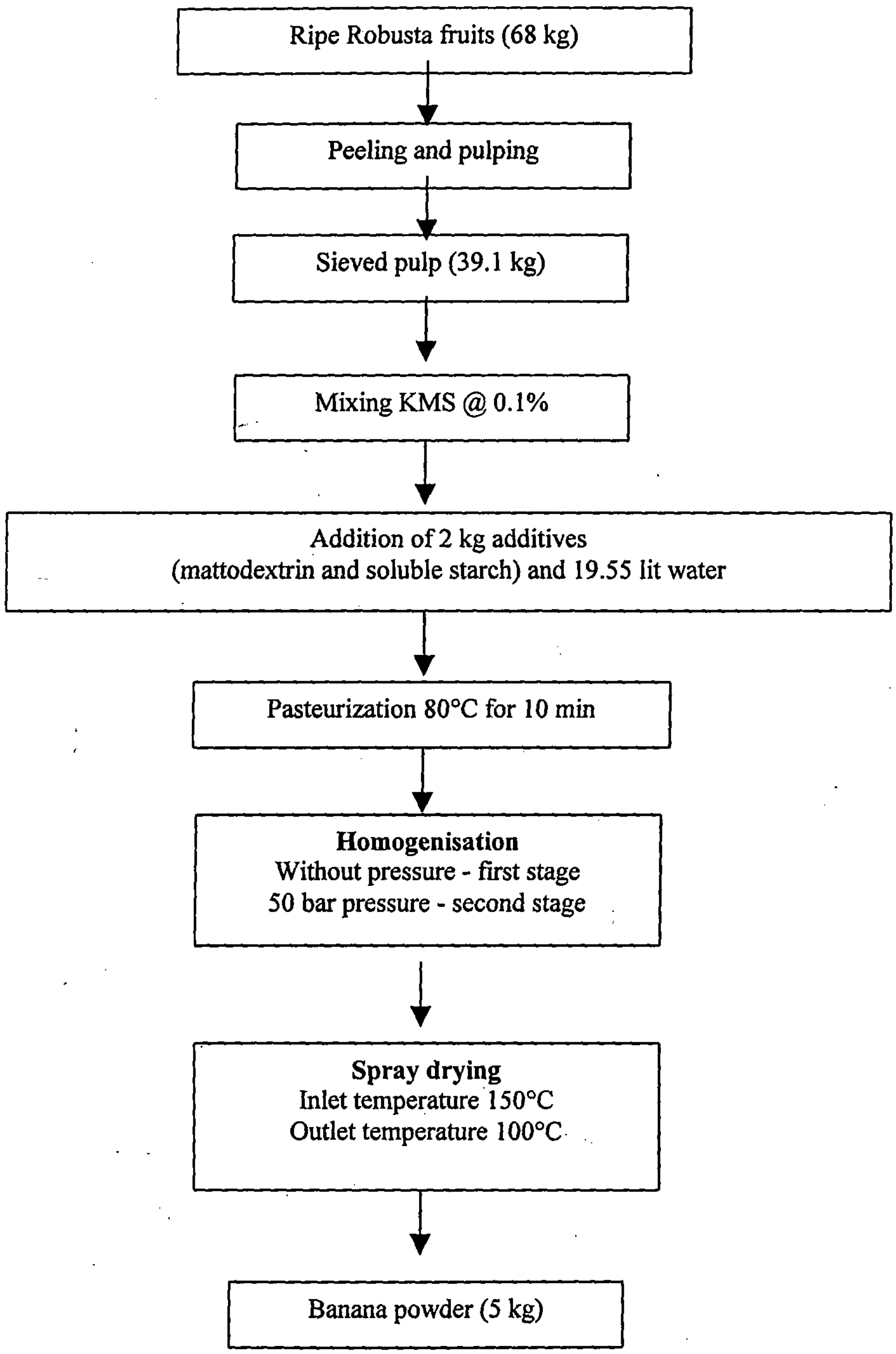
The above observations elicited that good quality spray dried banana powder could be obtained with an inlet air temperature of 150°C and additive proportion of two per cent maltodextrin and three per cent soluble starch (corresponding to 25 per cent additive level on dry basis). The material and process flowchart for spray dried banana powder is given in Fig. 11.

5.1.2 Experiment on drum drying

The drum drying experiment consisted of drying ripe Robusta pulp to which soluble starch at varied levels was added. The drum temperature was maintained at 152°C, steam pressure was maintained at four bar and speed of drum at three revolutions per minute (rpm). Among the various levels of soluble starch, 2.5 per cent (on wet basis) gave the best quality flakes with regard to colour, flavour, moisture and recovery percentage. Greensmith (1998) also reported successful drum drying of banana pulp with two per cent additive and drum temperature of 171°C.

The addition of soluble starch to ripe banana pulp facilitated the gelatinization of the starch during preheating prior to feeding between the rotating heated drums. The gelatinized starch when dried resulted in crisper flakes that could be easily removed from the drums and subsequently powdered. Besides, the addition of starches to banana pulp markedly reduced hygroscopicity and enhanced storage stability.

Fig. 11. Material and process flowchart for spray dried banana powder



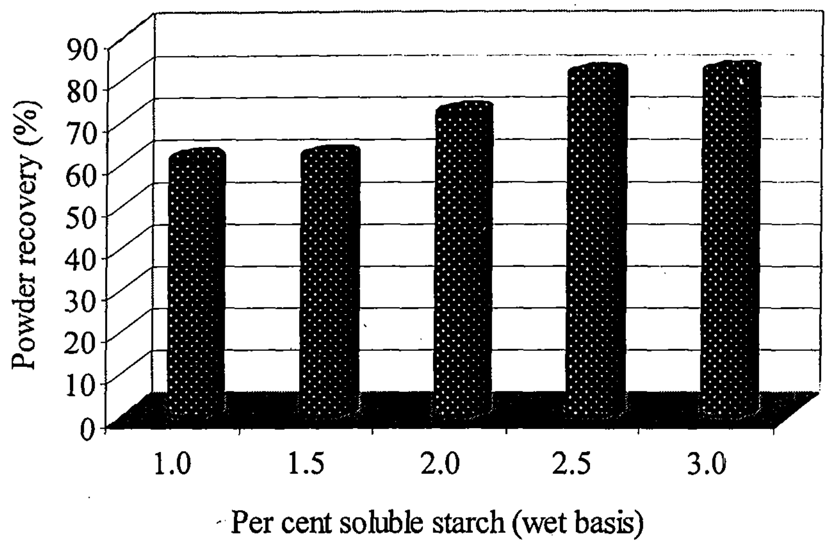


Fig. 12. Effect of additive levels on the recovery of drum dried banana flakes

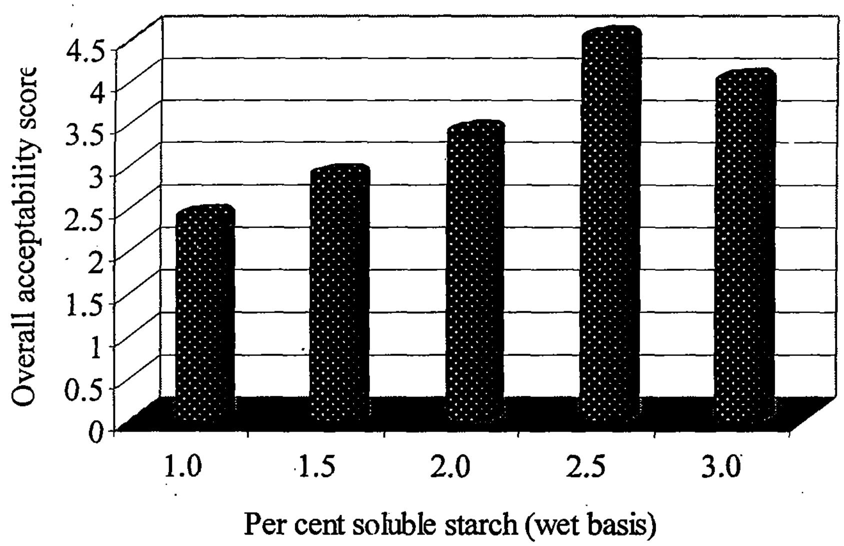


Fig. 13. Effect of additive levels on overall acceptability of drum dried banana powder

Torrey (1974) reported that the drying characteristic of pumpkin puree was improved by adding controlled amounts of starch prior to dehydration on a drum drier. Cai and Corke (2000) reported the reduction in hygroscopicity of spray dried betacyanin extracts from amaranthus by addition of starches to the spray feed.

The 2.5 per cent soluble starch on wet basis, evolved in the present study corresponds to 12.5 per cent starch on dry basis. Torrey (1974) insisted that the amount of starch added to the pumpkin puree to be drum dried should not be more than 30 per cent on dry weight basis. The additive level used in the drum drying experiment is within the limit prescribed.

In the present drum drying experiment, it was found that soluble starch levels less than 2.5 per cent (on wet basis) gave flakes that were moist, dark brown with charred flavour and lesser recovery percentage. The lesser starch increased the hygroscopicity and resulted in moist flakes. These moist flakes remained sticking to the heated drums and could not be removed easily. Therefore the sticky flakes remained attached to the hot drums for a few more seconds resulting in charring and discolouration. This ultimately reflected in lower recovery percentage.

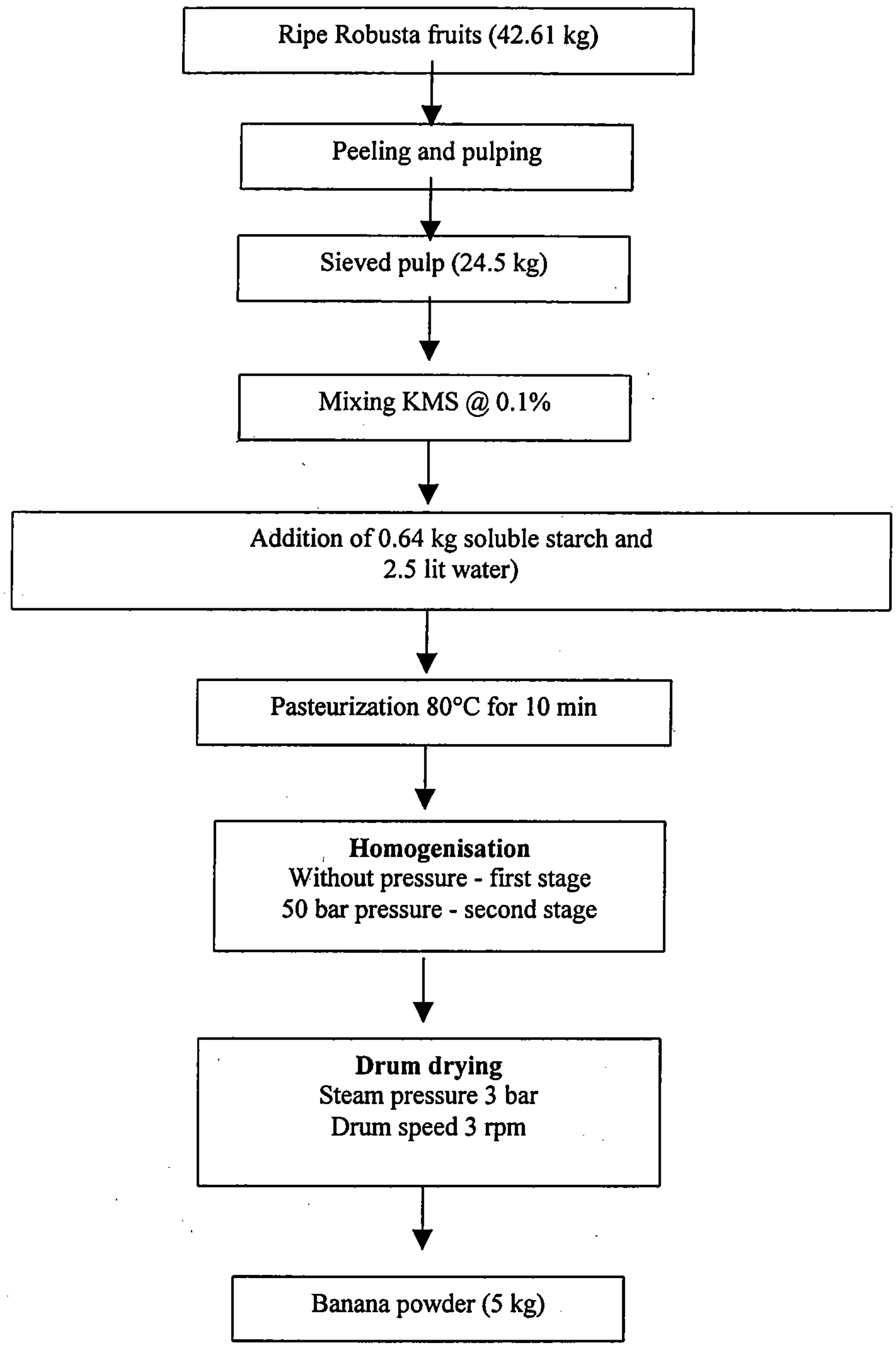
In light of the above discussion, 2.5 per cent soluble starch (on wet basis) as additive could yield good quality drum dried banana powder. The material and process flowchart for drum dried banana powder is given in Fig. 14.

5.1.3 Experiments on cabinet drying

Experiments were conducted with varied drying temperatures and additive levels to standardize technology for production of cabinet dried ripe banana powder.

The ripe Robusta pulp without additive was dried in a cabinet drier at 60°C, 70°C, 80°C and 90°C. Though the drying time decreased with increasing drying temperature, satisfactory dried product could not be achieved. The dried banana pulp

Fig. 14. Material and process flowchart for drum dried banana powder



with moisture in the range of 7.0 to 7.5 per cent, remained leathery and flexible and could not be powdered. Srivastav *et al.* (2002) also reported that fully ripe bael pulp could not be dried to desired level even after 30 hours of drying in a cabinet drier at 60°C. Torrey (1974) found that ripe sliced bananas dipped in aqueous solution of calcium hydroxide took 150 hours to dry at 65°C.

The sugary, thermoplastic and mucilagenous nature of ripe banana pulp made the drying difficult. Moreover, the higher humidity due to evaporation of moisture from the pulp inside the cabinet drier posed a hindrance to the complete drying and evolution of crisper flakes that could be powdered.

Mugula *et al.* (1994) tried to produce banana powder of silk variety (Poovan) by oven-drying of ripe slices at 60°C for 54 hours to a moisture content of 13.73 per cent followed by milling of dried slices. The storage stability of the product (high moisture of 13.73 per cent) and the energy efficiency involved in 54 hours of drying are a matter of concern.

Bhaskar *et al.* (2003) reported that blanched and sulphited ripe banana pulp could be dried in a cabinet drier for 11 hours at 60°C. The dried product with 6.78 per cent moisture was kept in a dessicator and then ground to fine powder. But the banana powder when packed in 150 gauge polyethylene gave a shelf-life of only 30 days under ambient conditions.

In the above report, it is evident that the dried banana pulp with 6.78 per cent moisture when kept in dessicators lost further moisture and therefore were amanable for powdering. But in the present study, dessicators were not used because they can accommodate only very small quantities. Despite the addition of soluble starch to the ripe pulp and use of higher drying temperature (80°C) banana powder could not be produced successfully using a cabinet drier.

This could be due to high fructose in the banana pulp that is very thermoplastic and hygroscopic. More the sugar, more difficult becomes the drying. Wauters *et al.* (2002) opined that carbohydrates when dried from a non-crystallized feed; do not dry properly because of their thermoplastic nature.

Szentmarjay *et al.* (1996) reported that food products with thermoplastic properties became deliquescent and sticky in a definite critical temperature-moisture range. The phenomenon of thermoplasticity was a consequence of hygroscopic nature and 'case-hardening' process.

During drying of thermoplastic pulps like banana, as water moved towards the surface of the product, it tended to carry dissolved solids with it. As the water evaporated from the surface, these solids could be concentrated forming a hard glassy layer known as case-hardening. This in combination with shrinkage effects tended to block pores, preventing effective drying.

Case hardening can be avoided by increasing the relative humidity of the drying air to about 30 to 35 per cent or more so that the rate of drying is slowed during the initial stage. This can be accomplished commercially by mixing fresh and recirculated air. Pallai *et al.* (2001) suggested the use of microwave energy to avoid case hardening and consequently the thermoplasticity phenomenon.

Taking into account the energy involved in very long hours of drying in a cabinet drier, thermoplastic nature of the fruit pulp and practical considerations in use of dessicators during large scale production, it was concluded that the cabinet drying method was not a feasible choice for obtaining ripe banana powder.

5.1.4 Comparison of spray dried and drum dried banana powder

In the present study, an attempt was made to compare the physico-chemical, organoleptic and economics of production of spray and drum dried banana powder so as to suggest the best drying method to obtain quality ripe banana powder.

5.1.4.1 Physical characteristics

Moisture

Moisture is an important parameter in dehydrated fruits, which directly influences the microbial activity, non-enzymatic browning, solubility, bulk density, flowability and hygroscopicity. Moisture determines the storage stability of a product. Lesser the moisture, more the shelf-life.

In the present study, moisture content of spray and drum dried powder did not differ significantly. This could be due to the same drying temperatures used in both drying methods (150°C). In both the powders, the moisture was found to be less than 1.5 per cent, a safe limit for long term storage. The lower moisture content was due to the higher drying temperatures (150-160°C) used in spray and drum drying processes. Al-kahtani and Hassan (1990) reported that moisture content of food powders decreased with an increase in drying temperature.

Laxminarayana *et al.* (1997) reported a moisture content of 2.60 per cent in spray dried ready-to-use banana milk shake powder, while Loesecke (1998) reported a moisture content of 2.59 per cent in drum dried banana powder. The moisture content of banana powder obtained in the present study was lesser compared to the above reports.

Bulk density (BD), Average particle density (AVP) and Percentage volume occupied by powder particles (PVPP)

Bulk density influenced the packaging and transportation costs. In instant fruit powders, manufacturers prefer lower bulk density because the product will look bulkier besides having good instant characteristics. In products used as food ingredients, like banana powder, in the present study, a higher BD may be preferred, with a wider range of particle size - small particles fill the voids between larger ones, excluding air and promoting a longer storage life (Szentmarjay *et al.*, 1996).

In the present study, it was found that the BD, AVP and PVPP of spray and drum dried banana powder did not differ significantly indicating the physical similarity of the powders. This was due to the same drying temperatures employed in both the methods viz. 150°C in spray drying and 152°C in drum drying.

Athanasia *et al.* (2004) opined that increased drying temperatures decreased the bulk density of tomato powder due to an increase in particle size and a greater tendency for the particles to be hollow. Al-Kahtani and Hassan (1990) also reported that the drying temperature was one of the factor that determined the bulk density of roselle powder.

While spray drying, lower bulk density could be achieved by decreased feed rate and feed solids, aeration of the feed, increased viscosity of feed, higher drying temperature and nozzle atomization (Kjaergaard, 1974). Hall and Hedrick (1971) reported that normal bulk density of spray dried milk powder varied between 0.5 to 0.6 g ml^{-1}. The values for bulk density, obtained in the present study (0.70 to 0.72 gml^{-1}) are higher compared to spray dried milk powder. Banana powder, being a food ingredient, a higher BD is preferred.

Solubility

There was no significant difference in solubility between the drum and spray dried banana powder. This could be due to similar moisture levels present in the powders. Papadakis *et al.* (1998) reported that moisture content was one of the factor determining the solubility of raisin extract powder. The solubility values obtained in the present study (89.8-92.40%) was comparable with that obtained by Laxminarayana *et al.* (1997) for banana milk shake powder (90.15%).

Soluble solids and dispersed solids

The spray and drum dried banana powder did not show significant difference in soluble and dispersed solids. This could be due to the similar solubility and dispersibility of the two powders. For a fruit powder, more the soluble solids, better is the instant character.

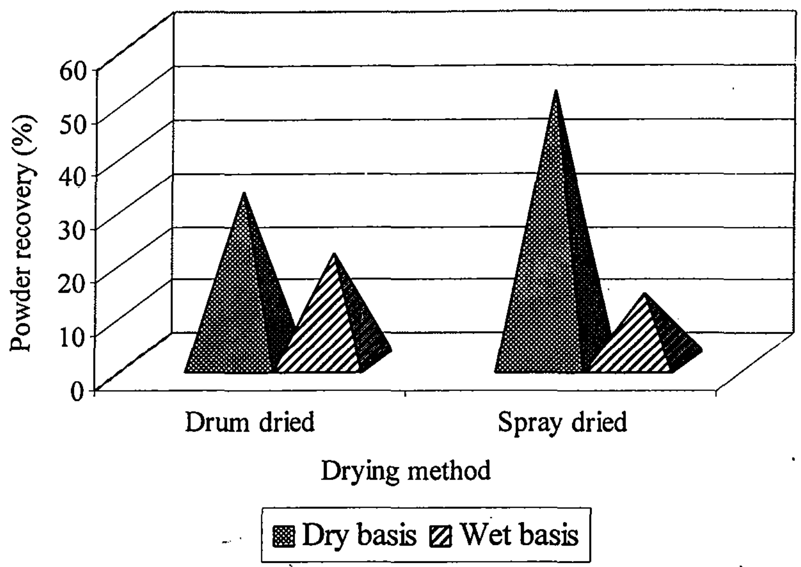


Fig. 15. Banana powder recovery in drum and spray drying methods - A comparison

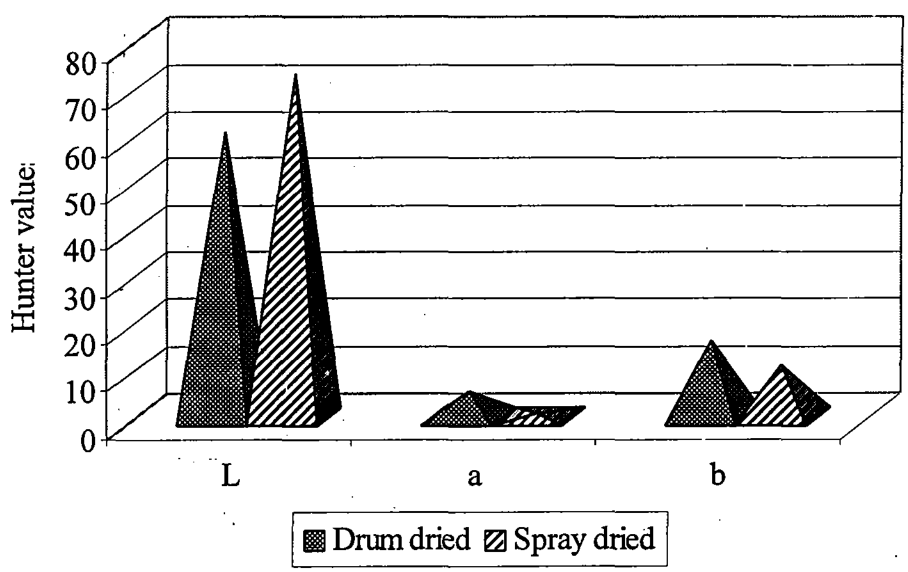


Fig. 16. Hunter colour values of drum and spray dried banana powder

Dispersibility

The non-significant difference in dispersibility of spray and drum dried banana powder could be attributed to the similar bulk density of the two powders and common carrier matrix (soluble starch) used. Reineccius (2004) reported that the dispersibility of spray dried food flavours was influenced by bulk density and the carrier matrix used. He found that generally low density particles were difficult to disperse. In the present study, both drum and spray dried banana powder exhibited a dispersibility above 95 per cent due to their higher bulk densities (0.70 to 0.72 g ml^{-1}).

Sinkability

The drum and spray dried banana powder showed non-significant difference in sinkability. This could be due to similar bulk densities. Sinkability which reflects the rate of sedimentation depended on the bulk density. The more denser the particles, the more the sinkability. Hall and Hedrick (1971) reported that higher the occluded air (low bulk density) in the particle, lower was the sinkability.

Powder recovery

The wet and dry recovery of banana powder was more in drum drying process compared to spray drying. This could be due to the entrainment and wall losses of powder in spray drying.

Loesecke (1998) reported that during spray drying of banana pulp, two major types of powder losses occurred; wall losses and entrainment losses. The former was caused by poor atomization in which the material was thrown against the drier walls where it sticked and became charred. The latter was caused by the powder being carried through the exhaust ducts. He suggested that these losses could be minimised by decreasing the velocity of the exhaust air, installation of efficient dust collectors and proper atomization.

Taking into account the higher dry recovery (82 per cent) and wet recovery (20.4 per cent) of banana powder through drum drying, it may be concluded that for economic production of ripe banana powder, drum drying method was most preferred as it could recover majority of the fruit solids into the final powder. Moreover capital investment required for scaling up of a drum drier is very less when compared to a spray drier.

Additive level in the powder

It was found that the drum dried banana powder contained lesser additive (12.5 per cent) in the final powder than spray dried product. This was due to the use of lesser additive (2.5 per cent soluble starch on wet basis) in the drum drying process compared to the spray drying method (five per cent additive on wet basis).

For a fruit powder, more of fruit solids (> 50%) and less of additive solids (< 40%) is the preferred character. The presence of higher amounts of fruit solids in drum dried banana powder reflected its superior quality.

Rehydration ratio

The rehydration ratios of drum and spray dried banana powder were on par with each other. This was due to the similar moisture contents and hygroscopicity of the two powders.

Sagar (2001) reported that osmotically dehydrated onion flakes showing lesser rehydration ratio when less hygroscopic. Banana powder, being highly hygroscopic showed higher rehydration ratios of 4.67 and 4.85 for drum and spray dried powders respectively.

Hunter colour values

The spray dried banana powder showed higher 'L' value and lower 'a' and 'b' hunter values compared to drum dried powder. The higher 'L' value reflected the visual lightness and lower 'a' and 'b', the lesser redness and yellowness of the spray dried powder. The hunter readings indicated the off-white colour of the spray dried powder and the yellow colour of the drum dried product.

The lighter colour of the spray dried powder was due to lesser drying time, higher additive level and lesser feed TSS. The yellow colour of the drum dried powder could be due to the caramelisation of sugar during the drying process when the pulp remained attached to the hot revolving drum for a few more seconds compared to the spray drying process. Similar result was obtained by Maya (2004) while drying sapota pulp.

5.1.4.3 Micro structure

The microstructure of spray dried banana powder was spherical with smooth surface. Similar reports exist in spray dried coconut powder by Ganesan and Gothandapani (1999) and spray dried sapota-milk beverage powder by Maya (2004).

Particle shape strongly influences the appearance, flowability and dispersibility of a powder. Spherical particles are desirable for higher aroma retention, higher bulk density and best flowability (Reineccius, 2004).

The present study revealed that the microstructure of drum dried banana powder was elongated oblong with rough surface. The particle size was also larger compared to the spray dried product. This was due to the mechanical process of milling the drum dried banana flakes in the mixie, which has resulted in larger particles with irregular shapes and sizes. Another reason could be due to the mechanical pressing of the feed between the drums while the feed pulp is carried forward in the drum drier.

5.1.4.4. Moisture sorption behaviour

Water is often the main component of a foodstuff which also contains carbohydrates, proteins, fats and mineral salts. At particular conditions of temperature and moisture, the interactions between these constituents can cause browning, lipid oxidation and other deteriorative changes besides providing appropriate conditions for microbial growth.

Moisture sorption isotherms, depicting the relationship of moisture content of a food product with the water activity at a given temperature, are therefore of special interest in the design of food preservation processes such as drying, packaging, storage etc. They are required for the prediction of food stability, shelf-life, glass transitions and for estimating drying times (Khalloufi *et al.*, 2000).

In the present study, the critical points (stage at which product just becomes lumpy) were found to be 5.10 per cent and 4.8 per cent moisture for drum and spray dried banana powder respectively. In both powders, the Equilibrium Relative Humidity (ERH) at critical points was less than 50 per cent. Products having ERH less than 50 per cent are usually considered hygroscopic (Ranganna, 1995) and therefore the banana powder falls under hygroscopic category requiring special packaging with protection from moisture pick-up, oxidation and flavour loss.

The sorption isotherms observed for spray and drum dried banana powder followed a sigmoidal pattern. Vidales *et al.* (1995) reported sigmoidal sorption isotherms for sugar impregnated strawberries. Mathlouthi and Roge (2003) also reported that two isotherms most frequently found for food products are Type 2 (sigmoidal) and Type 4 (J type) isotherms.

In the case of fruit powders, the moisture sorption isotherms may be used to predict caking. The caking (or lumping) of fruit powders can be considered as a spontaneous agglomeration phenomenon. It is generally caused by wetting of the particle surface which causes its plasticization and dissolution (Mathlouthi and Roge, 2003). For safe long term storage of fruit powders without caking, the moisture content of the product should not go above the critical moisture content. The caking phenomenon is observed when product moisture raises above the critical moisture content at which water is released from the powder particles, which form solid bridges and agglomerate.

The storage temperature together with water content play a major role in the process of plasticization that leads to the agglomeration of food powders (caking). So suitable moisture proof packaging material such as aluminium foil laminated pouches should be chosen for packaging the hygroscopic banana powder so that the products do not cross their critical moisture contents during storage.

In a moisture sorption isotherm, the layer below the danger point corresponds to the monolayer which is used to establish the most stable moisture content of dried foods. At the monolayer, the rate of deterioration is theoretically zero since there is not enough water present to act as a solvent to move molecules around to react and deteriorate (Hardy *et al.*, 2002). In the present study, the danger points of drum and spray dried banana powder were found to be 4.40 and 4.10 per cent moisture respectively. These moisture contents are the safe limits for stable long-term storage of banana powder without deterioration, and hence such moisture barrier packaging materials like aluminium foil laminated pouches are needed.

5.1.4.4 Chemical characteristics

The higher total soluble solids, reducing sugar, total sugar and crude fibre recorded in drum dried banana powder could be due to the higher fruit solids present (87.5%) compared to spray dried powder (75.0%). Similar result was reported by Maya (2004) in roller dried sapota-milk beverage powder.

The higher acidity, protein and total ash observed in spray dried banana powder could be due to the higher levels of starch (Maltodextrin and soluble starch) used as additive.

The measurement of alcohol soluble colour at 420 nm indicated the degree of non-enzymatic browning (NEB). The lower NEB for spray dried powder reflected its lighter colour compared to drum dried powder. This was due to the lesser drying time, higher additive level and lower TSS of the feed in the spray drying method. The higher TSS of the feed during drum drying of banana pulp could have resulted in caramelisation imparting a yellowish colour to the drum dried banana powder and thereby higher NEB value.

5.1.5.6 Gas chromatography - Mass spectrometry

GC-MS analysis

The flavour compounds identified through GC-MS analysis in fresh pulp, spray and drum dried banana powder were predominantly alcohols and their esters. This confirms the finding of Seymour (1993) who stated that esters account for about 70 per cent of the volatile compounds in banana wherein acetates and butyrates predominate.

The compounds identified in fresh Robusta pulp were 2 pentanol, 3 hydroxy 2 butanone, 3 methyl 1 butanol, Hexanal, E2 hexenal, Isoamyl acetate and isoamyl butyrate. Similar compounds were also reported by Jordan *et al.* (2001) in fresh banana.

In the present study, except isoamyl butyrate, no other compounds present in fresh pulp could be detected in spray and drum dried banana powder. This could be due to the higher drying temperature (> 150°C) employed in the spray and drum drying processes which volatilized the flavour compounds. It was found that the boiling points of flavour compounds present in fresh banana was less than 150°C and therefore these compounds got volatilized during the drying process. Isoamyl butyrate, with a boiling point of 185°C could be retained in the banana powder.

The flavour compounds viz., Diethyl succinate, 2 phenyl ethanol, Furaneol and ethyl cinnamate, though not found in fresh banana, could be detected in spray and drum dried banana powder. These could probably be generated during the thermal dehydration process involving degradation of sugars and amino acids.

Miranda *et al.* (2001) reported that Furaneol (4-hydroxy-2, 5-dimethyl-3 (2 H) - furanone) was formed from thermal degradation of 6-deoxysugars in the presence of amino acids and hexoses. Furaneol is also detected in heat processed foods such as cooked beef, roasted almonds, popcorn and roasted coffee. It gives a fruity caramelized odour and taste.

Miranda *et al.* (2001) found that ethyl cinnamate was responsible for the most characteristic note of banana passa (a dehydrated ripe banana fruit). So it is concluded that the characteristic fruity caramel flavour in banana powder is due to Furaneol and the banana fig like aroma is contributed by ethyl cinnamate. These two major compounds in addition to other compounds characterize the peculiar fruity flavour of spray and drum dried banana powder.

5.1.4.7 Organoleptic evaluation

The flavour, texture and overall acceptability scores of drum and spray dried banana powder were on par with each other indicating their organoleptic similarity. This may be due to their comparable physical and chemical characteristics. The off-white colour of spray dried powder fetched higher organoleptic colour scores compared to the yellow colour of drum dried powder. Though colour wise, spray dried powder was superior, the taste panel ranked both the powders in the same scale as evidenced by the overall acceptability scores.

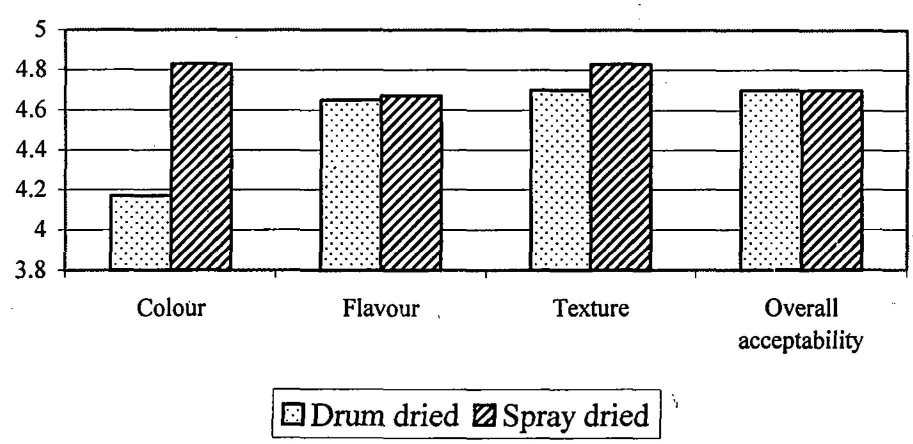


Fig. 17. Organoleptic characters of drum and spray dried banana powder

5.1.4.8 Cost of production

The cost of production for 100 grams of spray and drum dried banana powder worked out to be Rs.26.61 and Rs.18.66 respectively. The spray dried powder was 42.6 per cent costlier compared to drum dried powder. This was due to the higher cost of raw material and machineries. The raw material cost was more for spray dried powder owing to lesser powder recovery which necessitated the use of larger quantities of banana. Taking into account the economics of production and quality characteristics, drum dried banana powder seems to be a cheaper and comparable alternative to spray dried banana powder.

5.1.5 Packaging and Storage studies

Fruit powders considerably deteriorate during storage. The rate of degradation usually depends on the type of packaging material, packaging method and storage conditions. The drum dried and spray dried banana powder were evaluated for their shelf-life, physical, chemical and microbial changes during storage under ambient conditions after packaging with two types of materials viz. metallised polyester pouches and aluminium foil laminated pouches with four methods of packaging viz. nitrogen flushing, CO_2 flushing, vacuum pack and air pack.

5.1.5.1 Packaging material and shelf-life

The drum and spray dried banana powder could be stored for more than a year under ambient conditions when packed in aluminium foil laminated pouches whereas in metallised polyester pouches, the shelf-life was only three months. This was due to the characteristic qualities of the aluminium foil pouches like good barrier properties for light, gases, oils, volatile compounds and water vapour. The excellent barrier properties of aluminium foil protected the product against moisture ingress, discolouration, caking and flavour loss.

Aluminium foil pouches are particularly useful in packaging hygroscopic products like banana powder. Aluminium foil laminate used here also have extra features like temperature resistance, strength, durability, compatibility, flexibility, printability, non-toxicity, low weight and corrosion resistance.

The metallised polyester pouches manufactured by vacuum deposition of a thin continuous layer of metal on to a polyester film has good barrier properties compared to polyethylene but higher permeabilities to oxygen and water compared to aluminium foil laminates (eg.) water permeability of aluminium foil laminate is less than 0.05 g/m^2/day compared to 2.52 g/m^2/day for metallised polyester (Gvozdenovic *et al.*, 2000) and this explains the reason for lesser shelf life in metallised polyester pouches.

Owing to the low moisture permeability of aluminium foil, banana powder remained free flowing with minimum browning even after one year of storage under ambient conditions. Therefore it is concluded that aluminium foil laminated pouches are needed for packing hygroscopic banana powder.

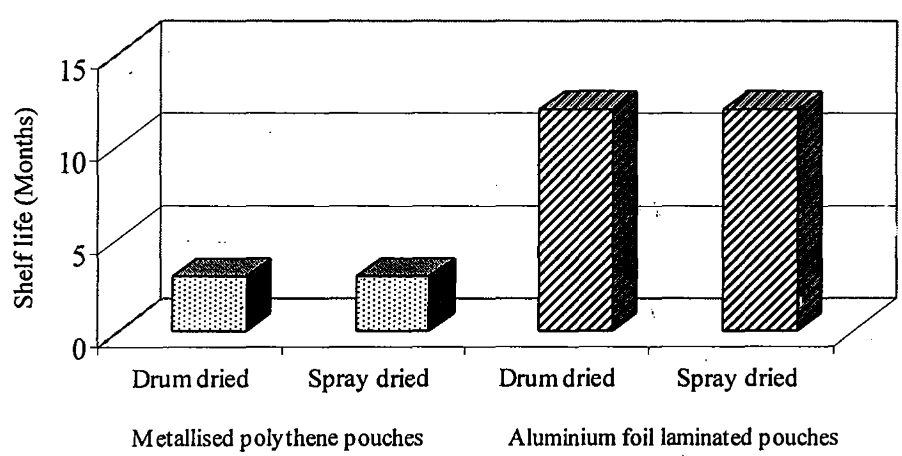


Fig. 18. Effect of packaging material on shelf life of banana powder at room temperature

5.1.5.2 Packaging methods and quality of banana powder during storage

Packaging is a means of providing the correct environmental conditions for food during the length of time it is stored and/or distributed to the consumer. The atmospheric oxygen can deteriorate the dried foods through the oxidative phenomena that it produces. The action of oxygen can be eliminated by packaging methods like vacuum packing, flushing with nitrogen and carbon-di-oxide. The changes in physico-chemical, microbial and organoleptic characters during storage of banana powder packed using various methods under ambient conditions are discussed below.

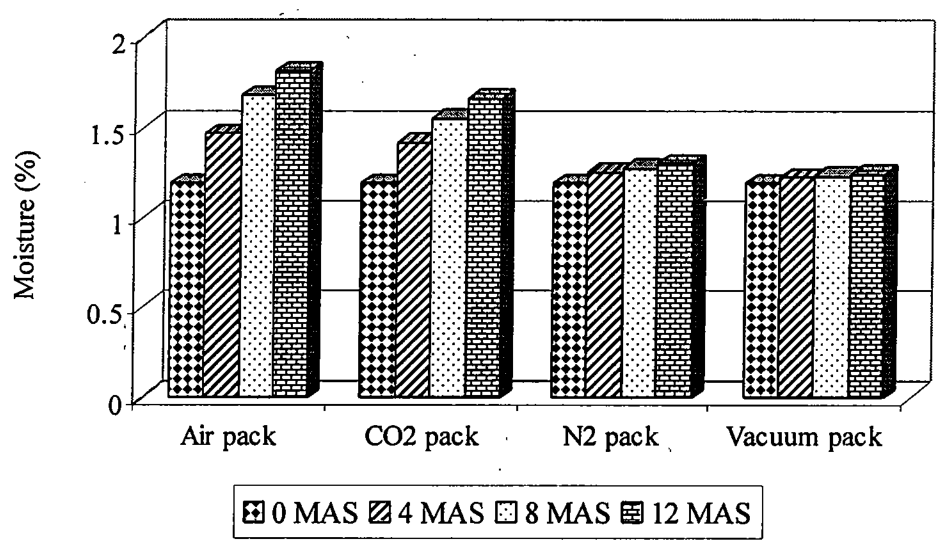


Fig. 19. Changes in moisture pickup during storage of drum dried banana powder in aluminium foil pouches

MAS - Months after storage

Changes in physico-chemical characters

Irrespective of the packaging methods, the moisture, non-enzymatic browning, reducing and total sugar of the banana powder progressively increased throughout the storage period whereas the acidity of the powder decreased. Similar trend was reported by Roy and Singh (1979b) in bael fruit powder, Kumar and Sreenarayanan (2000) in dehydrated onion flakes and Sagar *et al.* (2000) in ripe mango powder.

The increase in reducing and total sugar of banana powder during storage is attributed to polysaccharide hydrolysis and non-reducing sugar inversion. The decrease in acidity during storage could be due to the increase in reducing sugars and pick up of moisture by the powder.

The moisture increase was more in metallised polyester pouches compared to the aluminium foil. This was due to the higher permeability of metallised polyester to water vapour (2.52 $g/m^2/day$) compared to aluminium foil laminates (< 0.05 $g/m^2/day$). The increase in the non-enzymatic browning of banana powder during storage was due to the increase in moisture of the product.

Among the packaging methods, moisture and non-enzymatic browning during storage were minimum in vacuum packed samples and maximum in air packed (control) samples. The lesser moisture in vacuum packed samples was due to the elimination of air from the package by creation of vacuum. Sagar *et al.* (1999) also reported lower moisture in vacuum packed dehydrated ripe mango slices.

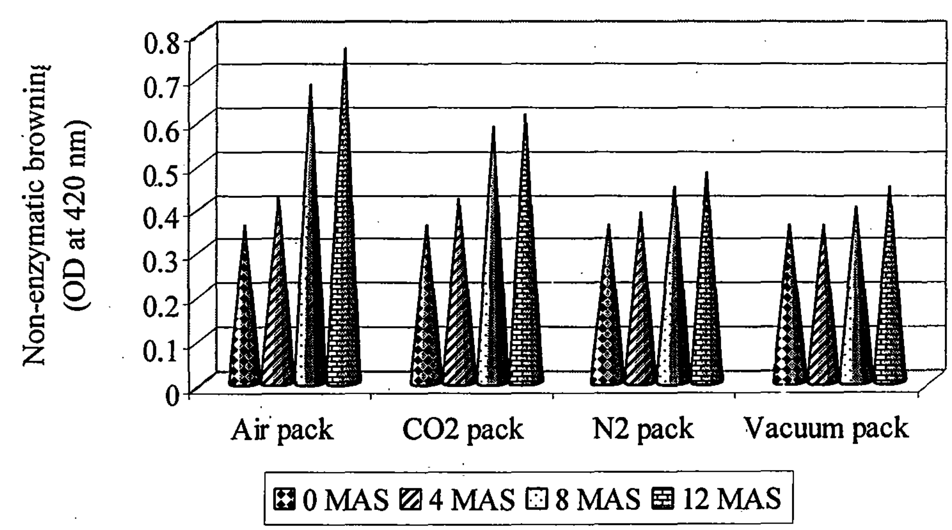


Fig. 20. Changes in non-enzymatic browning during storage of drum dried banana powder in aluminium foil pouches

MAS - Months after storage

The lower non-enzymatic browning (NEB) in vacuum packed banana powder was due to lesser moisture and absence of air in the pack. Browning in dehydrated foods may be produced by the interaction of the nitrogenous constituents with the sugars and organic acids (Maillard reaction). The rate of browning depends on factors like pH, moisture, storage temperature and storage atmosphere. NEB increases when the product moisture increases and when the product is exposed to air. Gvozdenovic *et al.* (2000) reported that browning of powdered orange depended on the barrier characteristics of the packaging material as well as the packing condition. It was found that vacuum packing had the greatest protective effect against browning.

Changes in Hunter colour values

The increase in Hunter values 'a' (redness) and 'b' (yellowness) with decrease of 'L' (visual lightness) during storage of banana powder under ambient conditions was due to the darkening of the product. The higher 'L' value and lower 'a' and 'b' hunter values in vacuum packed samples reflected the lesser browning of the product compared to the air packs (control). The presence of oxygen is very important in non-enzymatic browning reaction. The absence of air in vacuum packed samples greatly reduced the browning reaction. Similar result was observed by Lal *et al.* (1989) in freeze dried banana powder.

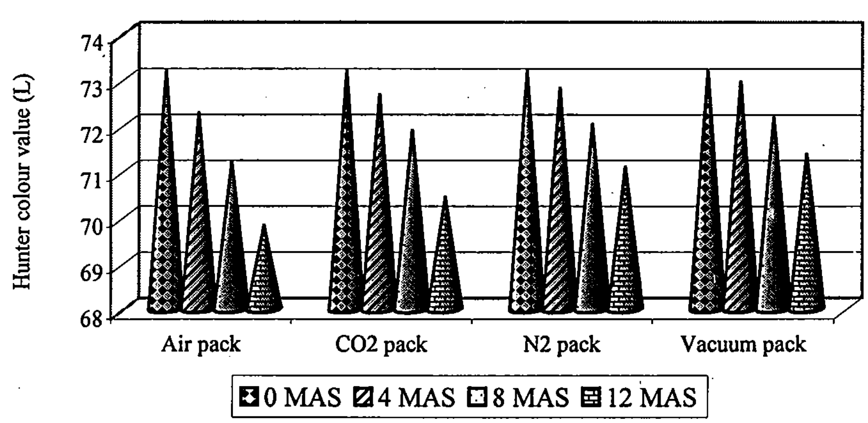


Fig. 21. Changes in hunter colour value (L) during storage of spray dried banana powder in aluminium foil pouches

MAS - Months after storage

Changes in microbial status

The bacterial and fungal counts during storage of banana powder in aluminium foil laminated pouches remained well within the limits prescribed by ICMSF (1986) even after one year of storage under ambient condition indicating the microbial safety of the product. However, samples packed in metallised polyester pouches showed bacterial counts exceeding the prescribed limit (10 x 10^3 cfu/g) at the end of three months of storage indicating that the packaging material was not ideal for long term storage of banana powder. The higher permeability of metallised polyester pouches to oxygen and water resulted in faster degradation of the powder and reduced shelf-life.

Among the packaging methods, the vacuum packed powder recorded the lowest bacterial and fungal counts. This was due to the low moisture and absence of air in vacuum packs which inhibited the growth of micro-organisms.

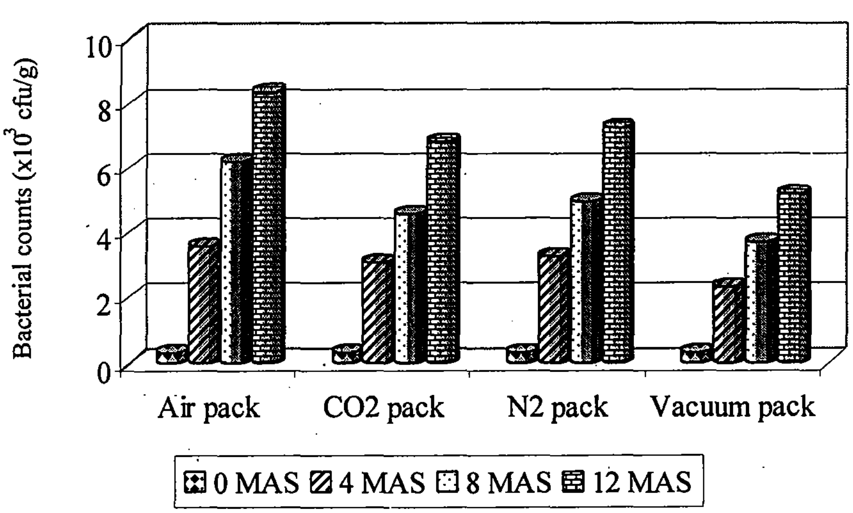


Fig. 22. Changes in bacterial counts (x10^3 cfu/g) during storage of spray dried banana powder in aluminium foil pouches

MAS - Months after storage

Changes in organoleptic characters

Banana powder packed in aluminium foil laminated pouches remained organoleptically acceptable for one year whereas those packed in metallised polyester pouches remained acceptable only for three months under ambient conditions. The good barrier properties of aluminium foil reduced the chemical and microbial deterioration of the banana powder. Therefore the powder remained free flowing with minimum changes in colour, taste and texture throughout the storage period.

The higher colour and flavour scores in vacuum packed samples were due to lesser browning and retention of flavour compounds under vacuum. Nitrogen packed samples showed the highest scores for texture. The lesser moisture and elimination of air by the inert nitrogen maintained the texture of the powder particles.

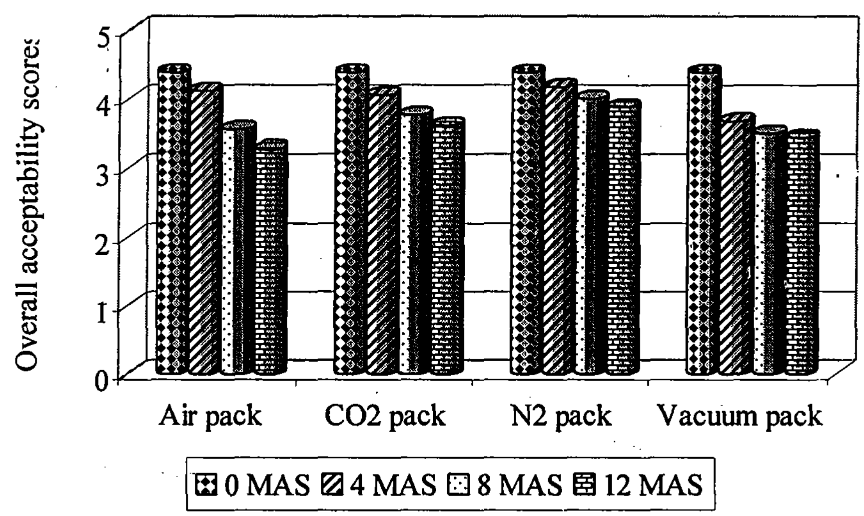


Fig. 23. Changes in overall acceptability scores during storage of drum dried banana powder in aluminium foil pouches

MAS - Months after storage

The least scores for texture in vacuum packs were due to the compression of the powder particles into a hard mass which affected the flowability, texture and visual appeal. Ranganna (1995) also stated that vacuum packing was not advisable for fruit powders due to the compression and caking of particles.

The highest scores for overall acceptability recorded by the nitrogen packs were due to the better retention of colour, flavour and texture. Nitrogen packing effectively delayed the onset of deteriorative auto-oxidative reaction. Sagar *et al.* (1999) also observed that nitrogen packed dehydrated ripe mango slices retained the colour and quality during storage under ambient conditions.

5.2 DEVELOPMENT OF TECHNOLOGY FOR BANANA JUICE BASED BEVERAGE

The results of experiments carried out on enzyme aided banana juice extraction with different varieties, blending of clarified juice with other fruit juices and storage stability of banana-mango RTS beverage are discussed below.

5.2.1 Experiment on enzyme aided banana juice extraction

The pulp of four varieties of banana viz. Robusta, Poovan, Palayankodan and Karpooravalli were treated with commercial pectinase enzyme @ 5 ml/kg of pulp and incubated at two temperatures viz. 50°C for two hours and room temperature for four hours. The results are discussed below.

Physico-chemical characters of banana juice

Among the four banana varieties, Palayankodan recorded the maximum juice recovery and Karpooravalli the least. This could be due to the genomic difference between the varieties. Palayankodan with genome AAB has more of acuminata strain and more amanable for juice extraction. The Karpooravalli genome being ABB with more of balbisiana characters imparted a starchy consistency to the pulp and therefore lesser juice recovery.

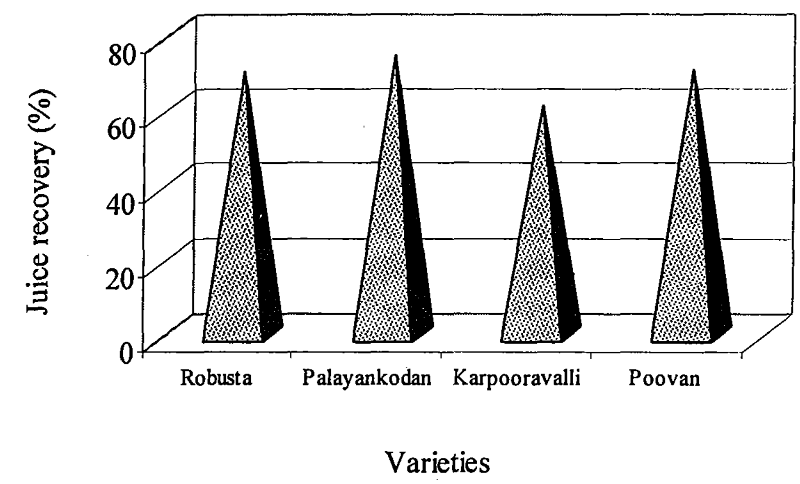


Fig. 24. Recovery of enzyme clarified banana juice

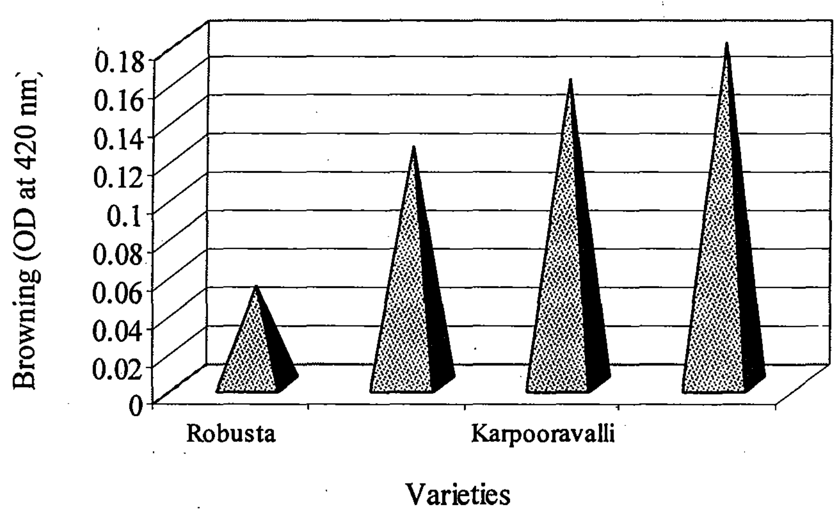


Fig. 25. Browning in enzyme clarified banana juice

The higher total solids and sugars in Karpooravalli juice were due to the sweeter pulp. The increased acidity of Palayankodan pulp reflected in the maximum acidity of its juice. The low non-enzymatic browning (NEB) of Robusta juice indicated the attractive light yellow colour of the juice.

In the present study, the banana juice yield ranged from 60-75 per cent. Viquez *et al.* (1981) reported a juice yield of 66 per cent while Yu and Wu (1987) obtained a juice yield of 69 per cent from banana treated with pectinase enzyme.

Among the incubation temperatures, the juice recovery was more at room temperature than at 50°C. This could be possibly due to the longer hours (four hours) of incubation at room temperature compared to two hours at 50°C. Though the enzyme activity is higher at 50°C compared to room temperature (28°C), the longer hours of incubation at room temperature exposed the pulp to the enzyme for longer time leading to breakage of pectic bonds effectively. This reflected in the higher juice recovery at room temperature.

The total soluble solids (TSS), total sugars and acidity were higher for juice extracted at 50°C. This could be due to the higher starch hydrolysis. Similar observation was made by Kyamuhangire *et al.* (2002) in banana juice. The lesser non-enzymatic browning of juice incubated at room temperature indicated the lesser maillard type browning. At higher temperature, the maillard reaction is faster and therefore the NEB of juice incubated at 50°C was higher. Based on the juice recovery, quality and colour of clarified juice, the enzymatic extraction of banana pulp incubated at room temperature for four hours was found superior.

Organoleptic characters of banana juice

The incubation temperatures did not affect the organoleptic scores but among the varieties, Robusta juice ranked first for taste and overall acceptability. This was due to the well balanced brix/acid ratio, flavour and colour of the juice. Robusta juice was selected for further blending and bottling studies based on its organoleptic superiority.

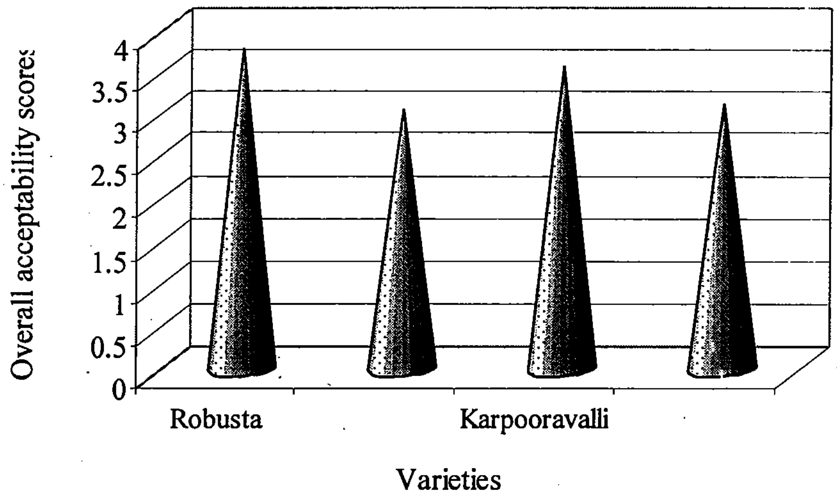


Fig. 26. Overall acceptablity scores of enzyme clarified banana juice

5.2.2 Experiment for selection of best blending proportion of banana juice

Clarified Robusta juice was blended with juices of Pineapple, Mango, Guava and Mandarin orange in various proportions. The RTS made from such blended juice were evaluated for their bio-chemical and organoleptic quality.

The 50:50 blend of banana with other fruit juices gave the highest scores for taste and overall acceptability. The juice blends with higher proportion of banana juice (> 50%) gave lesser organoleptic scores owing to the poor colour and acidic taste of banana juice. The disadvantages in banana juice viz. non-attractive colour and acidic taste could be overcome by mixing equal amounts of other fruit juice. The excellent flavour of banana juice together with the colour and taste blend of other fruits contributed to a better RTS beverage compared to RTS made with 100 per cent banana juice.

Blending of fruit juices helps in improving nutrient elements, reducing cost of production by using cheaper fruits in the blends and also leads to new product development (Kalra *et al.*, 1991). Blending with banana juice helped in incorporating the excellent flavour of banana into the beverage besides reducing the cost of production. Blending also masked the defects in banana juice such as acidic taste, poor colour and consistency. Sahni and Khurdiya (1993) observed that blended nectar of mango with pineapple in the ratio 2:2 markedly upgraded the colour of the beverage. Bhupinder *et al.* (2003) found that the inkling flavour of papaya was masked by the sweet flavour of mango in the RTS prepared with 90:10 papaya to mango blend.

5.2.3 Experiment for selection of best fruit blend with banana juice

Of the various fruits blended with banana viz. mango, orange, pineapple and guava, the banana-mango RTS gave the best quality in terms of physico-chemical and organoleptic attributes. The excellent flavour and acidic taste of banana juice blended very well with the superior colour and consistency of mango pulp and therefore preferred by the panelists over other fruit blends.

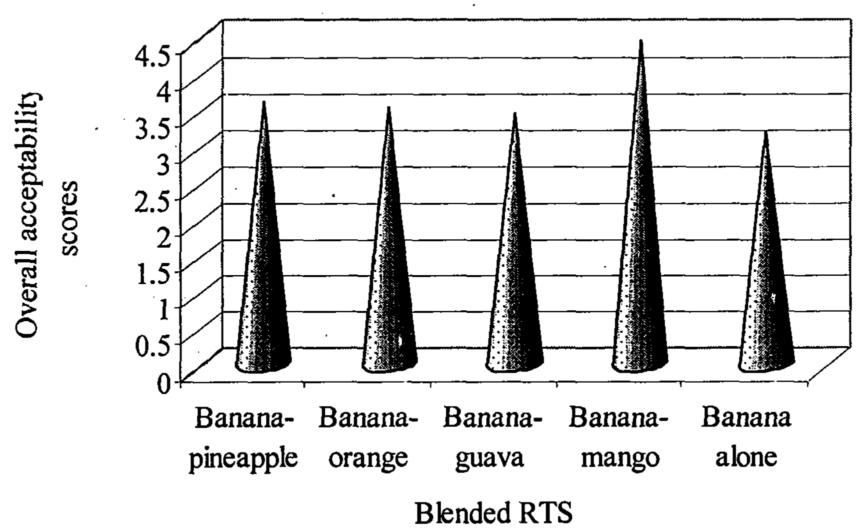


Fig. 27. Overall acceptablity scores of banana RTS blended with various fruit juices

The mango pulp imparted the attractive orange colour and thicker consistency to the RTS and therefore helped to overcome the defects in banana juice. The mango pulp also contributed to the carotene and markedly upgraded the nutritional status of the RTS. Sahni and Khurdiya (1993) reported that the pale colour of pineapple juice could be overcome by blending with mango juice.

5.2.4 Storage studies on banana-mango RTS beverage

The storage stability of banana-mango RTS beverage under ambient conditions was studied for a period of six months. It was found that the total soluble solids, acidity and reducing sugar increased during storage while the total sugars decreased. Similar trend during storage was reported by Teotia *et al.* (1997) in Muskmelon RTS beverage and Krishnaveni *et al.* (2001) in jackfruit RTS beverage. The colour index of banana-mango RTS beverage was higher than banana RTS alone because of the rich orange colour imparted by the mango pulp.

The banana-mango RTS could be successfully stored upto six months under ambient conditions without any deterioration as evidenced by the acceptable microbial counts and organoleptic scores. The blended banana-mango RTS was organoleptically superior to banana RTS. The blended RTS had attractive orange colour, good flavour, thicker consistency and better taste than the banana RTS which was dull coloured with thinner consistency.

5.2.5 Cost of production

The cost per bottle (200 ml) of banana-mango RTS was Rs.3.84 while that for pure mango RTS was Rs.4.23 (Appendix-IV). Compared to pure mango RTS, the blended beverage was cheaper besides giving the same quality attributes with regard to colour, flavour, texture and taste. By blending mango juice with banana juice, the cost of production of pure mango RTS can be brought down.

Summary

6. SUMMARY

The present investigation on "Development of juice-based beverage and ripe-fruit powder from banana (*Musa spp.*)" was undertaken at the department of Processing Technology, College of Horticulture, Vellanikkara during the period 2001-2004 utilizing the facilities at CFTRI, Mysore. The objectives of the study were to develop a drying and packaging regime for ripe banana powder and to develop a beverage based on clarified banana juice.

Technology for spray and drum dried banana powder was standardized through drying and packaging experiments. Good quality spray dried banana powder could be obtained with an inlet air temperature of 150°C, keeping the outlet temperature at 100°C with two per cent maltodextrin and three per cent soluble starch on wet basis as additive.

Successful drum drying could be achieved with drum temperature of 152°C with drum speed of three rpm and soluble starch 2.5 per cent on wet basis as additive. Drum drying was found better in terms of higher recovery, lesser additive, better quality and lesser cost of production.

Moisture sorption studies revealed that banana powder was highly hygroscopic requiring special packaging techniques. Gas Chromatography-Mass Spectrometry analysis revealed that the caramelized fruity fig like aroma of banana powder was due to Furaneol and Ethyl cinnamate. Banana powder could be stored for one year under ambient conditions without deterioration when packed in aluminium foil laminated pouches with nitrogen.

Banana powder can be used as an ingredient in baby food, health food, instant beverage mix, breakfast cereals, flavourings, bakery and dairy products. The cost of production of 100 grams of spray and drum dried banana powder worked out to be Rs.26.61 and Rs.18.66 respectively.

The technology for banana juice based beverage was also standardized. Clear banana juice could be extracted using commercial pectinase enzyme @ 5 ml / kg pulp and incubating for four hours at room temperature. Robusta juice was superior in terms of colour, flavour and overall acceptability compared to Poovan, karpooravalli and Palyankodan juices.

Blended banana-mango RTS beverage in the ratio of 50:50 was preferred by the taste panel over other fruit blends. The disadvantages in banana juice viz., lack of colour, consistency and acidic taste could be overcome by mixing equal amounts of mango juice. Blending banana juice with mango pulp helped in incorporating the excellent flavour of banana and reduced the cost of production of mango RTS beverage.

The cost of production of banana-mango RTS beverage when worked out came to be Rs.3.84 per 200 ml bottle while that of pure mango RTS beverage was Rs.4.23. The blended RTS beverage could be stored for six months under ambient condition without deterioration. With liberalization in industrial policy and globalization, more opportunities are created for export of value added and nutritious products from banana. India being the largest producer of banana in the world can tap this potential by exporting products like ripe banana powder and juice based beverages.

References

REFERENCES

Adeyemi, I.A., Akanbi, C.T. and Fasoro, O.G. 1991. Effect of soyfractions on some functional and rheological properties of maize-banana mixtures. *J. Fd. Process. Preserv.* 15: 31-43

Al-Kahtani, H.A. and Hassan, B.H. 1990. Spray drying of roselle (*Hibiscus sabdariffa* L.) extract. *J. Fd. Sci.* 55: 1073-1076

Ambadan, S. 1985. Sapodilla, a delicious dehydrated product. *Indian Hort.* 30: 13

Amerine, M.A., Pangborn, R.N. and Rosessler, F.B. 1965. *Principles of Sensory Evaluation of Food.* Academic Press, London, p.350

Arsdel, V.W.B. 1973. *Food Dehydration.* Second edition, West Port, Connecticut, p.215

Aruna, K., Dhanalakshmi, K. and Vimala, V. 1998. Development and storage stability of cereal based papaya powder. *J. Fd. Sci. Technol.* 35: 250-254

Athanasia, M.G., Konstantinos, G.A. and Nikolaos, A.K. 2004. Influence of spray drying conditions on tomato powder properties. *Drying Technol.* 22: 1129-1151

Attiyate, Y. 1978. Breakthrough in spray-drying improves quality and shelf-life. *Fd Engng. Int.* 3: 48-51

Bains, M.S., Ramaswamy, H.S. and Lo, K.V. 1989. Tray drying of apple puree. *J. Fd. Engng.* 9: 195-201

Bauchan, P.C. 1972. Utilization of local Malaysian fruits - Development of some products from Durian. *Publ .Fd. Technol. Res. Dev. Center (Malaysia).* 69: 22

Beckett, D.C., Emmons, D.B. and Elliot, J.A. 1962. The determination of bulk density, particle density and particle size distribution in skim milk powder. Sixteenth International Dairy Congress, Copenhagen. *Abstract* : 913

Berlin, E., Anderson, B.A. and Pallansch, M.J. 1973. Water sorption by dried dairy products stabilized with carboxymethyl cellulose. *J. Dairy Sci.* 56: 685-689

Bhandari, B.R., Datta, N. and Hower, T. 1997. Problem associated with spray drying of sugar rich foods. *Drying Technol.* 15: 671-684

Bhandari, B.R., Senoussi, A., Dumoulin, E.D. and Lebert, A. 1993. Spray drying of concentrated fruit juices. *Drying Technol.* 11: 1081-1092

Bhandari, V., Balachandran, R. and Prasad, D.N. 1984. Influence of stabilizers and emulsifiers on the ultra structure of spray dried ice cream mix. *N.Z. J. Dairy Sci. Technol.* 19: 55-61

Bhaskar, N.K., Maheshwari, P.N. and Singh, K. 2003. Studies on optimization of pre-treatment and processing conditions in preparation of Banana powder. Fifth International Food Convention, 5-8 December, 2003, Central Food Technological Research Institute, Mysore, India. *Abstract*: 74

Bhupinder, K., Spinderjit, K., Tejinder, S., Harinder, K. and Gurusharan, K. 2003. Development of value added ready-to-serve beverage based on combination of papaya and mango. Fifth International Food Convention, 5-8 December, 2003, Central Food Technological Research Institute, Mysore, India. *Abstract*: 27

BIS. 1981. *Handbook of Food Analysis. IS: SP: 18 (Part XI). Dairy Products*. Bureau of Indian standards, New Delhi, p.187

Borges, S.V., Reis, A.L.S.H., Jorge, F.C., Pinto, P.R. and Oliveiera, V.M. 2002. Spray drying of tropical fruit juices. *Alimentaria* 334: 125-130

Bose, A.N. and Dutt, J.M.A. 1952. Dehydration of mango pulp. *Indian Fd Packer* 6: 12

Bowrey, R.G., Buckle, K.A., Hamey, F. and Pavenayotin, P. 1980. *Fd. Technol. Aust.* 32: 290-291

Brennan, J.G., Herrera, J. and Jowitt, R. 1971. A study of some of the factors affecting the spray drying of concentrated orange juice on a laboratory scale. *J. Fd Technol.* 6: 295-307

Brown, M. 1999. Focusing on freeze drying. *Fd. Manufacture* 74: 34-36

Burr, H.K., Boggs, M.M., Morris, H.J. and Venstrom, D.W. 1969. Stability studies with cooked legume powders. *Fd. Technol.* 23: 842-844

Cai, Y.Z. and Corke, H. 2000. Production and properties of spray dried Amaranthus betacyanin pigments. *J. Fd. Sci.* 65:1248-1252

Candelaria, N.M. and Raymundo, L.C. 1994. Vacuum puffing and dehydration of fruits and vegetables.. *Philipp. Agricst.* 77: 251-260

Cangrong, L., Jianguo, M. and Xushiying. 2001. Effects of storage conditions on non-enzymic browning of tomato powder. *Fd. Ind.* 5: 24-26

Chan, W.Y. and Chiang, B.H. 1992. Production of clear guava nectar. *Int. J. Fd. Sci. Technol.* 27: 435-441

Chavan, V.D., Adsule, R.N. and Kadam, S.S. 1993. Processing of Ber III. Preparation of dried Ber powder and tuty-fruity. *Bev. Fd. Wld.* 20: 28-29

Cheman, Y.B., Irwandi, J. and Addullah, W.J.W. 1999. Effect of different types of maltodextrin and drying methods on physico-chemical and sensory properties of encapsulated durion flavour. *J. Sci. Fd. Agric.* 79: 1075-1080

Chen, B.H. and Tang, Y.C. 1998. Processing and stability of carotenoid powder from carrot pulp waste. *J. Agric. Fd. Chem.* 46: 2312-2318

Chen, P.Z. and Lin, M. 1997. Application of enzyme preparation in clarification of banana juice. *Fd. Res. Dev.* 18: 22-24

Chitra, P. and Manimegalai, G. 2002. Sustainability of banana for processing into RTS beverage. Global Conference on Banana and Plantain, 28-31 October, 2002, Bangalore, India. *Abstract*: 20

Chopda, C.A. and Barett, D.M. 2001. Optimization of guava juice and powder production. *J. Fd. Process. Preserv.* 25: 411-430

Cooke, R.D., Breene, G.R., Ferber, C.E.M., Bert, P.R. and Jones, J. 1976. Studies on mango processing. *J. Fd. Technol.* 11: 463-473

De, S. 1976. Dried channa. *Indian Dairy Man* 28: 389-391

Deka, C.B. and Sethi, V. 2001. Preparation of mixed fruit juice spiced RTS beverage. *Indian Fd. Packer* 55: 58-61

Deka, C.B., Sethi, V., Parsad, R. and Batra, P.K. 2001. Application of mixtures methodology for beverages from mixed fruit juice/pulp. *J. Fd. Sci. Technol.* 38: 615-618

Deshpande, H. 2004. BARC adds to banana bite. *The New Indian Express*, August 12, 2004, p.5

Devaraju, K.R., Rokhade, A.K. and Patil, C.P. 2002. Comparitive efficacy of pectinase enzyme on juice recovery and certain quality parameters in Ber fruits. *Bev. Fd. Wld.* 29: 34

Duck, S.A., Kang, L.W. and Dong, S.L. 1997. Processing of powdered jujube juice by spray drying. *J. Korean Soc. Fd. Sci. Nutr.* 26: 81-86

FAO. 2002. Food and Agriculture Organization Agriculture data. Home page of FAO. [On line] available http://www.fao.org.

*Fernandez, Z.F., Guerra, N.B., Diniz., N.M.A., Salgado, S.M., Guerra, T.M.M., Lopes, A.C.S., Neta, J.C.P.S., Padilha, M.R.F., Magalbaes, S.S. and Fatima, P.M.R.

1998. Development of milk beverage based on pumpkin flakes. *Archivos Latinoamericanos de Nutricion.* 48: 175-178

Ganesan, V. and Gothandapani, L. 1999. Microstructure of spray-dried and partially defatted coconut skim milk powder. *J. Fd. Sci. Technol.* 36: 268-269

Gangopadhyay, H., Choudhari, D.R. and Mukharjee, S. 1976. Dehydration of green mango pulp in double drum drier. *Indian Fd. Packer* 30: 51-55

Ganjyal, G., Pattanshetti, S.V. and Chavan, G.S. 1999. Studies on the production of sapota (*Achras zapota*) powder. ASAE-CSAE-SCGR Annual International meeting, 18-21 July, 1999, Toronta, Canada. *Abstract*: 16

Ganjyal, G., Pattanshetti, S.V. and Chawan, G.S. 1998. Studies on the production of sapota powder. Fourth International Food Convention, 23-27 November, 1998. Central Food Technological Research Institute, Mysore. India. *Abstract*: 158

Garcia, R., Leal, F. and Rolz, C. 1988. Drying of bananas using microwave and air ovens. *Int. J. Fd. Sci. Technol.* 23: 73-80

Gowda, D.I.N. 2002. Studies on enzymatic liquefaction of jackfruit pulp. Souvenir of Fifteenth Indian Convention of Food Scientists and Technologists, 12-13 December, 2002, Central Food Technological Research Institute, Mysore, India. *Abstract*: 23

Greensmith, M. 1998. *Practical Dehydration - Dehydration of Fruits*. Second edition, Woodhead Publishing Ltd., England, p.177

Gvozdenoviz, J., Popov-Raljic, J. and Curakovic, M. 2000. Investigation of characteristic colour stability of powdered orange. *Fd. Chem.* 70: 291-301

Hall, C.W. and Hedrick, T.I. 1971. *Drying of Milk and Milk Products*. Second edition. The AVI Publishing Company, West Port, USA, p.338

*Hardy, J., Scher, J. and Banon, S. 2002. Water activity and hydration of dairy powders. *Lait* 82: 441-452

Hashimoto, T., Hagiwara, T., Suzuki, T. and Takai, R. 2003. Study on the glass transition of bonito dried fish by differential scanning calorimetry and dyamic mechanical analysis. *Fisheries Sci.* 69: 1290

Hassan, M. and Ahamed, J. 1998. Sensory quality of foam-mat dried pineapple juice powder. *Indian Fd. Packer* 52: 31-33

Hauser, G., Mager, K., Maller, R.R. and Masters, K. 2002. General hygienic design criteria for the safe processing of dry particulate materials. *Trends Fd. Sci. Technol.* 12: 296-301

Hoover, M.W. 1973. A process for producing dehydrated pumpkin flakes. *J. Fd. Sci.* 38: 96-98

Huet, R. 1974. Aroma retention in tropical fruit powders obtained in a vacuum microwave oven. *Fruits* 29: 399-405

Huggart, R.L., Moore, E.L. and Wenzel, F.W. 1951. The measurement of clarification in concentrated citrus juice. *Proc. Fla. St. hort. Soc.* 64: 185-188

ICMSF. 1986. *Micro-organism in Foods. 2. Sampling for Microbiological Analysis. Principles and Specific Applications.* Second edition. International Commission on Microbiological Specifications for Foods, University of Toronto Press, Toronto, Canada. p.131

Ilangantileka, S.G., Salokhe, V.M. and Hong, J. 1991. Development of a drum dryer to produce dehydrated flakes from mungbean. *J. agric. Engng.* 28:344-351

Iordanidou, P., Voglis, N., Liadakis, G.N., Tzia, C. and Karayiannis, I. 1999. Utilization of apricot processing wastes. *Acta Hort.* 488: 609-614

Jackson, T. and Badrie, N. 2002. Quality changes on storage of Caribbean banana wines: Effect of pectolase concentration and incubation period. *J. Wine Res.* 13: 43-56

Jaleel, S.A., Basappa, S.C., Ramesh, A. and Sreekantiah, K.R. 1979. Developmental studies on enzymatic processing of banana II Pilot scale investigations. *Indian Fd. Packer* 33: 10-14

Jaya, S. 2004. Vacuum drying of mango pulp. *Drying Technol.* 22: 2211-2213

Jayaraman, K.S., Goverdhanan, T., Sankaran, R., Bhatia, B.S. and Nath, H. 1974. Compressed ready-to-eat fruited cereals. *J. Fd. Sci. Technol.* 11: 181-185

Jayaraman, K.S. and Gupta, D.K.D. 1992. Dehydration of fruits and vegetables: Recent developments in principles and techniques. *Drying Technol.* 10: 1-50

Jayaraman, K.S., Ramanuja, M.N., Goverdhanan, T., Bhatia, B.S. and Nath, H. 1976. Technological aspects of use of ripe mangoes in the preparation of some convenience foods for defence services. *Indian Fd. Packer* 30: 76-82

Jianwen, T. and Liangjuan, W. 2002. The effect of acidification and juice concentration on spray drying of longan. *Fd. Ferment. Inds.* 28: 39-42

Johari, G.P., Hallbruker, A. and Mayer, E. 1987. The glass liquid transition of hyper quenched water. *Nature* 330: 552-553

John, J.P. and Narasimham, P. 1993. Comparitive studies on controlled low temperature vacuum dehydration and other methods of dehydration of Breadfruit. Third International Food Convention, 7-12 September 1993, Central Food Technological Research Institute, Mysore, India. *Abstract*: 2

Jong, T.Y., Geo, P.H., Young, J.K., Young, K.S., Jong, R.S. and Hyon, Y.L. 2002. Production method of potato flake by drum dryer. *J. Korean Soc. hort. Sci.* 43: 183-186

Jordan, M.J., Tandon, K., Shaw, P.E. and Goodner, K.L. 2001. Aromatic profile of Aqueous Banana Essence and Banana fruit by Gas chromatography - Mass spectrometry (GC-MS) and Gas chromatography - Olfactometry (GC-O). *J. Agric. Fd. Chem.* 49: 4813-4817

Joshi, V.K., Chauhan, S.K. and Lal, B.B. 1991. Extraction of juices from peaches, plums and apricots by pectinolytic treatments. *J. Fd. Sci. Technol.* 28: 64-65

Kalra, S.K., Tandon, D.K. and Singh, B.P. 1991. Evaluation of mango-papaya blended beverage. *Indian Fd. Packer* 45: 33-36

Kalsi, H. and Dhawan, S.S. 2001. Preparation of guava powder by osmo-air drying and its sotrage studies. *Bev. Fd. Wld.* 28: 33-34

*Karatas, S. and Esin, A. 1990. A laboratory scraped surface drying chamber for spray drying of tomato paste. Lebensmittel-Wissenschaft-Technologie 23: 354-357

Kasnavia, A.M. 1984. Protein enriched mango powder. Ph.D. thesis, University of Mysore, Mysore, India, p.109

Kee, H.J., Jung, S.T., Park, Y.K. and Jung, D.O. 2000. Effects on anticaking of powdered onions by treatment of anticaking agents. *Korean J. Fd. Sci. Technol*. 32: 629-633

Kerkhof, P.J.A.M. and Schoeber, W.J. 1974. Theoretical modelling of the drying behaviour of droplets in spray drier. *Advances in Preconcentration and Dehydration of Foods* (ed. Spicer, A.). Applied Science Publishers Ltd., London, pp. 500-513.

Khalloufi, S., Giasson, J. and Ratti, C. 2000. Water activity of freeze dried mushrooms and berries. *Can. agric. Engng*. 42: 51-56

Khurdia, D.S. and Roy, S.K. 1974. Studies on guava powder by cabinet drying. *Indian Fd. Packer* 28: 5-8

King, V.A.E. 1985. Studies on the production of banana juice powder using spray drying. *J. Chinese agric. chem. Soc.* 23: 62-70

Kitson, J.A. and Sugisawa, H.S. 1974. Sugar captured flavour granules. *Can. Inst. Fd. Sci. Technol. J.* 7: 5-15

Kjaergaard, O.G. 1974. Effect of the latest development on design and practise of spray drying. *Advances in Preconcentration and Dehydration of Foods* (ed. Spicer, A.). Applied Science Publishers Ltd., London, pp. 513-514

Kopelman, I.J. and Saguy, T. 1977. Drum dried beet powder. *J. Fd. Technol.* 12: 615-621

Kotecha, P.M., Adsule, R.N. and Kadam, S.S. 1994. Preparation of wine from over-ripe banana fruit. *Bev. Fd. Wld.* 21: 28-29

Krishnamoorthy, G.V. and Varma, V.K. 1978. Studies on preparation of fruit slabs from papaya. First Indian Convention of Food Scientists and Technologists, 23-24 June, 1978. Central Food Technological Research Institute, Mysore, India. *Abstract*: 87

Krishnaveni, A., Manimegalai, G. and Saravanakumar, R. 2001. Storage stability of jack fruit RTS beverage. *J. Fd. Sci. Technol.* 38: 601-602

Kumar, P. and Sreenarayanan, V.V. 2000. Studies on storage of dehydrated onion flakes. *Indian Fd. Packer* 54: 73-74

Kyamuhangire, W., Pehrson, R. and Galan-Sauco-V. 1998. Adaptation of the traditional banana juice extraction technology to a mechanical process and factors influencing juice release. *Acta Hort.* 490: 577-582

Kyamuhangire, W., Myhre, H., Sorensen, H.T. and Pehrson, R. 2002. Yield, characteristics and composition of banana juice extracted by the enzymatic and mechanical methods. *J. Sci. Fd. Agric.* 82: 478-482

Lagunes, A.G., Galindo, H.S., Guerrero, O. and Rivera, J.A. 1999. Stability and sensory quality of spray dried avacado paste. *Drying Technol.* 17: 317-326

Lakshminarayana, G.S., Ghosh, B.C. and Kulkarni, S. 1997. Technology of ready to use banana milk shake powder. *J. Fd. Sci. Technol.* 34: 41-45

Lal, B.B., Genzalez, A.M. and Wesali, M.A. 1989. Some aspects in storage behaviour of freeze dried banana powder. *Indian Fd. Packer* 43: 38-41

Lazar, M.E. and Morgan, A.I. 1966. Instant apple sauce. *Fd. Technol.* 27: 531-533

Lenart, A. and Lewicki, P.P. 1988. Osmotic preconcentration of carrot tissue followed by connection drying. *Preconcentration and Drying of Food Materials* (ed. Bruin, S.). Elsevier Science, Amsterdam, pp.307-308

Lloyd, R.J., Chen, X. and Hargreaves, B.J. 1996. Glass transition and caking of spray dried lactose. *Int. J. Fd. Sci. Technol.* 31: 305

Loesecke, H.W. 1998. *Drying and Dehydration of Foods*. Allied Scientific Publishers, Bikaner, India, p.300

.Lueck, H. and Grothe, J. 1973. Fruit juice flavoured milk, a healthy beverage. *South African J. Dairy Technol.* 5: 47-52

Mahajan, B.M., Mathur, O.N., Bhattacharya, D.C. and Srinivasan, M.R. 1979. Production and shelf-life of spray dried srikand powder. *J. Fd. Sci. Technol.* 16:14-18

Malhotra, G.S. and Mann, R.S. 1989. Studies on the formulation of ready-to-reconstitute coffee complete powder. *Indian J. Dairy Sci.* 42: 554-557

Malleshi, N.G., Daodu, M.A. and Chandrasekhar, A. 1989. Development of weaning food formulations based on malting and roller drying of sorghum and cowpea. *Int. J. Fd. Sci. Technol.* 24: 511-519

Mani, S., Jaya, S. and Das, H. 2002. Sticky issues on spray drying of fruit juices. ASAE/CSAE North-Central Intersectional Meeting, 27-28 September, 2002, Saskatchevan, Canada. *Abstract*: 168

Marchal, L.M., Beeftink, H.H. and Tramper, J. 1999. Towards a rational design of commercial maltodextrins. *Trends Fd. Sci. Technol.* 10: 345-355

Mathlouthi, M. and Roge, B. 2003. Water vapour sorption isotherms and the caking of food powders. *Fd. Chem.* 82: 61-71

Maya, T. 1999. Evaluation of sapota [*Manilkara achras* (Mill.) Fosberg] for post-harvest qualities. M.Sc. thesis, Kerala Agricultural University, Thrissur, India, p.57

Maya, T. 2004. Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]. Ph.D. thesis, Kerala Agricultural University, Thrissur, India, p.112

Mir, M.A. and Nath, N. 1995. Loss of moisture and SO_2 during air cabinet drying of mango puree. *J. Fd. Sci. Technol.* 32: 391-394

Miranda, E.J.F., Nogueira, R.I., Pontes, S.M. and Rezende, C.M. 2001. Odour-active components of banana passa identified by aroma extract dilution analysis. *Flavour Fragr. J.* 16: 281-285

Mircea, E.D. 1995. *Fruit and Vegetable Processing - FAO Agricultural Services Bulletin, No.119.* International Book Distributing Co., Lucknow, p.194

Mugula, J.K., Lyimo, M.H. and Kessy, F.L. 1994. Production and storage stability of non-alcoholic banana beverage powder. *Pl. Fd. Human. Nutr.* 45: 155-163

Mui, W.W.Y., Durance, T.D. and Scaman, C.H. 2002. Flavour and texture of banana chips dried by combinations of hot air, vacuum and microwave processing. *J. Agric. Fd. Chem.* 50: 1883-1889

*Munyanganizi, B. and Coppens, R. 1976. Comparison of two methods for extracting banana juice from two different varieties. *Industries Alimentaires et Agricoles* 93: 707-711

Nakadi, S.K., Kotecha, P.M. and Kadam, S.S. 2001. Studies on ready-to-serve (RTS) beverage based on pomegranate and mango. *Bev. Fd. Wld.* 28: 36

Narayana, C.K., Sathiamoorthy, S and Evelin Mary, A. 2002. Studies on ready-to-serve beverage from enzyme clarified banana juice. *Prog. Hort.* 34: 65-71.

Narayana, C.K., Ramajayam, D. and Sathiamoorthy, S. 2004. Studies on the preparation of nectar from clarified banana juice. National Seminar on Diversification of Agriculture through Horticultural Crops, 21-23 February, 2004, National Dairy Research Institute, Karnal, India. *Abstract* : 6

NHB. 2001. *Horticulture Production Year Book.* National Horticulture Board, Gurgaon, Haryana, p.102

Nogueira, R.I. and Park, K.J. 1992. Drying parameters to obtain 'Banana-passa'. *Drying 92* (ed. Mujundar, A.S.). International Drying Symposium (IDS/92), Montreal, Canada, 2-5 August, 1992, Elsevier Science Publishers, Amsterdam, pp.874-883

Occena, L.G., Bennink, M.R., Vebersax, M.A. and Chung, Y.S. 1997. Evaluation of drum dried meals prepared from split beans protein quality and selected antinutritional factors. *J. Fd. Process. Preserv.* 21: 335-344

Padival, R.A. and Srinivasan, M. 1966. Preparation of dehydrated powder from pumpkin. *J. Fd. Sci. Technol.* 4: 164-165

Pallai, E., Szentmarjay, T. and Szijjarto, E. 2001. Effect of partial processes of drying in inert particles on product quality. *Drying Technol.* 19: 2019-2032

Palmu, T.P., Jardine, J. and Matta, V. 1999. Production of a banana extract containing no polyphenol oxidase by ultrafiltration. *J. Sci. Fd. Agric.* 79: 643-647

Pandey, A.K. and Singh, I.S. 1999. Studies on preparation and preservation of guava RTS beverage. *Indian J. Hort.* 56: 130-132

Panse, V.G. and Sukhatme, P.V. 1976. *Statistical Methods for Agricultural Workers.* Indian Council for Agricultural Research, New Delhi, p.381

Papadakis, S.E., Gardeli, C. and Tzia, C. 1998. Raisin extract powder: Production, physical and sensory properties. Proceedings of Eleventh International Drying Symposium (IDS '98), November 1998, Halkidiki, Greece. *Abstract*: 45

Patil, D.L. and Magar, N.G. 1973. Varietal differences on the nutrient composition of banana powders. *Curr. Sci.* 43: 249-251

Patil, V.R., Rokhade, A.K. and Patil, C.P. 2002. Studies on dehydration of sapota slices. *Bev. Fd. Wld.* 29: 17-18

Pheantaveerat, A. and Anprung, P. 1993. Effect of pectinases, cellulases and amylases on production of banana juice. *Food* 23: 188-196

Phongkitwithoon, N., Suwit, S., Sailom, S. and Yoovidhya, T. 1999. Process parameters for banana powder production using drum dryer. [on line] available http:///www.kmutt.ac.th/organization/Engineering/Food/to44y99.html

Pokharkar, S. and Mahale, D. 2000. Process development of banana dehydration. *Bev. Fd. Wld.* 27: 38

Phahar, W.A. and Leung, H.K. 1985. Storage stability of dehydrated and soy. Fortified fermented maize meal. *J. Fd. Sci.* 50: 182

Price, C., Danforth, D.M., Morris, J.R. and Banks, S. 1993. Market development for blueberry juice blends. *Ark. Frm. Res.* 42: 14-15

Pushpa, G., Amutha, S. and Thirumaran, A.S. 2002. Production of RTS beverage from major varieties of banana of Tamil Nadu. Global Conference on Banana and Plantain, 28-31 October, 2002, Bangalore, India. *Abstract*: 10

Rajamala, R., Tyagi, S.M. and Chauhan, G.S. 1995. Effect of enzymic liquefaction of banana pulp on juice yield and its characteristics. *Bev. Fd. Wld.* 22: 10-12

Rakhi, S., Singh, D. and Tyagi, S.M. 2002. Preparation of instant mushroom soup. Fifteenth Indian Convention of Food Scientists and Technologists, 12-13 December 2002. Central Food Technological Research Institute, Mysore, India. *Abstract*: 49

Ranganna, S. 1995. *Hand Book of Analysis and Quality Control for Fruit and Vegetable Products*. Second edition. Tata MaGraw-Hill Publishing Co. Ltd., New Delhi, p.2240

*Rao, R.H.G. and Gupta, P.M. 2002. Development of spray dried orange juice blended skim milk powder. *Lait* 82: 523-529

Reineccius, G.A. 2004. The spray drying of food flavours. *Drying Technol.* 22: 1289-1324

Roos, Y. and Karel, M. 1991. Phase transitions of mixtures of amorphous polysaccharides and sugars. *Biotech. Prog.* 7: 49-53

Roy, S.K. and Singh, R.N. 1979a. Studies on utilization of bael fruit (*Aegle marmelos*) for processing. *Indian Fd. Packer* 31: 9-14

Roy, S.K. and Singh, R.N. 1979b. Studies on utilization of bael fruit (Aegle marmelos Correa) for processing. IV. Storage studies of bael fruit products. *Indian Fd. Packer* 33: 3-9

Ruales, J., Polit, P. and Nair, B.M. 1990. Evaluation of the nutritional quality of flakes made of banana pulp and fullfat soya flour. *Fd. Chem.* 36: 31-43

Saca, S.A. and Lozano, J.E. 1992. Explosion puffing of bananas. *Int. J. Fd. Sci. Technol.* 27: 419-426

Sagar, V.R. 2001. Preparation of onion powder by means of osmotic dehydration and its packaging and storage. *J. Fd. Sci. Technol.* 38: 525-528

Sagar, V.R. and Khurdiya, D.S. 1998. Improved products from ripe mango. *Indian Fd. Packer* 52: 27-31

Sagar, V.R. and Khurdiya, D.S. 1999. Studies on dehydration of Dashehari Mango slices. *Indian Fd. Packer* 53: 5-9

Sagar, V.R., Khurdiya, D.S. and Balakrishnan, K.A. 1999. Quality of dehydrated ripe mango slices as affected by packaging material and mode of packaging. *J. Fd. Sci. Technol.* 36: 67-70

Sagar, V.R., Khurdiya, D.S. and Maini, S.B. 2000. Quality of ripe mango powder as affected by storage temperature and period. *J. Fd. Sci. Technol.* 37: 165-168

Sahni, C.K. and Khurdiya, D.S. 1993. Blended beverages from mango pulp. Third International Food Convention, 7-12 September, 1993, Central Food Technological Research Institute, Mysore, India. *Abstract*: 23

Sapers, G.M., Panashiuk, O., Tallfy, F.B. and Shaw, R.L. 1974. Flavour quality and stability of potato flakes: Effect of drying conditions, moisture content and packaging. *J. Fd. Sci.* 39: 555-558

Sethy, G.R., Saroja, S. and Nanjundaswamy, A.M. 1978. Studies on drum drying of protein incorporated banana powder. First Indian Convention of Food Scientists and Technologists, 23-24 June 1978. Central Food Technological Research Institute, Mysore, India. *Abstract*: 87

Seymour, G.B. 1993. Banana. *Biochemistry of Fruit Ripening* (eds. Seymour, G.B., Taylor, J.E. and Tucker, G.A.), Chapman and Hall, New York, pp.83-106

Shah, A., Gupta, D.K. and Arya, S.S. 2000. Value-added products development of horticultural produce. *Indian Hort.* 45: 18-21

Shahabuddin, N. and Hawlader, M.N.A. 1990. Evaluation of drying characteristics of pineapples in the production of pineapple powder. *J. Fd. Process. Preserv.* 14: 375-391

Shahadan, S. and Abdullah, A. 1995. Optimizing enzyme concentration, pH and temperature in banana juice extraction. *Asean Fd. J.* 10: 107-111

Sharma, K.D., Sethi, V. and Maini, S.B. 2000. Effect of pre-treatment and packaging on chemical and sensory characteristics of dried apple. *Indian Fd. Packer* 54: 52-59

Sharma, S.P., Bhanumurthi, J.L. and Srinivasan, M.R. 1974. Studies on the production and storage behaviour of spray dried mango-milk powder. *J. Fd. Sci. Technol.* 11: 171-174

Siddappa, G.S. and Ranganna, S. 1961. Strained baby foods: Drying of strained mango pulp and mango custard. *Fd. Sci.* 32: 37-40

Sims, C.A. and Bates, R.P. 1994. Challenges to processing tropical fruit juices: banana as an example. *Proc. Fla. St. hort. Soc.* 107: 315-319

Singh, D.K., Bhonde, S.R. and Pandey, V.B. 2004. Studies on screening of white onion varieties for dehydration qualities. National Seminar on Diversification of Agriculture through Horticultural Crops, 21-23 February, 2004, National Dairy Research Institute, Karnal, India. *Abstract*: 8

Singh, N.I., Mayer, D.C. and Lozano, Y. 2000. Physico-chemical changes during enzymatic liquefaction of mango pulp (cv. Keitt). *J. Fd. Process. Preserv.* 24: 73-85

Singh, R.D.A. and Tomar, M.C. 2000. Studies on osmotic dehydration of some varieties of ripe mangoes grown in U.P. *Indian Fd. Packer* 54: 66-72

Singh, S., Ladkani, B.G., Kumar, A. and Mathur, B.N. 1993. Development of whey based banana beverage. Third International Food Convention, 7-12 September, 1993, Central Food Technological Research Institute, Mysore, India. *Abstract*: 14

Sole, P. 1996. Bananas (Processed). *Processing Fruits - Science and Technology, Vol.2. Major Processed Products* (eds. Simogyi, L.P., Barrett, D.M. and Hui, Y.H.). Technomic Publishing Company, Switzerland, pp.364-385

Srivastav, P.P., Chattopadhyay,S. and Prasad, S. 2002. Development of dehydrated bael. Fifteenth Indian Convention of Food Scientists and Technologists, 12-13 December 2002, Central Food Technological Research Institute, Mysore. India. *Abstract*: 102

Strolle, E.O. and Cording, J. 1965. Moisture equillibria of dehydrated mashed potato flakes. *Fd. Technol.* 19: 853-855

Szentmarjay, T., Pallai, E. and Regenyi, Z. 1996. Short-time drying of heat sensitive, biologically active pulps and pastes. *Drying Technol.* 14: 2091-2115

Talley, F.B., Komanowskey, M., Cording, J. and Eskew, R.K. 1966. Flavour and storage stability of dehydrated pumpkin. *Fd. Technol.* 20: 1369-1370

Teaotia, S.S., Mehta, G.L., Tomar, M.C. and Garg, R.C. 1976. Studies on dehydration of tropical fruits in Uttarpradesh: 1. Mango (*Mangifera indica* L.) *Indian Fd. Packer* 31: 15-18

Teotia, M.S., Kaur, S. and Berry, S.K. 1997. Utilization of musk melon ready-to-serve beverage from enzyme clarified juice. *Indian Fd. Packer* 51: 11-17

Thakur, N.K., Kaushal, L.B.B. and Joshi, V.K. 1999. Standardization of method and treatment for clarification of kinnow juice. *Indian Fd. Packer* 53: 27-31

Tiwari, R.B. 2000. Studies on blending of guava and papaya pulp for RTS beverage. *Indian Fd. Packer* 54: 68-72

Tiwari, R.B. and Dinesh, M.R. 2001. Evaluation of seven exotic red-fleshed guava varieties for processing into RTS beverage. *Indian Fd. Packer* 55: 58-62

Torrey, M. 1974. *Dehydration of Fruits and Vegetables*. Noyes Data Corporation, London, p.285

Tsami, E., Krokida, M.K. and Drovzas, A.E. 1999. Effect of drying method on the sorption characteristics of model fruit powders. *J. Fd. Engng.* 38: 381-392

Valdez, C.C., Lopez, C.Y., Schwartz, S., Bulux, J. and Solomons, N.W. 2001. Sweet potato buds: The origins of designer food to combat hypovitaminosis in Guatemala. *Nutr. Res.* 21: 61-70

Vidales, S.L., Malec, L.F. and Gerschensin, L.N. and Alzamora, S.M. 1995. Water sorption characteristics of sugar impregnated strawberries. *Drying Technol.* 13: 1993-2010

Viquez, F., Lastreto, C. and Cooke, R.D. 1981. A study of the production of clarified banana juice using pectinolytic enzymes. *J. Fd. Technol.* 16: 115-125

Waskar, D.P. and Garande, V.K. 1999. Standardisation of a method of juice extraction from ber fruit. *J. Fd. Sci. Technol.* 36: 540-541

Waskar, D.P., Gaikwad, R.S. and Damame, S.V. 1998. Studies on various methods of dehydration of leafy vegetables. *Orissa J. Hort.* 26: 29-30

Wauters, P.A.L., Jakobsen, R.B., Litster, G.M.H. and Meesters, B.S. 2002. Liquid distribution as a means to describing the granule growth mechanisms. *Powder Technol.* 123: 166-177

Wink, W.A. 1946. Determining the moisture equilibrium curve of hygroscopic material. *Ind. Engng. Chem. Anal. Ed.* 18: 251-252

Young, S.Y., Kang, H.H., Chang, K.S. and Chang, Y. 1998. Effect of some anticaking conditioners on the flowability of dried garlic powder. *Korean J. Fd. Sci. Technol.* 30: 1357-1361

Yu, T.H. and Wu, C.M. 1987. Production of clarified banana juice using pectinolytic enzymes. *Fd. Sci. China* 14: 154-164

* Originals not seen.

Appendices

APPENDIX - I

Cost of production of 100 bottles (200 ml/bottle) of mango Ready-To-Serve beverage

Sl. No.	Item	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Raw material			
	a) Mango fruit	10.07 kg	20/kg	201.40
	b) Sugar	2.28 kg	16/kg	36.48
	c) Citric acid	21.90 g	150/kg	3.29
	e) Potassium meta-bi-sulphite (KMS)	2.13 g	180/500 g	0.77
	f) Synthetic yellow food colour	2.0 g	45/100 g	0.90
	g) Banana essence	12.5 ml	200/500 ml	5.00
II	Fuel		75 p/kg of beverage	15.00
III	Labour			
	a) Skilled labour	4 h	200/8 h	100.00
	b) Attendant (women)	4 h	100/8 h	50.00
			Total	412.84
IV	Interest on working capital @ 12%			0.12
V	Interest on fixed capital @ 12%			1.04
VI	Depreciation of machineries and accessories @ 10%			0.87
VII	Total cost of production			414.87
VIII	Processing loss (2%)			2 bottles
IX	Actual quantity of beverage			98 bottles
X	**Cost per bottle (200 ml)**			**4.23**

APPENDIX-II

Machineries used in the production of spray and drum dried banana powder

1. **Spray drying**

S. No	Machinery	Cost (Rs)	Working time (min) for 5kg banana powder	Depreciation @ 10%	Interest @12%
1	Spray drier (15kg H_2O/hr)	15 lakhs	60	17.127	20.553
2	Homogenizer	26000	20	0.099	0.199
3	Steam Processing Vats	30000	30	0.171	0.206
4	Steam Boiler	2.5 lakhs	60	2.855	3.425
5	Fruit Pulper	40000	15	0.114	0.137
6	Mini Pulverizer	10000	10	0.019	0.023
7	Packaging machine	1.5 lakhs	20	0.286	0.343
			Total	**20.671**	**24.806**

2. **Drum drying**

S. No	Machinery	Cost (Rs)	Working time (min) for 5kg banana powder	Depreciation @ 10%	Interest @12%
1	Drum drier	5.5 lakhs	60	6.280	7.536
2	Homogenizer	26000	20	0.099	0.119
3	Steam Processing Vats	30000	30	0.171	0.206
4	Steam Boiler	2.5 lakhs	60	2.855	3.425
5	Fruit Pulper	40000	15	0.114	0.137
6	Mini Pulverizer	10000	10	0.019	0.023
7	Packaging Machine	1.5 lakhs	20	0.286	0.343
8	Hot air oven	50000	60	0.571	0.685
			Total	**10.395**	**12.474**

APPENDIX-III

Economics for a pilot plant producing 1000 kg drum dried banana powder
(Assuming that plant is working for 16 hours continuously in two shifts)

S.No	Item	Quantity	Rate (Rs)	Amount (Rs)	Total (Rs)
1	Raw material				
	a) Banana	8522 kg	12/kg	102264	108024
	b) Additives	128 kg	45/kg	5760	
2	Fuel charges				
	a) Diesel	48 lit	22/lit	1056	7056
	b) Electricity	2000 units	3/unit	6000	
3	Labour charges (per month)				
	a) Manager	1	9000	9000	
	b) Shift Supervisor	2	6000	12000	2000
	c) Processing Associates	4	5000	20000	(per day)
	d) Unskilled labour	4	3000	12000	
	e) Administrative Assistant	2	3500	7000	
4	Fixed capital				
	a) Land and Buildings			15 lakhs	
	b) Machinery & Accessories			41.6 lakhs*	
5	Depreciation of machineries*@ 10%				759.82
6	Interest on fixed capital @ 12%				1860.82
7	Interest on working capital @ 12%				38.49
8	**Total cost of production**				**119739.13**
	Cost for one kg drum dried product				119.70

***Cost of machineries involved in drum drying**

S. No	Machinery	Cost (lakh Rs)
1	Drum drier	25
2	Homogenizer	5
3	Steam processing Vats	3
4	Steam Boiler	5
5	Packaging machine	1.5
6	Mini pulverizer	0.5
7	Fruit pulper	1.6
	Total	**41.6**

APPENDIX- IV

Cost of machinery used in banana RTS preparation

S. No	Machinery	Cost (Rs)
1	Blender	5000
2	Crown cork sealing machine	2000
3	Accessories	2500
	Total	**9500**

APPENDIX-V

Score sheet for Banana powder

Name of the Scorer : ________________________________ Date : ___________

Please score the given product (Banana powder) using the following 5 point Hedonic scale:

Score	**Inference**
5	Like very much
4	Like
3	Neither like nor dislike
2	Dislike
1	Dislike very much

Product Code	Colour	Flavour	Texture	Overall acceptability
1				
2				
3				
4				

Remarks: (Please write which flavour is dominating, whether you find the colour appealing)

……

……

Signature

APPENDIX-VI

Score sheet for Banana Ready-To-Serve (RTS) Beverage

Name of the scorer : ________________________________ Date : ____________

Please score the given RTS beverage using the following 5 point Hedonic scale:

Score	**Inference**
5	Like very much
4	Like
3	Neither like nor dislike
2	Dislike
1	Dislike very much

Product Code	Colour	Taste	Flavour	Consistency	Overall acceptability
1					
2					
3					
4					

Remarks: (Please write which flavour is dominating, whether you find the colour appealing)

....

....

Signature

DEVELOPMENT OF JUICE-BASED BEVERAGE AND RIPE-FRUIT POWDER FROM BANANA (*MUSA SPP.*)

By

A. EVELIN MARY

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture

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2005

ABSTRACT

The study on "Development of juice-based beverage and ripe-fruit powder from banana (*Musa spp.*)" was carried with the objective of developing a drying and packaging regime for ripe banana powder and to develop a beverage based on clarified banana juice.

Technology for spray and drum dried banana powder was standardized through drying and packaging experiments. Good quality spray dried banana powder could be obtained with an inlet air temperature of 150°C, keeping the outlet temperature at 100°C with two per cent maltodextrin and three per cent soluble starch on wet basis as additive.

Successful drum drying could be achieved with drum temperature of 152°C with drum speed of three rpm and soluble starch 2.5 per cent on wet basis as additive. Drum drying was found better in terms of higher recovery, lesser additive, better quality and lesser cost of production.

Moisture sorption studies revealed that banana powder was highly hygroscopic requiring special packaging techniques. Gas Chromatography-Mass Spectrometry analysis revealed that the caramelized fruity fig like aroma of banana powder was due to Furaneol and Ethyl cinnamate. Banana powder could be stored for one year under ambient conditions without deterioration when packed in aluminium foil laminated pouches with nitrogen.

Banana powder can be used as an ingredient in baby food, health food, instant beverage mix, breakfast cereals, flavourings, bakery and dairy products. The cost of production of 100 grams of spray and drum dried banana powder worked out to be Rs.26.61 and Rs.18.66 respectively.

The technology for banana juice based beverage was also standardized. Clear banana juice could be extracted using commercial pectinase enzyme @ 5 ml / kg pulp and incubating for four hours at room temperature. Robusta juice was superior in terms of colour, flavour and overall acceptability compared to Poovan, karpooravalli and Palyankodan juices.

Blended banana-mango RTS beverage in the ratio of 50:50 was preferred by the taste panel over other fruit blends. The disadvantages in banana juice viz., lack of colour, consistency and acidic taste could be overcome by mixing equal amounts of mango juice. Blending banana juice with mango pulp helped in incorporating the excellent flavour of banana and reduced the cost of production of mango RTS beverage.

The cost of production of banana-mango RTS beverage when worked out came to be Rs.3.84 per 200 ml bottle while that of pure mango RTS beverage was Rs.4.23. The blended RTS beverage could be stored for six months under ambient condition without deterioration. With liberalization in industrial policy and globalization, more opportunities are created for export of value added and nutritious products from banana. India being the largest producer of banana in the world can tap this potential by exporting products like ripe banana powder and juice based beverages.