VALUE ADDITION IN SAPOTA
[Manilkara achras (Mill.) Fosberg]

By

T. MAYA

THESIS

submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Processing Technology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA. INDIA

2004

DECLARATION

I hereby declare that this thesis entitled **"Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara

T. Maya

CERTIFICATE

Certified that this thesis, entitled **"Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]"** is a record of research work done independently by **Miss. T. Maya** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

8/6/04

Dr. P. Jacob John
Chairman, Advisory Committee
Associate Professor and Head
Department of Processing Technology
College of Horticulture
Vellanikkara

Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Miss. T. Maya,** a candidate for the degree of **Doctor of Philosophy in Horticulture,** with major in Processing Technology, agree that this thesis entitled **"Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]"** may be submitted by **Miss. T. Maya,** in partial fulfilment of the requirement for the degree.

5/6/04

Dr. P. Jacob John
(Chairman)
Associate Professor and Head
Department of Processing Technology
College of Horticulture
KAU. P.O. Thrissur

5/6/04

Dr. R. Rajendra Kumar
Associate Professor & Head
Dairy Plant
College of Veterinary and Animal Sciences
Mannuthy
(Member)

5/6/04

Dr. Augustine Antony
Associate Professor
Department of Soil Science and
Agricultural Chemistry
College of Horticulture
(Member)

Dr. Sajan Kurian
Associate Professor
Regional Agricultural
Research Station, Kumarakom
(Member)

Dr. K.B. Sheela 5/6/04
Associate Professor
Department of Processing Technology
College of Horticulture
(Member)

EXTERNAL EXAMINER

Professor (Hort)
HC & R.I. TNAU
Periyakulam
Coimbatore.

Dedicated to
my teacher s

ACKNOWLEDGEMENT

First and foremost, I thank ***Dr.P.Jacob John,*** *Associate Professor and Head, Department of Processing Technology and Chairman of my advisory committee for his invaluable guidance and unstinted co-operation which made this thesis a reality. I am genuinely indebted to him for his constant encouragement and affectionate advice rendered during the academic career.*

With deep reverence, I express my sincere thanks to ***Dr.R.Rajendra Kumar,*** *Head, Dairy Plant, College of Veterinary and Animal Sciences and member of advisory committee for his treasured technical guidance, sustained interest kind concern and ever-willing help rendered for the successful completion of the research work. He has been a support during each step of the way and my unfading gratitude and obligation remain with him forever.*

My profound thanks are due to ***Dr.Sajan Kurien,*** *RARS, Kumarakom for offering all possible help during the thesis work as a member of the advisory committee.*

Heartfelt thanks are due to ***Dr.Augustine Antony,*** *Department of Soil Science and Agricultural Chemistry for his precious suggestions and timely help rendered duing the lab analysis.*

I would like to sincerely thank ***Dr.K.B.Sheela,*** *Department of Processing Technology for extending all possible help in times of need during the course of study.*

I am deeply obliged to Sri.S.Krishnan, Associate Professor, Department of Agricultural Statistics for his invaluable guidance and assistance provided for the statistical analysis of data.

I owe special thanks to Dr.Indira Devi, Department of Agricultural Economics and Sri.Philip Sabu, Department of Rural Marketing Management for their immense help and constructive suggestions during the preparation of the manuscript.

I am thankful to Dr.Sreenivasa Rao and Sri.Omanakuttan, Central Institute of Fisheries Technology, Cochin for extending all possible help for packaging studies in the research programme.

I am highly indebted to Dr.Geevarghese, Dr.Sathyan, Dr.Rajkumar, Sri.Sudheer Babu and Dr.Sreekumar, College of Veterinary and Animal Sciences, Mannuthy for extending all possible help during various stages of the thesis work.

The candid suggestions of Dr.V.K.Raju and Dr.P.B.Pushpalatha, Department of Processing Technology are gratefully acknowledged.

I am thankful forever to Sri.Sreekumar and Sri.Rajesh, Dairy Plant, Mannuthy, without whom it would have been difficult to conduct the study.

I am thankful to Sri.K.G.Krishnan and Smt.K.S.Radha, Department of Processing Technology and Smt.Droupathy, Biochemisty lab for their prompt help during the course of work.

I would like to place on record my sincere gratitude to all the faculty members of College of Horticulture and in particular to Dr.Prasannakumari Amma and Dr.V.K.Mallika for their rentless help and constant encouragement throughout my academic career.

I reckon with love, the virtuous support given by all my friends especially Smitha Revi, Thanuja, Romy, Mini, Usha, Priya, Parvathy and Sujatha during the course work.

I am forever beholden to Achan, Amma, Chitta, Unnichettan, Ashachechi and my sweet friend Annie Mathew for their moral support constant prayers, personal sacrifices and unceasing encouragement during the research work.

Thanks are due to Sri.Joy and Sri.Jomon of J.M.J. Computer centre for prompt and neat typing of the manuscript.

A special word of thanks is due to Smt.Liza Mathew, Smt.Lakshmidevi, Sri.Premchand and Sri.Syed Muhammed for their splendid support and encouragement during the final stage of thesis work.

The award of CSIR Senior Research Fellowship is thankfully acknowledged.

Above all I bow my head before GOD ALMIGHTY for blessing me with health, strength and confidence to get through all tedious circumstances and for showering flowers of success throughout my academic career.

MAYA.T.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

APD - average particle density
BD - bulk density
PVPP - percentage volume occupied by the powder particles
SMBP - sapota-milk beverage powder
UHT - ultra-high temperature
TSS - total soluble solids
HTST - high temperature short time
rpm - revolutions per minute
msnf - milk solids not fat
snf - solids not fat
TS - total solids
CMC - carboxy methyl cellulose
N_2 - nitrogen
CO_2 - carbon dioxide
GMS - glycerol mono-stearate
SA - sodium alginate
RH - relative humidity
D.E. - dextrose equivalent
HDPE - high density polyethylene
LDPE - low density polyethylene
TLC - thin layer chromatography
cfu - colony forming units
OD - optical density
ERH - equilibrium relative humidity
EMC - equilibrium moisture content
MAS - months after storage
DAS - days after storage
NEB - non-enzymatic browning

LIST OF APPENDICES

Introduction

INTRODUCTION

Value addition has now become the watchword as it involves processing and preservation of commodities, which otherwise get obscure and disposed at a cheaper price. India is the second largest producer of fruits with an annual production of 46.04 million tonnes (Shikamony and Sudha, 2003). But more than 40 per cent of production goes waste for want of post-harvest handling and processing. Hence India has to now usher in a 'rainbow revolution' so that these protective foods are preserved or processed to meet the nutritional requirements for the one billion population in the country. Emergence of convenience foods in urban India is an important turnaround and there exists ample scope to introduce wide range of value added fruit products, that are nutritious, delicately flavoured and are also globally competitive. Agro-processing industry, if given proper policy direction, now possess huge potential to become a major 'sunrise industry' in the country.

India is the largest producer of sapota, a highly delicious dessert fruit which enjoys much popularity throughout India as "Chikku" of retail trade. The crop once grown only in peninsular India, is presently cultivated on a larger scale in dry arid regions and waste lands owing to its hardy nature, wide adaptability, low cost of production and high economic returns with minimum inputs. The area under the crop has increased tremendously from a mere 800 ha in 1954 (Chadha, 1992) to the present area of 64,400 ha (Negi and Mitra, 2001).

Keeping in view of its immense potential for export as a tropical fruit, sapota is now included as a priority item under horticultural produce. Though preference and demand of sapota is very high, it is not matched with export earnings or trade due to high perishability and lack of value added products. Instantly prepared "Chikku shake" a blend of sapota and milk is a very popular beverage sold in the juice parlours, when the fruit is readily available in the market. Even though the fruit is rich in sugars and minerals it lacks appreciable quantities of protein, hence blending with milk fills this lacuna.

Fortification with vitamins and minerals is a frequent practice in beverage industry, but with proteins of animal origin is very rare. Moreover beverage industry offers a large potential for internal consumption and for export market. Hence, in view of increasing popularity of sapota-milk beverage a study has been hitherto undertaken to prepare the beverage as an instant powder with extended shelf-life and convenience in use and also to have the beverage in ready-to-drink form in consumer bottles.

Review of Literature

2. REVIEW OF LITERATURE

Sapota, a delicious tropical fruit, has very high rate of respiration and short shelf-life resulting in huge post-harvest loss accounting to about 30-35% of the production. India is the largest producer of sapota with a production of 8,00,300 MT. The area under this crop increased drastically from 27,200 ha in 1991-92 to 64,400 ha in 1999-2000 (Negi and Mitra, 2001). The increasing trend in production and poor shelf-life warrants serious marketing problem in the coming years. Value added products from sapota are the only solution to tide over this problem. In the present study an attempt has been made to develop value added products viz. sapota-milk beverage powder and bottled sapota-milk beverage.

Literature on related works hitherto carried out at different places is reviewed and presented here under the titles.

2.1 SAPOTA FRUIT CHARACTERS

Sapota [*Manilkara achras* (Mill.) Fosberg], a native of Mexico and Central America belongs to the family Sapotaceae. In India, it is grown only for its edible part whereas in Mexico, Venezuela and Guatemala, it is mainly grown for the extraction of gum from the fruit. Fruits ripen in about five days after harvest at room temperature.

Ethylene, a ripening hormone is essential to be present in the required quantities for ripening of the fruit. Among various simple ripening media like paper pack, sawdust and paddy straw, paddy straw was found to be the best in accelerating ripening of fruits treated with ethrel and gave higher overall organoleptic rating (Ingle *et al.*, 1981).

Ingle *et al.* (1982) obtained the best organoleptic score in fruits treated with 100 ppm ethrel while Suryanarayana and Goud (1984) used 5000 ppm for quick ripening and improved quality. Sapota followed a climacteric pattern of respiration and the climacteric peak varied in different varieties viz. fifth day in Kalipatti, sixth day for Oblong and eighth day for Cricket Ball (Selveraj and Pal, 1984).

The sapota fruit is a good source of digestible sugar which ranges from 12 to 18 per cent. Composition of ripe fruit per 100 g of edible portion is 73.7 g moisture, 21.4 g carbohydrate, 0.7 g protein, 1.1 g fat, 28 mg calcium, 27 mg phosphorus, 2 mg iron, 6.0 mg ascorbic acid and 10.9 g total digestible fibre (Sulladmath and Reddy, 1990).

2.2 SAPOTA PROCESSING

Constraints in processing of sapota are related to heat labile delicate flavour of the pulp which is lost during heat processing. Undesired colour of the pulp, intensive labour in peeling and deseeding and presence of gummy latex are other limitations. However attempts have been made to develop various products from the fruit. But no promising results were obtained for its industrial processing.

Thapa (1980) attempted osmotic dehydration of segmented sapota and recommended 25 h of osmotic dehydration at room temperature with a ratio of 1:3 (fruit:syrup) and subsequent air drying for eight hours. Sun dried product did not retain the flavour, whereas air dried product was quite acceptable as a snack fruit.

Chadha (1992) reported flocculation of particles of hard tissue in RTS beverage and non-retention of characteristic flavour in products like jam and dehydrated chunks made from sapota.

Pandurang (1996) observed development of acidity in jam and squash, which is probably due to release of tannins from the bound form in the case of pulp obtained from immature ripe fruits. Due to presence of stone cells a gritty sensation was present in the squash an undesirable character.

Gautam and Chundawat (1998) have developed a procedure for the preparation of sapota wine. Pasteurized sapota pulp was inoculated with 2 per cent of 24 h old culture of wine yeast, and incubated at room temperature for four days. This was then filtered and the fermented juice was again kept for six more days for the completion of fermentation process.

Among various methods evaluated for extraction of pulp, the recovery of sapota pulp was higher (82.3%) in enzyme extraction process, but quality was found better in cold extraction process with a recovery percentage of 79.74 per cent (Dengale *et al.*, 1998).

According to Kulkarni (1998) some of the milk and fruit based beverages which are likely to have demand in future are combinations of milk with fruits like mango, sapota, banana and straw berry.

2.3 DEHYDRATION OF FRUITS/MILK

Canned fruits and vegetables and their products constitute about 40 per cent of the production of processed products in the country. These products contain a lot of moisture and add to the tonnage in their transportation, which not only necessitates higher cost of transportation but also results in lot of spoilage. Concentration of fruit juices removes moisture, but adds to the storage problem and more so in a tropical country like India where the ambient temperature during summer months ranges between 32-45°C. Dehydration overcomes the above problems to a great extent. Dehydration of food saves 80 per cent in shipping, 77 per cent in storage space and 82 per cent in handling cost. Further the price of the ultimate products in terms of the canned products is considerably reduced owing to the reduction in the cost of the container, minimum labour requirement for production and packing and reduced distribution cost. Convenience, versatility and storage stability are other advantages of dehydrated fruit products (Nanjundaswamy, 1984).

India is the largest producer of milk and second largest producer of fruits. Milk shakes, a blend of milk and fruit pulp, are a product of western origin and are now highly popular even in the villages of our country. Excellent export potential exists for these beverages if produced in dehydrated form, at the same time the product will also be nutritionally superior due to combination of two of the natural products viz. milk and fruit (Kulkarni, 1998). Sapota being a low acid fruit (p^H-5.5) can be successfully used in milk based beverages without precipitating casein.

2.3.1 Spray drying

Spray drying is a versatile drying technique suited equally to both heat sensitive and non-heat sensitive products. 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. The resulting fine particles while still in suspension are collected by a cyclone separator. 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 up to a high temperature.

Lazar *et al.* (1956) has reported a procedure for spray drying tomato concentrate, in which concentrate of 30 per cent total solids was diluted with a solution of sodium chloride and sodium bisulfite in proportions to adjust the feed paste to 20 per cent tomato solids, two per cent sodium chloride and 200 ppm SO_2 (all on wet basis) which was then spray dried at a maximum air temperature of 110°F.

According to Siddappa and Ranganna (1961) mango pulp spray dried did not dry well in the spray drier in spite of the slow feeding. A part of the feed which did not dry well was deposited in the form of thick band on the sides and at the top of the chamber. Further the particles of the powder were also deposited on the vertical walls and in the cone and were therefore not carried properly to the receiver along with the draught of the outgoing air. The dried product, however reconstituted easily in water but its flavour was deteriorated to some extent.

Infant food based on soybean was developed by Chandrasekhara *et al.* (1966). Powdered barley malt was added to debittered soy dhal, centrifuged and the liquor from centrifuge was warmed to 60°C. Weighed quantities of ground nut oil, skim milk powder, acid hydrolysed starch and buffer salts were added, homogenized and spray dried at 250°C inlet and 100°C outlet temperature.

Coulter and Breene (1967) successfully spray dried a wide variety of fruits and vegetables using condensed skim milk as the carrier in conventional milk drying equipment after sieving through a 0.70 mm screen. The proportion of skim milk solids required ranged from zero per cent with peas and corn, 50 per cent with cranberry and blueberry and 60-70 per cent with tomatoes and other highly hygroscopic fruits like apple, banana and pineapple. Mizrahi *et al.* (1967) reported that isolated soybean protein (ISP) at levels of 4-20 per cent on dry basis might be used as a drying aid, an anti-caking agent and nutritional supplement in the manufacture of banana powder.

Concentrated orange juice without additives could not be spray dried because of the heavy wall deposits resulting from hygroscopic and thermoplastic nature of the product. Liquid glucose (39-43 DE) proved to be the most effective additive, to reduce wall deposition markedly and for producing a free flowing product. The highest feed rate (34 g min^{-1}) was possible at an air inlet temperature of 140°C.

Recovery was 90 per cent with inlet and outlet air temperatures of 130°C and 85°C respectively and feed rate was maintained at 15 g min^{-1}, feed temperature at 80°C, speed of atomizer 31,000 rpm and air flow rate at 1700 ft h^{-1} (Brennan *et al.*, 1971).

Spray dried mango milk-shake powder was developed by Sharma *et al.* (1974). Concentrated skim milk (30% TS), cream and sugar were well mixed and preheated to 50°C. Glycerol monostearate and sodium alginate in the ratio of 1:1 at the rate of one per cent of total solids of the mix was added with vigorous mixing for complete incorporation. The heated mix was filtered and homogenized at a temperature of 65-70°C followed by pasteurization at 65.5°C for 30 minutes and cooled to 10°C. The fruit pulp (20 % TS) was mixed with cooled concentrated milk. Each 100 kg mix was made to contain 36 kg fruit, 10.8 kg sugar, 52.6 kg concentrated skim milk, 14.0 kg cream and 400 g stabilizer. The mix was filtered and spray dried at an inlet and outlet air temperature of 170-175°C and 98-160°C respectively to give a product with final moisture content of 2.5 per cent.

Cooke *et al.* (1976) found that mango puree after enzyme treatment to reduce viscosity could be spray dried in a co-current laboratory spray drier fitted with a centrifugal atomizer operated at 14,000 rpm after diluting the feed stock with distilled water (2:1 v/v). The feed rate was 250 ml min^{-1} and inlet and outlet temperatures were 154°C and 88°C respectively.

Jayaraman *et al.* (1976) successfully spray dried mango pulp in admixture with skim milk powder or double strength fresh whole milk. Total solids of the mix was adjusted to 15-20 per cent with water to facilitate drying. Spray drying was carried out with inlet and outlet air temperatures of 160-180°C and 60-70°C respectively using compressed air at a pressure of 1-2 kg cm^{-2} and 2.5 to 3.0 kg h^{-1} feed rate.

Patil and Magar (1976) successfully produced banana powder by spray drying. Ripe fruits were macerated and homogenized in waring blender with minimum quantity of water to prepare thick saturated slurry. The slurry was then atomized in spray drier chamber and dried using an inlet air temperature of 185°C with constant stirring. After four minutes the dried product was pulverised and passed through a 50 mesh sieve. Moisture content of the spray dried product varied from 2.5 to 4.35 per cent. The powder was stored in air tight polyethylene bags in an air tight container.

Milk-shake mix with 4 per cent fat and 13 per cent msnf was developed by Sharma and Gupta (1978). The whole milk was warmed to 40°C and skim milk powder was slowly added with continuous stirring to make msnf 13 per cent. The temperature of the mixture was then raised to about 70°C and sugar-stabilizer mixture was added slowly with thorough mixing followed by filtering, homogenization and pasteurization at 71°C for 30 minutes, the mix was then spray dried at an inlet and outlet air temperature of 180°C and 95°C respectively.

Ice cream mix of 37.3 per cent total solids and containing only 25 per cent of the total amount of sugar was spray dried and the powder was dry blended with refined sugar in the ratio 100 parts : 41 parts to obtain free flowing ice cream mix powder (Bhandari and Balachandran, 1984).

Rao and Mathur (1987a) described a method for production of spray dried infant formula. Skim milk was concentrated to 20 per cent total solids mixed with freshly separated cream and ground nut oil (62:38) and heated to 95°C. Vitamin mix and malto-dextrin were added, homogenized and spray drier in a co-current spray drier maintaining inlet air temperature of 210°C and outlet air temperature of 95°C.

An infant formula intended for the dietary management was prepared by Rao and Mathur (1987b). Sucrose and maltodextrin were mixed with skim milk, to get 28 per cent maltodextrin and 5 per cent sucrose in the final product, forewarmed and concentrated to 30 per cent total solids under a vacuum of 650 mm Hg. Buffalo cream, ground nut oil and vitamin mineral mixture were then mixed, forewarmed and homogenized. The formula mix thus prepared was spray dried successfully employing an inlet temperature of 210°C, keeping the outlet temperature at 90°C.

Lupin milk prepared from sweet lupin (*Lupinus albus*) by a three stage grinding of blanched beans, was successfully spray dried at an inlet and outlet air temperature of 170°C and 90°C respectively (Camacho *et al.*, 1988).

In their attempt to spray dry coconut milk, Dacosta and Cal-Vidal (1988) added anticaking agents, surface acting agents and corn starch at 15-20 per cent w/v. Coconut milk was homogenized after adding the additives and successfully spray dried using disc atomizer (10000 rpm) using inlet and outlet air temperature of 200 ± 10°C and 85 ± 10°C respectively.

In India starch or skim milk is incorporated into fruit puree prior to spray drying. Typically starch or skim milk is added at the rate of 10 per cent of the fruit pulp. In a typical industrial process for spray drying mango, 5 per cent liquid glucose and 0.5 per cent tricalcium phosphate were incorporated to the pulp. The mixture heated for 30 minutes at 50°C was homogenized and spray dried using rotary atomizer (16,000 rpm) at 165°C and 80-85°C as inlet and outlet temperature respectively. Dehumidified air at 30°C was used to cool the powder. Powder collected in polythene bags were stored at 4°C for at least 15 minutes before transporting to dehumidified packing room.

In commercial installations the solution or slurry to be dried is atomized (2-500 μm), either by high speed rotary atomizer (6000-20,000 rpm) or by high pressure nozzles (2000-10,000 psi) into rapidly circulating hot air. Evaporation occurs in a fraction of a second and overall time in the drier is usually less than 30 s. Most of the dried product (containing 1-3.5% moisture) falls to the bottom of the spray chamber wherein modern versions it is continuously removed (Jagtiani *et al.*, 1988).

Planovskii and Golovach (1988) tried the spray drying of apple juice blended with skim milk. The product obtained had 1.1 per cent fat and 5 per cent moisture. This product could be used in the manufacture of ice cream, beverages and other confectionary.

Salooja and Balachandran (1988) described a process for production of spray dried malted milk powder. The wort obtained from mashing process of barly malt was mixed with skim milk and toned milk to obtain 7.5 per cent fat and 13 per cent protein in the final dried product. Preheated malted milk was concentrated to 40 per cent total solids and spray dried with 195 ± 10°C and 90 ± 2°C as inlet and outlet temperature respectively.

Camacho *et al.* (1989) reported that sweet lupin slurry balanced to 20 per cent total solids was formulated with a blend of 0.2 per cent NaCl, 0.3 per cent tricalcium phosphate, 0.09 per cent sodium bisulfate, 0.44 per cent cocoa and 0.12 per cent flavourings. When spray dried at inlet temperature of 170-210°C and outlet temperature of 90°C using centrifugal atomizer (35,000 rpm), it yielded a good quality powder.

To conserve heat energy during spray drying it is necessary to remove as much of water as possible by vacuum evaporation of the feed mix. For concentrated skim milk, viscosities at 47 and 57 per cent total solids were 70 and 140 mPa s^{-1} respectively. For a concentrate at 50 per cent total solids a pressure of at least 25 mPa was necessary to ensure effective atomization. By using high atomization pressure and inlet air temperature, the volumetric heat transfer coefficient of a spray drier was increased from 48 to 70 kJ $m^{-3}\,h^{-1}\,K^{-1}$ (Hayashi and Kudo, 1989).

Andrushchenko and Kashurin (1990) suggested feeding solution having 20-30° Brix at 60°C and drying with air having temperature of 100-120°C at inlet, 80-100°C in the spray zone and 75-85°C at the outlet as optimum to get products with little degradation of sucrose into reducing sugar.

Spray dried beverage powder was produced from a 1:3 mixture of carrot juice and ultra filtration permeate of whole milk added with 0.2 per cent stabilizer (El-shibiny *et al.*, 1994). They reported that homogenisation at 200 kg cm^{-2} and concentration under vacuum to 25 per cent total solids prior to spray drying gave a product with 4.42 per cent moisture.

Fresh cheese whey was concentrated in vacuum pan to 42 per cent total solids and lactose crystallization was carried out with the addition of alpha lactose monohydrate (0.07%). Mushroom pieces (4%) were then cooked in concentrated whey for 10 minutes and blended in a colloidal mill. Corn flour (2.5%) cooked for 8-10 minutes to gelatinize starch was then mixed with mushroom-whey slurry and spray dried to give a final moisture content of 3 per cent in the powder (Ghosh and Singh, 1995).

Milk was concentrated to 40 per cent total solids, mixed with tea leaf infusion, 25 per cent of required amount of sugar, 0.5 per cent stabilizer and 0.5 per cent emulsifier and spray dried at an inlet temperature of 180°C and outlet temperature of 80°C, to obtain ready-to-reconstitute tea complete powder (Jha and Mann, 1995).

Spray dried coconut skim milk powder was produced by Ganeshan (1996). Coconut milk obtained by wet grinding and pressing of coconut kernels was centrifuged to obtain coconut skim milk. Coconut skim milk thus obtained was concentrated in vacuum evaporator to 40 per cent total solids and spray dried in Anhydro spray drier using atomizer speed of 22,000 rpm (feed rate 3 l h^{-1}, feed temperature 35°C) at an inlet temperature of 120°C and outlet air temperature of 80°C.

Ready-to-reconstitute mushroom soup powder was produced by spray drying by Singh and Singh (1996). Mushroom slices (4%) were cooked in vacuum concentrated whey (45% TS) at 100°C for 10 minutes, blended in a grinder with the addition of 2.5 per cent corn starch and spray dried under controlled condition.

Technology for ready-to-use banana milk-shake powder was given by Lakshminarayana *et al.* (1997). Twenty five litres of pasteurized cow milk (2% fat) was condensed to 32-36 per cent TS, blended with 0.015 per cent CMC and homogenized at 38-40°C under 100 bar pressure. Approximately 5 kg banana was mixed with water (1.0-1.5%), heated to 85-90°C for 5-10 minutes, cooled and then blended with homogenized milk and rehomogenized at 38-40°C under 50 bar pressure. The mix was spray dried at an inlet temperature of 160-180°C and outlet air temperature of 85-95°C. Ground sugar was blended with dried mix to give a final sugar content of 42.5 per cent.

Tirumalesha and Jayaprakash (1997) prepared ice cream mix by spray drying the admixture of butter milk concentrate and whey protein concentrate (40:60) at 170°C inlet and 90°C outlet temperature, followed by dry blending with sugar (75%).

Carotenoid powder (antioxidant with anti-tumor properties) was prepared from carrot pulp by spray drying. The most appropriate condition for processing was found to be 15 per cent solid content in the feed, and spray drying with inlet and outlet temperature of 135-140°C and 90-100°C respectively (Chen and Tang, 1998).

Kulkarni (1998) opined that some of the milk and fruit based beverages can be produced in dehydrated form. The production of these types of products can result in excellent value added products for spray drying plants of our country which are being used for only 40 percent of its capacity. These products have excellent export opportunities.

Soymilk was successfully spray dried by Perez-Munoz and Flores (1998) using an APV concurrent flow spray drier with an inlet air temperature of 255-275°C and atomizer speed of 19300-26800 rpm.

Gokavi (2000) reported procedure for production of malted cereal and milk based infant food. Cereal malt was cooked to which pasteurized whole milk containing buffer salts, soya oil, vitamin and mineral premix was added. The homogenized mix was concentrated at 40°C and 27 Hg pressure in a single evaporator to 40°Brix and dried in a spray drier at 150°C inlet and 90°C outlet temperature.

Rao and Gupta (2000) have outlined the procedure for spray drying of orange juice blended with skim milk. Orange juice concentrate of 60 per cent total solids was blended with condensed skim milk of total solids 30-35 per cent in the ratio 15:85 at temperature not exceeding 45°C. The blend with total solids content between 25-30 per cent was homogenized and spray dried at an inlet and outlet temperature of 180°C and 80-85°C respectively using two fluid nozzle spray drier provided with compressed air at a pressure of 124-137 kPa. The powder recorded 5.75 per cent moisture, 0.51 bulk density, 3.1 per cent acidity and solubility index of 25.

Chopda and Barret (2001) described a procedure for production of guava juice powder. Guava puree was treated with pectinase enzyme followed by centrifugation and ultra filtration to obtain clarified juice. It was then concentrated to 42°B, added maltodextrin and spray dried with inlet and out let temperatures of 160°C and 80°C respectively to obtain free flowing product with minimum moisture content of 3 per cent.

Babu and Gupta (2002) developed ready-to-reconstitute toned milk and lassi powder containing pineapple juice. Pineapple juice was mixed with concentrated milk as well as curd and spray dried. The powder packed in poly propylene pouches remained acceptable upto six months both at 37°C and room temperature.

According to Mani *et al.* (2002) spray drying of fruit juices is possible by adding high molecular weight components to the fruit juices or by modifying the drier chamber with rotating air broom system to avoid stickiness. Addition of malto-dextrin to mango juice was optimized with the ratio of 55:45 (fruit solids : malto-dextrin) with air inlet temperature of 167°C and outlet of 89°C. One kg of mango could produce 0.261 kg powder having 5 per cent moisture content.

2.3.2 Drum drying

Drum drying is generally used for drying of slurries, pulps and purees of food which could withstand high temperature for short time without serious flavour deterioration or loss of solubility. Food materials are 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 material from which the water is vapourised during partial revolution of the drums. The dried material is scraped from the rotating drum surface by a stationary knife (doctor blade) which is depressed against the drum at appropriate location.

Bose and Dutt (1952) produced ripe mango powder by drum drying. Properly ripe mangoes were peeled, sliced, mixed with equal volume of water and pulped. The pulp was fed to double drum drier which was kept at a temperature of 287°F, corresponding to a steam pressure of 40 psig. Time of dehydration was 6-8 seconds. The dried product obtained in the form of nice 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 2-3 rpm drum speed. 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 which reconstitute readily in cold water was produced with modified atmospheric double drum drier by Lazar and Morgan (1966). Peeled apple slices were steamed for 2 minutes at 212°F and made into sauce. Sucrose was added to raise the total solids content to 20°Brix and sodium bisulphate was added to obtain about 400 ppm SO_2 in the fresh sauce. Double drum drier with drums 12 inch diameter and 18 inches long separated by 0.008 inch was used which rotated towards each other at the top at 1.5 rpm. Steam at 60-70 psi filled the drums and a jet of chilled air was blown over the product film, just before it was scraped by the doctor blade. 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 4 rpm (drum 7.5" long and 6" diameter) at 70 lb steam pressure to obtain dehydrated powder.

For production of pure pumpkin powder canned puree was concentrated at atmospheric pressure to about 21 per cent solids and applied to a single drum drier operated at a steam pressure of 75 psi and speed of 5 rpm (Talley *et al.,* 1966).

Hoover (1973) reported the method for production of pumpkin flakes. The pumpkin pieces were ground and 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 syrup.

Mashed potatoes treated with sodium bisulfite was 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).

Green mango powder was prepared in an atmospheric drum drier by Gangopadhyay *et al.* (1976). The p^H 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 free flowing character of the finished product. Dehydration was carried out on a drum drier heated by steam at 50 psi and rotating at 4 rpm. The time of contact was about 15 seconds.

Mango pulp in admixture with skim milk powder in 1:1 ratio on the basis of brix of the pulp or double strength fresh whole milk (mango:milk 1:2) was drum dried with a roller of 6 inch diameter and 8 inch long with rotation of 2-3 rpm and steam pressure of 50 psi (Jayaraman *et al.*, 1976).

According to Kopelman and Saguy (1977) drum drying has much faster dehydration rate and better steam efficiency compared to conventional beet root 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 and dried in a drum drier at a steam pressure of 45 psig and drum speed 3.5 rpm, yielded 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 p^H to 5.5. The mix was then drum dried (4 rpm drum speed, 30-45 psi pressure and 0.15 mm drum clearance) to obtain free flowing mango powder.

Camacho *et al.* (1989) subjected lupin imitation milk from *Lupinus albus* to drum drying at steam pressures equivalent to temperatures of 150, 160 and 170°C to obtain powdered lupin milk.

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 5 rpm with 4.5 bar steam pressure (Malleshi *et al.*, 1989b).

Samah *et al.* (1989) reported that buffalo milk concentrated to 20-25 per cent total solids was dried on atmospheric and vacuum roller drier with steam pressures of 50 and 60 lb m^{-2} respectively.

Concentrated goat milk was dried on an atmospheric double drum drier maintained at 75 psi revolving at 18 rpm. The distance between the drums was 1.0-1.5 mm (Prakash *et al.*, 1990).

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 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 mungbean slurry to produce dehydrated mungbean flakes.

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 6 atmosphere, 0.75 m^2 contact surface and 1 rpm were added to dried whole milk and sugar to develop the product.

Valdez *et al.* (2001) reported that in 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.

2.3.3 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 4 h and subsequently dehydrated for 18 h at 60 ± 5°C in a cross flow drier to a moisture level of 3 per cent. The dried slices were powdered in a grinding machine to obtain good quality guava powder.

Cooke *et al.* (1976) observed that a stable mango foam produced by adding polyglyceryl stearate (1.5% dry solids basis) and mixing in a domestic mixer at maximum speed for 10 minutes was dried at 70°C for 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 h were successfully dehydrated in an electric cabinet through flow drier at 60°C for 8-12 h by Teaotia *et al.* (1976).

Papaya fruit pulp and enriched papaya fruit slabs incorporating 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 10 per cent moisture was prepared by drying the pulp containing sulphur dioxide, at 55-60°C for 17-18 h. The sheets were cut into pieces and further dried to less than 4 per cent moisture in the cabinet drier at 60 ± 5°C and were ground to fine powder in a grinding machine (Roy and Singh, 1979).

Ambadan (1985) developed a delicious dehydrated product from sapota. The method involves horizontal halving, drying in an electrical drier maintained initially at 70°C and finally at 55°C for 4 days (8 h operation/day). Vaghani and Chandawat (1986) opined that sapota slices steeped in 40 per cent sugar solution containing KMS (1%) for 20 min or dipped in sugar solution containing 20 per cent KMS for two minutes and subsequently dried under sun for getting a stable and quality product.

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. Again they opined that two stage operation with a 2 hour initial drying at 102°C followed by finish drying at 85°C for 3.5 h gave a good quality product.

The method of production of tray dried khoa as described by Rajorhia (1989) consisted of preparation of khoa from buffalo milk (5% fat and 9% SNF), heating the product to reduce the moisture to about 20 per cent and comminuting it to fine particles. Ground khoa was then uniformly distributed in trays in a thickness of 1 cm and dried in a tray drier at 70°C to get khoa powder with 3.8 per cent moisture.

Aruna *et al.* (1998) developed cereal based papaya powder. Cooked wheat flour was mixed with papaya pulp at 80-85°C and heated at this temperature to reduce volume to half. The mix was then dried in a drier at 60°C to obtain a product with five per cent moisture content.

Hassan and Ahamed (1998b) has developed foam-mat dried pineapple juice powder in which egg albumin (1%) was added to pineapple juice, blended for 10 minutes in a blender and spread on a tray at 3 mm thickness and dried at 55-60°C for five hours in a cabinet drier to reduce moisture content to 6 per cent. The product was detrayed, ground with addition of 1 per cent magnesium stearate, passed through 0.5 mm sieve and vacuum packed in 300 gauge 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. Fruit pieces of different sizes (0.25, 0.5 and 5 mm slices of fruit) were dried at temperatures 55, 65, 70°C in both vacuum and air draft oven. The drying time varied from 15-35 h in air draft oven and from 14-31 h in vacuum oven. The powder retained the natural colour and aroma of the ripe fruit and TSS and ascorbic acid content were the highest in the product dried at 65°C. The dehydrated sapota was powdered using a grinder and a ball mill to particle size of 105 microns. This sapota powder could be successfully incorporated in many sweet products, where texture is not a major factor of food quality.

Sagar and Khurdia (1998) attempted production of improved products using ripe mango powder for which each fruit was cut into six length wise slices dipped in an equal amount of 70°Brix sugar solution containing 0.1 per cent KMS, heated for 2 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 5 per cent. These slices were powdered with the help of a powder mill and sieved with 30 mesh sieve. Mango-shake obtained by mixing this with milk, water and sugar in the ratio of 6:12:6:1 was rated the best.

Waskar *et al.* (1998) reported that time required to dehydrate freshly harvested palak, methi and coriander leaves were the lowest and percentage yield of dry matter was the highest in cabinet drying and the product 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).

Ready-to-use banana milk-shake powder was prepared by mixing banana flour with skim milk powder and sugar in the ratio 1:1:4. The banana milk-shake prepared from this mix retained good organoleptic characteristics throughout the study period of 90 days (Chitra *et al.*, 2002).

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 h. The dried soup was gound 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 this desired level even after 30 h (Srivastav *et al.*, 2002).

2.4 PACKAGING AND STORAGE OF DEHYDRATED PRODUCTS

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 chemical and other changes causing deterioration and reduction in shelf-life of the product.

Strolle and Cording (1965) reported that potato flakes with 4 per cent moisture deteriorated in one month, but with 6.6 per cent remained acceptable for six months. The flakes with 5.0-6.6 per cent moisture possessed a shelf-life of 6 months when air packed and stored at room temperature.

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 N_2 packing. But in the atmosphere of air, it acquired a hay like off-flavour.

Nitrogen packing markedly increased shelf-life of cooked lima bean powder. However addition of 3 ppm BHT was beneficial in both air and nitrogen packs. The first flavour change in nitrogen packed, antioxidant treated powder of 4 per cent moisture was detected after 7.5 months at 38°C (Burr *et al.*, 1969).

Chandrasekhara *et al.* (1969) reported that infant food based on ground nut protein isolate and skim milk powder produced by spray drying had a shelf-life of 8 months at 45°C when packed in polyethylene aluminium laminate bags.

According to Khurdia and Roy (1974) guava powder packed in 200 guage polyethylene coupled with aluminium foil was found to be the best even after six months. Mango-milk powder with 2.5 per cent moisture when stored in tin plated hermetically sealed cans and gassed twice with N_2 at an interval of 24 h, remained acceptable even at the end of one year both at room temperature and 30 ± 1°C. But free fat and acidity showed a progressive increase (Sharma *et al.*, 1974).

Sood and Srinivasan (1975) observed that free fat in ice cream mix powder increased at a greater rate under nitrogen gas packing during storage and the product remained in good condition for four months under air packing. 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 N_2 packing respectively at room temperature (20 ± 2°C).

Love and Dugan (1978) reported that below the monolayer value (aw 0.11) greater lipid oxidation occurred in neutral lipids and phospholipids of air packed samples than in nitrogen packed samples.

Spray dried srikhand powder when packed in containers with double nitrogen gas packing, flavour and reconstitution of the product was satisfactory for about 45 days at room temperature (Mahajan *et al.*, 1979).

Aruna *et al.* (1998) reported that cereal based papaya powder when stored for nine months, non-enzymatic browning increased from 0.06 to 0.140 OD while moisture increased from 1.05 per cent to 11.9 per cent. The microbial counts such as viable bacteria, yeast and mould counts were found to increase slightly only after 6 months of storage.

George (1983) reported that metallised PE / poly laminate pouches (air packed and N_2 packed) were suited only for storage of whole milk powder for about 30 days. Delamination of metallised polyester and breakage of outer seal were also observed during storage. She also reported that whole milk powder became brown, insoluble and organoleptically unacceptable above 32 per cent RH with equilibrium moisture content of 5.3 per cent. Nanjundaswamy (1984) reported that fruit juice powders were free flowing till 8 months at room temperature and nitrogen packing did not showed any beneficial effect on storage and quality of the powder.

According to Mrithyunjaya and Bhanumurthi (1987), metallised polyester LDPE (MP) gave protection from deterioration similar to that of tin as observed from 180 days storage of spray dried whole milk powder. Rajorhia and Pal (1988) reported that gulabjamun mix powder possessed a shelf-life of less than 6 weeks.

Shah *et al.* (1987) suggested polyethylene aluminium foil laminated pouches as one of the suitable packaging material for dried products containing live *Lactobacillus* cells.

Malhotra and Mann (1989) reported that ready-to-reconstitute coffee complete powder could be stored for 3 months in metallised polyester LDPE laminate at 30 ± 1°C. During this period, moisture content increased from 2.28 to 2.29 per cent and p^H decreased from 6.45 to 6.37.

Malted ragi and green gram based drum dried weaning food recorded 65 per cent RH and 11 per cent moisture as critical levels. Samples packed in LDPE pouches were stable up to three months and in laminate pouches for five months under ambient conditions (Malleshi *et al.*, 1989a).

Wewala (1990) described that oxidative stability of dried whole milk stored for one year at 30°C improved significantly when water activity was increased from 0.09 to 0.28. They recommended that water activity of the dried milk should be in the range of 0.21-0.24 and to achieve this maximum moisture content should be raised to 3.4 per cent from the usual range of 2.5 to 3.0 per cent.

Lim *et al.* (1994) studied the physico-chemical properties of dried whole milk stored for four months at different temperature. Powder packed in kraft paper/ nylon polyethylene (NY-PE) with nitrogen and Al polyethylene laminate under vacuum recorded lower peroxide value and TBA value during storage.

Ready-to-reconstitute tea complete powder when stored in metallised polyester-LDPE laminate at 30 ± 1°C did not show any significant increase in free fat content (Jha and Mann, 1995).

Cereal based papaya powder when stored for nine months, non-enzymatic browning, expressed as optical density, increased from 0.06 to 0.140 while moisture content increased from 1.05 to 11.9 per cent (Aruna *et al.*, 1998).

2.5 RECONSTITUTION OF DEHYDRATED PRODUCTS

Sharma and Gupta (1978) reported that spray dried milk-shake mix was reconstituted by calculated amount of crushed ice so as to adjust solids level to 28 per cent in the final product and blended in a mixie for 90-120 seconds.

Dry mix for making shakes developed by Baudach (1983) was made into milk-shake by dispersing 50 g of the mix in 0.2-0.25 l cold water. It was reported that on rehydration with milk the mixture may be shaken by hand to obtain 400 per cent volume increase.

Ready-to-reconstitute tea powder was reconstituted into tea by dissolving about 15 g powder in 20 ml warm water followed by the addition of make up water to fill a cup of 140 ml (Jha and Mann, 1995).

Singh and Singh (1996) reported that spray dried whey based mushroom soup powder could be reconstituted well in 900 ml boiled water with constant stirring.

2.6 BOTTLED FRUIT-MILK BEVERAGE

Wheeler and Gillies (1973) developed an organoleptically acceptable banana-milk by mixing ripe Cavendish bananas and whole or partly skimmed milk in the ratio 1:5 by weight with the addition of 0.5 per cent glucose, heating to 38°C and single stage homogenization at 2000 psi. The drink was then HTST pasteurized at 72°C for 15 seconds.

A method of preparation of milk based fruit juice beverage was described by Guleria and Jain (1978). Fruit juice was mixed with whole milk in the proportion of 37.0 : 56.8 and sugar (6%) and stabilizer ((0.2%) were added.

Chemically preserved mango pulp neutralized with addition of sodium bicarbonate was found quite suitable for the preparation of milk-mango shake. The drink with a p^H of 6.5 was successfully sterilized at 116°C for half an hour to enhance the shelf-life of the developed beverage. However, flavour deteriorated with increase in processing temperatures from 63 to 100°C (Grewal and Jain, 1982).

A fruit flavoured milk drink at p^H 3.6-4.5 was made by mixing 3-5 parts cow milk, 4.5-6.5 parts syrup, 0.5 parts of an aqueous mixture containing 10-50 per cent w/v fruit juice, 4.2-6 per cent sodium hydroxycarboxylic acid (eg. lactic acid, citric acid, malic acid or tartaric acid) at 3.1-5.0 per cent and colourings and flavourings etc. as required (Nishiyama, 1982).

Process details for producing milk-based beverage containing up to 40 per cent (v/v) of grain extractives was given by Singh and Bains (1982). He reported that wheat extractives-milk beverage was found superior because of its excellent flavour.

In the investigation to prepare milk like beverage from defatted soy flour in combination with skim milk, coconut, soymilk and from wheat and ragi with malted green gram, pea nut and soyflour, wheat malt combination and soy flour with coconut and skim milk blend were found highly acceptable with high protein and energy content (Javalagi and Vaidehi, 1986).

Singh and Bains (1988) described a procedure for preparing grain extract-milk beverage. Extracts from germinated barley, wheat, triticale and corn showed compactability when blended with milk in proportions of 30, 40 and 50 per cent respectively. The p^H and fat content of the beverage blends were adjusted to 7.2 and 3 per cent respectively. The contents were stirred and warmed to 60°C before homogenization at 2500 psi. Three per cent sugar (w/v) was added and the beverage was hot filled (80°C) in glass bottles. Processing at 121°C for 15 minutes decreased p^H to 6.2. The wheat and barley extract beverages followed by triticale and corn beverages recorded excellent taste and smooth mouth feel.

Endres and Renner (1991) reported that the highest sugar content was demanded for chocolate milk-shake (3.8%), followed by straw berry milk-shake (3.7%) and vanilla and banana milk-shake (3.4%).

A process for manufacture of thick milk-shake was given by Nakaya *et al.* (1991). The ingredients viz. 40-70 wt per cent water, 0.3 wt per cent alcohol, 1-7 weight per cent protein, 1-25 wt per cent oil/fat and 15.3-40 wt per cent carbohydrate containing 15-35 wt per cent sugar were mixed and the ice cream thus obtained was shaken and mixed at a temperature in the range of ˉ20 to 8°C with or without addition of syrup such as fruit sauce to make milk-shake.

Al-Haq and Mahyuddin (1992) reported that out of 15 milk based beverages prepared from skim milk powder (3%), mango pulp (var. Chousa at 1-3%) and three stabilizers (Maxpectin Rs.450, Gelodan SM and CMC added at 0.2-0.3%), highest sensory score was achieved using Maxpectin RS 450 and 3 per cent mango pulp. This was subsequently manufactured on an industrial scale with pasteurization under HTST and asceptically packed in brick packs in a combiblock machine.

Skim-milk beverage containing 85 per cent skim milk, 15 per cent orange juice and sugar with small amount of mono-crystalline cellulose as stabilizer was prepared by Gutknecht (1992).

Rehman *et al.* (1992) reported that banana-milk beverages were developed with varying amounts of banana pulp. Maxpectin RRS 340 and Gelodan RSM at 0.15-0.20 per cent were found to be better stabilizers for manufacturing the beverages. Whey based beverage was developed by Singh and Kapoor (1993) by adding sugar, spices, citric acid, salts and jeera essence to paneer whey.

Ramesh *et al.* (1993) reported that it is possible to obtain a stable coffee flavoured milk-based sterilized drink by using trisodium citrate (0.02-0.03%) depending upon the level of acidity in the initial milk used for the preparation of the drink.

Ibrahim *et al.* (1993a) reported that guava-milk beverage was prepared by adding 6-11 per cent guava pulp and 3, 4 or 5 per cent sugar to skim milk, filtering and pasteurizing at 75°C for 5 minutes in glass bottles.

Optimum concentration of mango pulp and sugar for use in pasteurized mango-milk beverage prepared from standardized (1% fat) cow milk was 20 and 2 per cent respectively (Ibrahim *et al.*, 1993b).

Singh *et al.* (1993) reported that banana pulp was solubilized by hydrolysis of pectin using pectinase enzyme at 1 per cent concentration (v/w) which was used for preparing banana beverage with p^H 5.0 having 20 per cent banana juice, 73 per cent paneer whey and 7 per cent sugar. After bottling, the beverage was pasteurized at 85°C for 15 minutes.

Pineapple flavoured apple-milk based beverage was formulated by Al-Haq *et al.* (1996). It contained 13 per cent cane sugar, 3 per cent apple pulp, 2 per cent skim milk powder, 0.3 per cent Givaudans' stabilizer, 0.2 per cent citric acid, 0.02 per cent sodium citrate, 0.01 per cent potassium sorbate, 0.07 per cent pineapple flavour, colour as desired and water to 100 per cent. This was manufactured at a UHT installation using direct injection of steam at 144°C and packed in 250 ml brick packs.

Candia, a leading dairy company in France launched 'Viva Fruit' a combination of UHT milk and fruit to compete with cola flavoured beverages (Bystrom, 1996).

Date-juice milk drink was developed by mixing date juice with milk, bottling and heating in boiling water for 30 minutes. A 60:40 date:milk mixture produced more acceptable product than a 75:25 or 45:55 mixture. Optimum p^H of the drink was 6.6. The drink when compared with imported mango-milk drink which contained only lactose and sucrose, possessed higher sugar content and contained fructose also in addition to glucose, lactose. It was richer in calcium, phosphorus and magnesium and contained less sodium than mango-milk drink.

Hassan and Ahmed (1998a) developed mango-milk beverage by blending Dashehari variety of mango pulp and milk. The beverage contained 15 per cent milk, 30-40 per cent mango pulp and TSS was adjusted to 20°Brix by addition of sugar. The blended beverage was filled in 300 ml sterilized glass bottles, crown corked and thermal processed for 30 minutes at 88-90°C. The beverage recorded a p^H of 4.8 and 0.33 per cent acidity.

Milk-fruit juice mixtures were marketed successfully in countries such as USA, Japan and Netherlands. But in France sale of these dairy cocktails, a blend of UHT milk with fruit juice were on a decline. An alternative that might be promising would be fresh fruit juice products. Danone has already launched one such product, 'Danao', a pasteurized drink with 20 per cent skim milk and fruit juice (Renard, 1998).

Sharma and Shulka (1998) reported that addition of fruit juices to the milk byproducts in the manufacture of beverage not only improved nutritional quality but also made the beverage more delicious. The paneer whey based beverage containing 20 per cent apple juice and 10 per cent sugar was most accepted followed by skim milk with 20 per cent mango juice and butter milk with 30 per cent apple juice. However, when used in more than 10 per cent level, addition of guava juice did not improve organoleptic qualities of any of the milk byproducts based beverages.

2.7 STORAGE OF MILK BASED FRUIT BEVERAGES

Banana-milk prepared by mixing partly skimmed milk and Cavendish bananas subjected to HTST pasteurization at 72°C for 15 seconds and stored at 5°C recorded a keeping quality of two weeks (Wheeler and Gillies, 1973).

Al-Haq and Mahyuddin (1992) reported that milk based beverage prepared from skim milk powder (3%) and mango pulp (1-3%) upon pasteurization under HTST, when aseptically packed showed a shelf-life of 49 days under refrigerated condition.

Skim milk beverage containing 85 per cent skim milk and 15 per cent orange juice when processed at very high temperature remained shelf stable without refrigeration for six months to one year (Gutknecht, 1992).

Rehman *et al.* (1992) reported that banana-milk beverages when pasteurized at 80°C, bottled and stored at 4-8°C recorded a shelf-life of 1 month.

According to Ibrahim *et al.* (1993a), sterilization of beverage with 10 per cent guava pulp and 4 per cent sugar at 120°C for 15 minutes with addition of carrageenan as stabilizer showed a decrease in non-reducing sugar content and p^H and negligible change in reducing sugar content and viscosity during storage period of 90 days.

Singh and Kapoor (1993) reported that carbonation enhanced acceptability and addition of sodium benzoate at 300 ppm enhanced shelf-life of whey-jeera beverage.

Pineapple flavoured apple-milk based beverage containing three per cent apple pulp and 2 per cent skim milk powder manufactured at a UHT installation and packed in brick packs remained acceptable up to 90 days under refrigerated storage (Al-Haq *et al.*, 1996).

Date juice-milk drink developed by Yousif *et al.* (1996) was bottled and heated in boiling water for 30 minutes. Its storage at 25°C for 16 weeks resulted in significant reductions in pH, sugar and moisture content and colour change.

Hassan and Ahmed (1998a) reported that mango-milk beverage containing 15 per cent milk and 30-40 per cent mango pulp upon bottling and thermal processing for 30 minutes at 88-90°C remained highly acceptable up to six months of storage at room temperature. Study on effect of CMC, soluble starch, sodium alginate and pectin on preventing layer separation showed that pectin and sodium alginate at 0.5 per cent level gave the best result, but the product was more viscous and lost the flow behaviour.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]" was carried out at the department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur and utilizing the facilities of KAU Dairy Plant, Mannuthy, Thrissur during the period 2000-2004.

The objective of the study was to develop sapota-milk beverage, a nutritious value added product from sapota as an instant powder as well, as a bottled drink.

The whole programme was divided into three major parts.

1. Development of technology for instant sapota-milk beverage powder (SMBP)
2. Development of technology for bottled ready-to-serve sapota-milk beverage
3. Marketability of value added products

In this section, the details of the experiments carried out to meet the objectives of the study are explained.

3.1 DEVELOPMENT OF INSTANT SAPOTA-MILK BEVERAGE POWDER

For the development of instant sapota-milk beverage powder, three methods of drying viz. (1) spray drying, (2) roller drying and (3) cabinet drying were adopted. In all the drying experiments different combinations of fruit and milk solids were tried to develop the beverage powder having the best composition.

3.1.1 Experiments on spray drying

Experiments on spray drying were conducted with four different inlet air temperatures viz., 145, 165, 185 and 205°C and based on the result the following beverage mix compositions (Table 3.1) were spray dried at the standardised inlet air temperature while maintaining the outlet air temperature as 90°C.

Table 3.1. Beverage mix compositions used in spray drying experiments

Treatment*	Sapota : milk (solids basis)
S_1	1 : 3.0
S_2	1 : 2.5
S_3	1 : 2.0
S_4	1 : 1.5
S_5	1 : 1.0

*GMS and SA added at 1 per cent of total solids of the mix

3.1.1.1 Raw materials

Sapota pulp

Fully ripe fruits procured from local market were cleaned, cut into halves and pulp was scooped out after removing the seeds. The pulp was mixed thoroughly in a household mixer and sieved twice, first through 30 mesh and then through 60 mesh sieve. The pulp was then pasteurized at 85°C for 10 minutes, cooled and stored in stainless steel containers in deep freezer at -20±5°C, which served as feed stock for all the drying experiments (Fig. 3.1). Recovery percentage of pulp was calculated as percentage weight of strained pulp over the initial weight of ripe fruits.

Milk

Fresh pooled cow milk was obtained from Dairy Plant, Kerala Agricultural University, Mannuthy and fat percentage was estimated by Gerber method (BIS,1981).

Cane sugar, emulsifier and stabilizer

Cane sugar purchased from local market was used for all the experiments. Glycerol monostearate (GMS) and sodium alginate (SA) were used as emulsifier and stabilizer respectively in the experiments.

3.1.1.2 Preparation of beverage mix for spray drying

Various steps involved in the preparation of beverage mix for spray drying is shown in Fig. 3.2. Fresh cow milk was collected in a clean container, forewarmed to

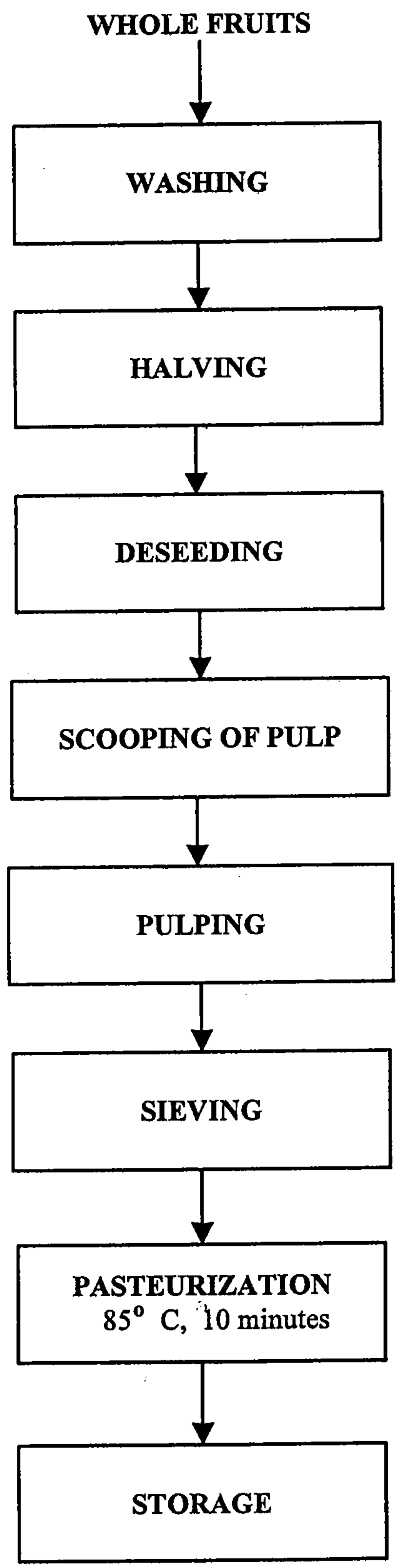


Fig. 3.1. Preparation of sapota pulp

40°C and fed to a cream separator (Alfa-Laval, 550 lph) to obtain skim milk. Skim milk was further heated to 85°C for 10 minutes for destruction of pathogenic microorganisms.

Skim milk was then subjected to vacuum concentration in a batch type, rising film vacuum evaporator (Anhydro, Denmark). Water supply to the condensor was regulated and sufficient vacuum was obtained in the calandria with liquid ring vacuum pump in a few seconds. Milk was drawn into the evaporator through an adjustable valve (A) at the top of the calandria (Fig. 3.3). The valve was closed once the entire quantity of milk was drawn and the steam inlet valve was opened very slowly and the boiling of milk was observed through the sight glass. The steam valve was adjusted such that the boiling of milk was maintained at 50-55°C and steam jacket temperature at 60-70°C. The boiling milk circulated from the calandria to the vapour separator and back again to the calandria. The vapour separated in the vapour separator was drawn into the spring type condenser, cooled and condensed by contact with water and then removed by the vacuum pump.

When the desired concentration was achieved the steam valve was closed, vacuum pump was stopped and the water supply to the condenser was also closed. The vacuum was released and the concentrated skim milk was drained through the drain valve (B) at the bottom of the calandria.

The solids content of the concentrated skim milk was observed using a hand refractometer (Erma hand refractometer). Calculated quantity of fruit pulp was added to get beverage mix with different composition as required for various trials. GMS and SA were taken in equal quantity (1% of total solids of the mix) were first dissolved in 50 ml of water at 65°C and then added to the mix with constant stirring.

Beverage mixes having various ratios of fruit and milk solids were homogenized using a two stage homogeniser (APV Gaulin, Gaulin Corporation, USA). The mix was heated to 65°C prior to homogenization. The homogenization pressure was adjusted to 150 kg cm^{-2} in the first stage and 35 kg cm^{-2} in the second

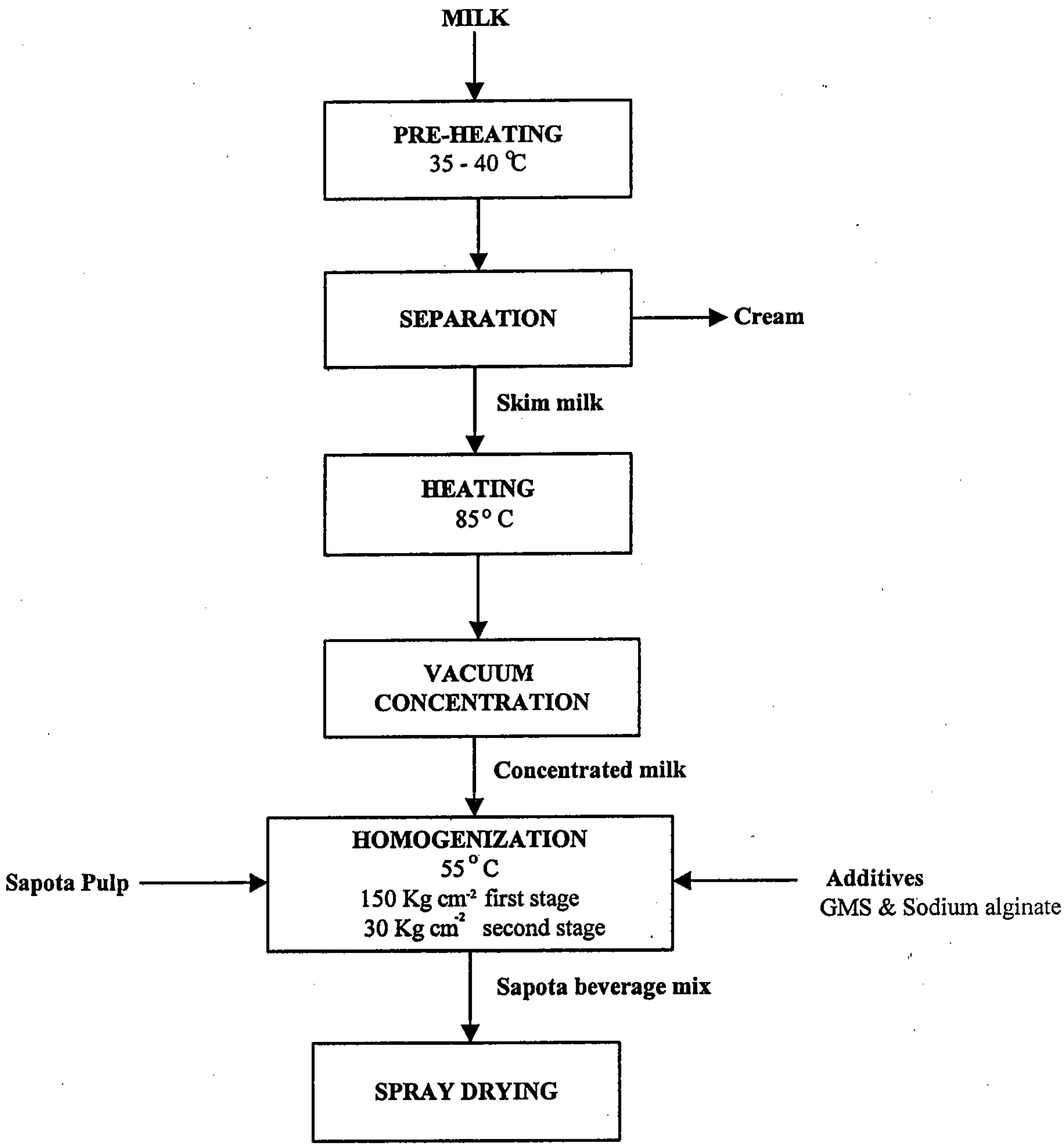


Fig. 3.2. Preparation of beverage mix for spray drying

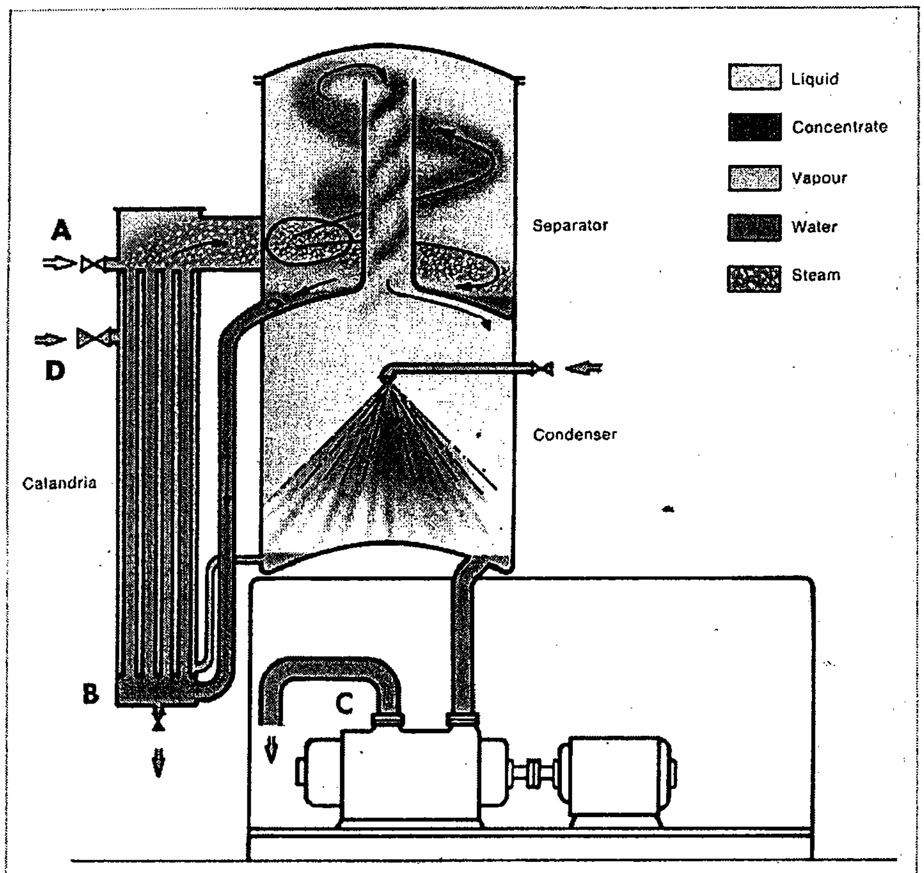


Fig. 3.3. Internal view of vacuum evaporator

stage respectively. The beverage mix prepared as discussed above was heated and then spray dried.

3.1.1.3 Spray drying of the beverage mix

A laboratory spray drier (Anhydro, Denmark) was used for conducting experiments on spray drying (Plate 1). Centrifugal type disc atomizer was used for atomization of the beverage mix and atomizer speed was maintained at 22,000 rpm.

The spray drier was thoroughly cleaned and the air blower and the electrical heating system were switched on. When the inlet air temperature reached 110°C, hot water at 80°C was fed into the feed bowl. The atomizer was switched on and the disc speed was slowly increased and maintained at 22,000 rpm. Water was fed into the atomizer with the help of a peristaltic pump. The feed rate of the water was adjusted such that the outlet temperature of air was maintained at 90°C. When the inlet air temperature reached the desired temperature and the outlet air temperature was stabilized at 90°C, prepared beverage mix was fed into the feed bowl. Atomization of the mix was observed through sight glass. The beverage mix after atomization mixed thoroughly with the hot air in the drying chamber and was instantly converted into powder. The powder particles were collected in the conical bottom of the drying chamber and then carried by the air into the cyclone separator. In the cyclone separator powder particles were separated from the air and were collected in a basket. Air was let, out to the atmosphere. The powder collected in the basket was cooled and then packed.

3.1.2 Experiments on roller drying

Experiments on roller drying of the beverage mix was carried out with two different steam pressures viz., 4 and 5 kg cm^{-2} and two different drum speed viz., 7 and 10 rpm. Beverage mix of the following composition (Table 3.2) were roller dried under the standardised steam pressure and drum speed.

Plate 1. 'Anhydro' laboratory spray drier

Table 3.2. Beverage mix compositions used in roller drying experiments

Treatment*	Sapota : milk (solids basis)	Fat percent of the milk
R_1	1 : 2.0	-
R_2	1 : 1.5	-
R_3	1 : 1.0	-
R_4	1 : 0.5	-
R_5	1 : 0.5	1.0
R_6	1 : 0.5	2.0

* GMS and SA added at 1% of the total solids of the mix

\- used skim milk

3.1.2.1 Preparation of beverage mix

Milk was separated as explained in 3.1.1.2 to obtain skim milk, which was used for all the treatments except R_5 and R_6. Milk was standardised by the addition of requisite quantity of cream of known fat percentage to the skim milk, calculated as per Pearson's square method for the treatments R_5 and R_6. Various steps involved in the preparation of the mix are shown in Fig. 3.4.

Required quantity of fruit pulp, GMS and SA were added and the mix was thoroughly homogenised and subjected to roller drying.

3.1.2.2 Roller drying of beverage mix

Nip feed atmospheric type double drum drier (Richard Simon, Nottingham, England) was used for roller drying of sapota-milk beverage mix (Plate 2). The length and diameter of drum were 0.6 m each.

The drums were cleaned thoroughly and the drive motor was switched on. The doctor blades were kept away from the drum surface and drum speed was adjusted. Steam was slowly admitted inside the drum and air cock was opened to vent out the air from inside of the drum. Condensate was allowed to go out from the inside of the drum through the steam trap. When the steam reached the standardized pressure, the beverage mix was fed into the feed tray. Mix slowly started flowing into the top gap between the two drums and made a thin coating on the drum surface. It was

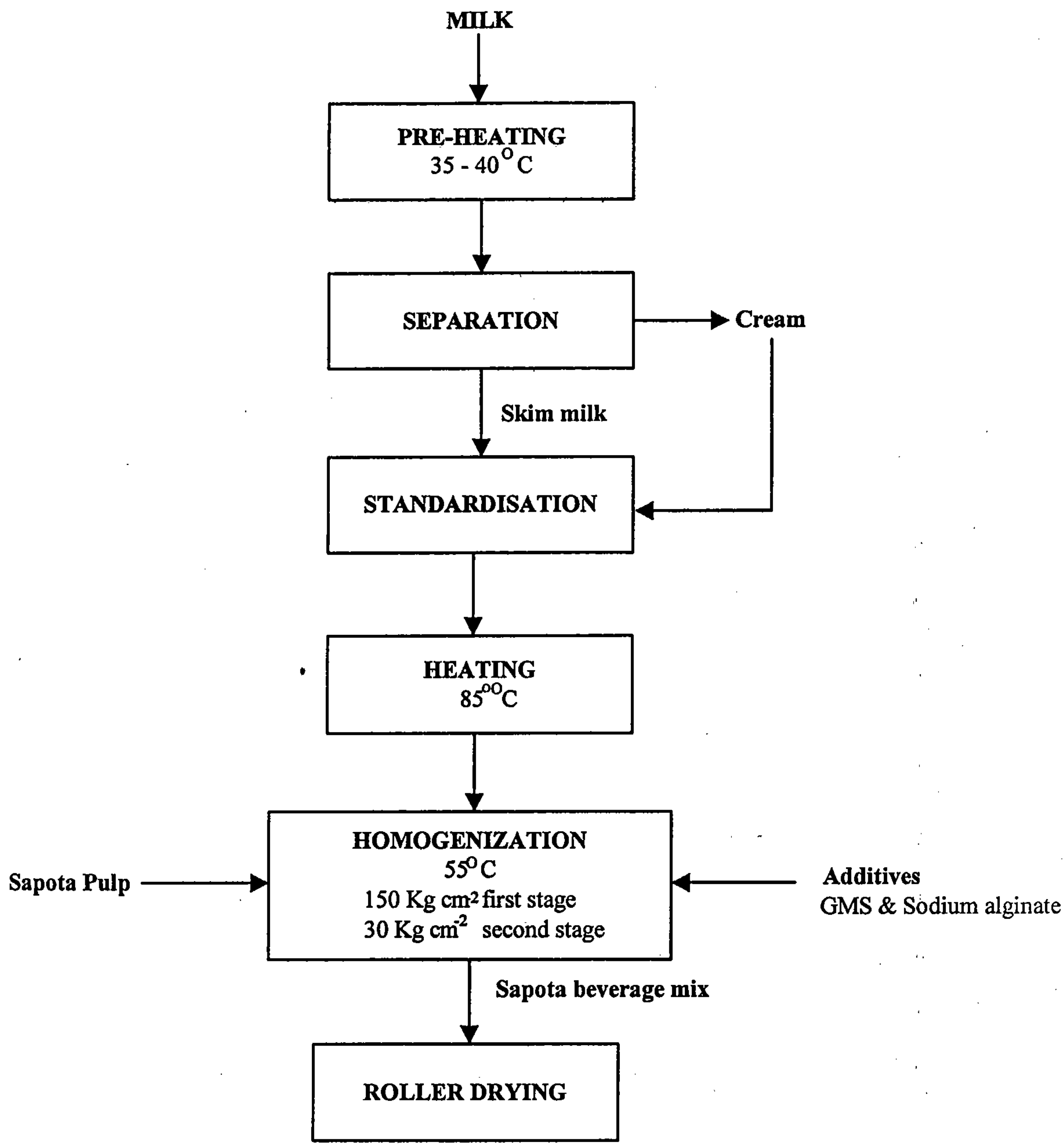


Fig. 3.4. Preparation of beverage mix for roller drying

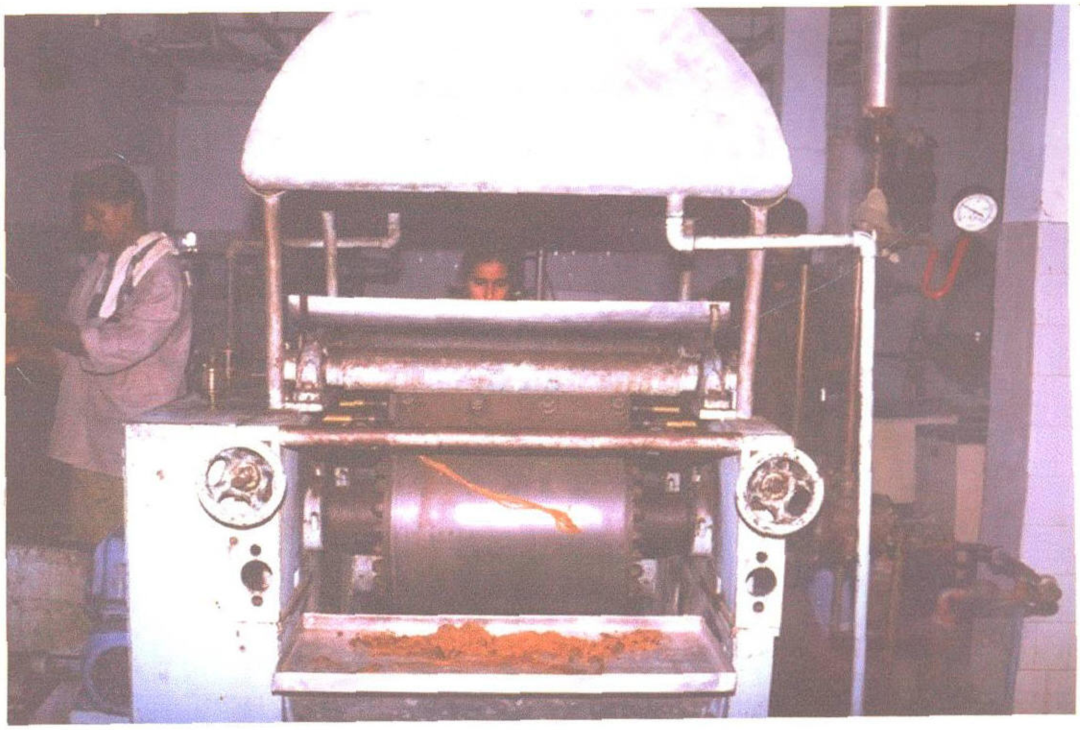


Plate 2. Roller drier

Plate 3. Cabinet drier

carried forward due to the rotation of the drum and mix was dried due to the heat provided by the steam flowing inside the drum. The doctor blades were adjusted to make contact with the drum surface. The dried film of beverage was scraped from the surface of the drums using the doctor blade riding on the surface when the drum makes 3/4[th] of a rotation. The thin flakes were collected on a tray and were ground to fine powder in a dry grinder. The powder obtained was sieved, cooled and packed.

3.1.3 Experiments on cabinet drying

Experiments on cabinet drying with three different drying temperatures viz., 60, 70 and 80°C were carried out and based on the result the following beverage mix compositions (Table 3.3) were cabinet dried at the standardised temperature.

Table 3.3. Beverage mix compositions used in cabinet drying experiments

Treatment*	Sapota : milk (solids basis)
C_1	1 : 2.0
C_2	1 : 1.5
C_3	1 : 1.0
C_4	1 : 0.5

*GMS and SA added at 1 per cent of total solids of the mix

3.1.3.1 Preparation of beverage mix

Steps involved in the preparation of beverage mix are shown in the Fig. 3.5. Spray dried skim milk power (Anikspray-Brooke Bond Lipton (I) Ltd., Calcutta-700 001) was used for cabinet drying experiment. Required quantities of fruit pulp and skim milk powder, GMS and SA were taken, mixed well and whipped in a wet blender for five minutes and subjected to cabinet drying.

3.1.3.2 Cabinet drying of beverage mix

Cabinet drier with inner dimensions as 0.9 x 1.0 x 0.61 m^3 with 2.5 kW heating capacity was used for cabinet drying of sapota-milk beverage mix (Plate 3). The mix prepared was spread on stainless steel plates at the rate of 2 kg m^{-2} and dried in cabinet drier at the standardized temperature. The product was detrayed in the form

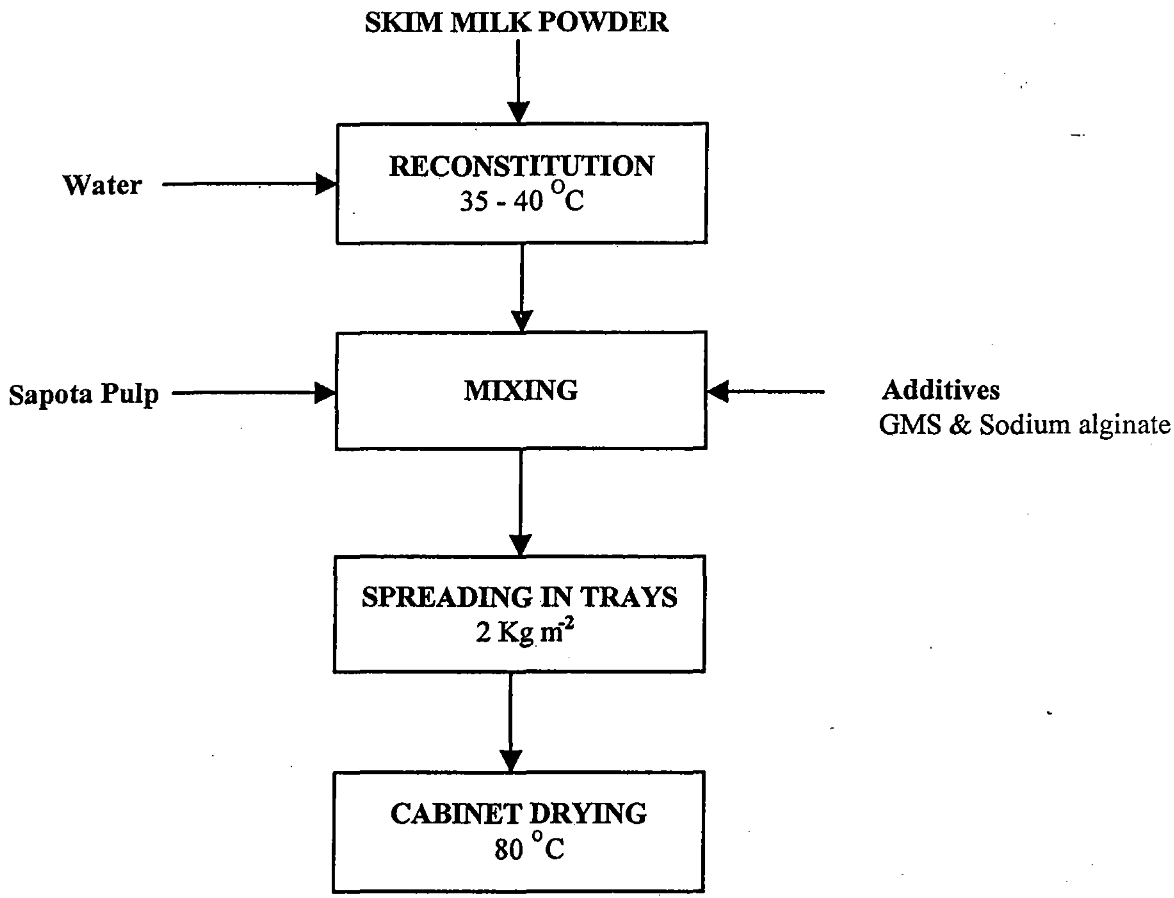


Fig. 3.5. Preparation of beverage mix for cabinet drying

of flakes and was then ground to fine powder in a dry grinder. The powder obtained was sieved, cooled and packed.

3.1.4 Sensory evaluation of the products

The best formulation in each drying method was identified based on sensory evaluation of the reconstituted product. For reconstitution 20 g of the beverage powder together with 6 g sugar was mixed thoroughly with 120 ml chilled water in a mixie for 3 minutes. A panel of 15 members evaluated the samples for colour, flavour, consistency and overall acceptability on a 5 point hedonic scale (Appendix-I).

3.1.5 Comparison of different drying methods for production of SMBP

The following physico-chemical and organoleptic properties of the best formulation identified in each drying method as well as its cost of production were evaluated and compared.

3.1.5.1 Moisture

Moisture content was determined by the toluene distillation method (Bradly, 1995). The moisture content (w%) was computed as

$$W\% = \frac{(V + 0.1)}{E} \times 100$$

where, V is the volume of water collected in the moisture trap in ml, 0.1 a correction factor for water sticking to the apparatus and E sample mass in gram.

3.1.5.2 Bulk density, average particle density and percentage volume occupied by powder particles

The method described by Beckett *et al.* (1962) was followed for the above estimation. For this 50 ml hexane was poured into a 100 ml graduated cylinder 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:

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

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

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

3.1.5.3 Solubility percent

Four gram beverage powder was taken in 50 ml boiling tube, added 32 ml water at 50±1°C and shaken for 10 seconds. The tube was then placed in water bath at 50±1°C for 5 minutes. To remove the fat, reconstituted product was filled up to the brim of the test tube, centrifuged at 770 g for 10 minutes, cooled in refrigerator and fat layer was removed with as little milk as possible. Again the milk was warmed to 27±1°C, shaken well and 2 ml of this homogenous mix was transferred to a dry tared aluminium dish (No.1). The tube was centrifuged again for 10 minutes and 2 ml of the upper layer of the supernatent liquid was transferred into another aluminium dish (No.2) without disturbing the sediment. Both the dishes were placed on a steam bath until apparently dry, then placed in air oven at 100±1°C for 90 minutes, then cooled and weighed (BIS, 1981).

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

Where,

W_1 - weight of the liquid taken in dish No.1

W_2 - weight of liquid taken in dish No.2

W_3 - weight of total solids in dish No.1

W_4 - weight of total solids in dish No.2

3.1.5.4 Soluble and dispersed solids

A known amount of formulated food was dispersed uniformly in 100 ml of water (40°C) and 10 ml of the liquid was taken and filtered through a pre-weighed filter paper. The filtrate was also taken, dried and weighed separately. Solids remaining on the filter paper gave the percent dispersed solids and the dried filtrate gave percent soluble solids.

3.1.5.5 Dispersibility

Dispersibility is inversely related to sedimentation and was expressed in terms of sedimentation of percent solids after 24 h. For this 52 g powder was mixed with 400 ml water in a mixie for 20 seconds allowed to stand for 5 minutes and kept in beakers of 25 ml capacity. The supernatant fluid was taken at 0 and 24 h to determine total solids (Sharma *et al.*, 1974).

3.1.5.6 Sinkability

Distilled water (3.5 ml) at 25°C was taken in a cuvette and 10 mg 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 6^{th} minute.

3.1.5.7 Hunter colour value

Colour of the powder was estimated as Hunter value L, a, b and DE using Hunter Lab colour measuring system (Hunter Associates Laboratory, Virginia) as described by Phahar and Leung (1985).

3.1.5.8 Specific gravity

Specific gravity of beverage powder after reconstitution was determined using standard specific gravity bottle. The reconstituted beverage as well as water was weighed at a temperature of 25°C and specific gravity was calculated using the formula suggested by Sommer (1951).

$$\text{Specific gravity} = \frac{\text{Weight in gram of the sample}}{\text{Weight in gram of water}}$$

3.1.5.9 *Relative viscosity*

Relative viscosity of the mix was determined using Ostwald Viscometer. The flow time for the mix and water was recorded at 24-25°C and the values for the relative viscosity was calculated by the formula (Plummer, 1979).

$$\eta rel = \frac{\eta_1}{\eta_2} = \frac{t_1}{t_2} \times \frac{\eta_1}{\eta_2}$$

where,

η_1 = viscosity of the mix of density η_1

η_2 = viscosity of water of density η_2

t_1 = time taken for the flow of the mix

t_2 = time taken for the flow of water

3.1.5.10 *Microstructure*

The powder was subjected to scanning electron microscopy (SEM) 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 and excess and loosely attached particles were removed by blowing the stub with an inert gas. The mounted powder was sputter coated with gold of approximately 150 A° thickness using Taab, K 550 Sputter coater and examined under a Hitachi S 530 scanning electron microscope at an accelerating voltage of 15 kV.

3.1.5.11 *Protein*

Nitrogen content of the samples were estimated which was then multiplied by a factor of 6.25 to get the protein content (AOAC, 1970).

3.1.5.12 Fat

One gram powder was taken in a beaker, mixed with 10 ml water to make it into smooth paste, warmed the mixture and 10 ml HCl was added. The contents after thorough mixing were transferred into Majonnier fat extraction tube and heated in a water bath for 20 minutes at 60°C with occasional shaking. Added 10 ml ethyl alcohol and proceeded further as in BIS (1981).

3.1.5.13 Free fat

The method described by Buma (1971) was followed for the estimation of free fat (FF). About 2.5 g of the dried sample was added to 100 ml of petroleum ether (boiling point 40-60°C) and shaken well for 30 minutes. The content of the flask was filtered through a Whatman No.I filter paper and filtrate was evaporated using a hot plate. The percentage of FF was calculated as

$$\text{FF (\%)} = \frac{\text{Weight in g of the fat}}{\text{Weight in g of the sample}} \times 100$$

3.1.5.14 Total carbohydrate

The total carbohydrate in the sample was estimated after hydrolyzing carbohydrates into simple sugar using 2.5 N hydrochloric acid (Sadasivam and Manickam, 1992). The excess acid was neutralized by adding solid sodium carbonate and made up to a known volume. Aliquots from this were used for colour development using anthrone reagent and optical density was measured using a spectrophotometer at 630 nm (Spectronic® 20).

3.1.5.15 Crude fibre

Hydrolytic degradation of the sample was done by boiling with acid solution (0.255 N sulphuric acid) followed by an alkali solution (0.835 N sodium hydroxide). Residue obtained was ignited after oven drying, weighed and expressed as percentage (Sadasivam and Manickam, 1996).

3.1.5.16 Total ash

The method described in AOAC (1990) was followed in determining the ash percentage of sample.

3.1.5.17 Sugar

Reducing, non-reducing and total sugar content was estimated by Lane and Eynon method (Ranganna, 1986).

3.1.5.18 Non-enzymatic browning

Non-enzymatic browning (NEB) was measured as alcohol extractable colour by soaking five gram sample in 15 ml water and 30 ml ethanol for two hours with occasional shaking. The solvent was filtered and optical density (OD) at 420 nm was expressed as an index of NEB.

3.1.5.19 p^H

The beverage powder (13 g) was reconstituted with 100 ml warm (35°C) water as suggested by Sharma *et al.* (1974) and p^H was directly read using digital p^H meter (ELICO L_1 612 p^H analyzer, Elico Limited, Hyderabad).

3.1.5.20 Titrable acidity

Titrable acidity was estimated as per AOAC (1975) method and expressed as percentage of citric acid. Before testing the acidity, 13 g of the beverage powder was reconstituted with 100 ml warm (35°C) water as suggested by Sharma *et al.* (1974).

3.1.5.21 Energy value

Gross energy value of the beverage powder was estimated using Bomb calorie meter.

3.1.5.22 Comparison of anthocyanidins

Spray, roller and cabinet dried sapota-milk beverage powder were compared for anthocyanidins by thin layer chromatography (TLC). Beverage powder (2 g) was extracted with 70 per cent acetone (10 ml), filtered through Whatman No.1 filter paper and filtrate taken to dryness by keeping under exhaust. Silica gel G (40 g) was mixed with distilled water (85 ml) and 300 µm thick layer was coated on glass plates of 20 x 20 cm size. The plates were taken to dryness by keeping under exhaust. It was further dried and activated by keeping in chromatographic oven at 120°C for 30 minutes. The concentrate was taken in small volume of ethanol and 10 µl was spotted on the plate and eluted with n-butanol-aceticacid-acetone-water (4:1:1:0.5) solvent system. After oven drying at 110°C for 20 minutes, the plate was observed under 'CAMAG' U-V betrachter at 366 nm.

3.1.5.23 Comparison of flavanoids

Fresh fruit as well as dehydrated samples were compared for flavanoids by thin layer chromatography .The samples (2 g) were hydrolysed with 2 M HCl for 40 minutes at 100°C. The cooled hydrolysate was re-extracted with ethyl acetate and combined extracts were concentrated to dryness. The concentrate was dissolved in small volume of ethanol and from this 10 µl was spotted on TLC plate. The samples were eluted using n-butanol-acetic acid-water (4:1:5) and observed at 366 nm U-V in CAMAG U-V betrachter after fuming with ammonia.

3.1.5.24 Organoleptic characters

Spray, roller and cabinet dried beverage powder was served to 40 respondents and were asked to evaluate the samples for colour, flavour, consistency and overall acceptability on a 5 point hedonic scale (Appendix-I).

3.1.5.25 Cost of production

Cost of production of five kilogram each of spray, roller and cabinet dried sapota-milk beverage powder was estimated first and from this cost of 30 g SMBP (which gives one glass beverage) packed in metallised polyester pouches was calculated. The following items of cost were considered for the estimation of cost of production.

i) Working capital: Working capital includes the cost of raw materials viz., sapota, milk, additives and sugar, 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 5 kg 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 machineries (Appendix-II).

(vi) Interest on fixed capital: Interest on fixed capital, excluding land and building, at the rate of 12 per cent per annum and apportioned on the basis of working hours was taken for estimation of cost of production.

3.1.5.26 Sorption behaviour

Moisture sorption studies were conducted by exposing beverage powders (2 g) to different relative humidity (RH) ranging from 12 to 94 per cent until equilibrium was reached. These atmospheric conditions were prepared by placing saturated salt solution in the bottom section of desiccators held at constant temperatures (28±2°C). The salts used and the corresponding RH (%) built up were as follows : lithium chloride (12), potassium acetate (22), magnesium chloride (33), chromium trioxide (40), potassium thiocyanate (46.6), magnesium nitrate (53), sodium nitrate (64), sodium chloride (75), potassium chloride (84.3) and potassium nitrate (94).

3.1.6 Storage studies

The best product formulation from each drying experiment was packed in metallised polyester - low density polyethylene pouches. The following methods of packaging were adopted in the present study.

P_1 - packed with nitrogen

P_2 - packed with carbon dioxide

P_3 - packed with vacuum

P_4 - packed with air as control

The pouches were stored under ambient conditions for six months and various qualities viz. moisture, non-enzymatic browning, free fat, p^H and titrable acidity were analysed at bimonthly intervals as per the procedures given in 3.1.5.

3.1.6.1 Enumeration of total microorganisms

The quantitative assay of the microflora was carried out by serial dilution pour plate technique. Nutrient agar medium and potato dextrose agar medium were used for the enumeration of bacterial and fungal population of the product respectively.

One gram of the sample was suspended in 100 ml of sterile Ringer's solution taken in a conical flask and shaken thoroughly for 30 minutes in orbital shaker. From this one ml of the supernatant was accurately pipetted using a micropipette into a test tube containing nine ml sterile Ringers solution to get 10^{-3} dilution. This procedure was once again repeated to get 10^{-4} dilution. One ml each of 10^{-3} and 10^{-4} dilution was used for enumeration of total fungal and bacterial count of the sample respectively. The bacterial count was taken after two days whereas fungal count was taken after four days. The number of organisms per gram of sample was calculated by applying the formula.

$$\text{No. of colony forming units (cfu) per gram of the sample} = \frac{\text{Mean number of cfu x dilution factor}}{\text{Quantity of the sample on weight basis}}$$

3.1.6.2 Sensory evaluation

The quality changes in the stored product in comparison to the fresh product were evaluated by a panel of 15 members on a 5 point hedonic scale (Appendix-III).

3.2 DEVELOPMENT OF BOTTLED SAPOTA-MILK BEVERAGE

The experiment was aimed at standardization of technology for bottled sapota-milk beverage. Beverage compositions as given in Table 3.4 were formulated and evaluated for organoleptic qualities.

Table 3.4. Different compositions of bottled sapota-milk beverage

Treatment	Fruit pulp (%)	Milk (%)
T_1	20	15
T_2	40	15
T_3	60	15
T_4	20	20
T_5	40	20
T_6	60	20
T_7	20	25
T_8	40	25
T_9	60	25

3.2.1 Preparation of beverage

Skim milk pasteurized at 85°C for 10 minutes was used for the beverage preparation. Calculated quantities of fruit pulp, milk, sugar and water were taken, GMS-SA mixture (1% of total solids of the mix) was dispersed in warm water (65°C) and added to the mix with constant stirring. The mix was then blended for two minutes in a wet blender and filled in pre-sterilized glass bottles (Fig. 3.6).

3.2.2 Optimisation of processing parameter

The best composition of beverage selected based on organoleptic score rating (Appendix-IV) was subjected to three different processing methods viz. sterilization at 15 psi for 20 minutes, pasteurization at 85°C for 20 minutes and pasteurization at 85°C for 30 minutes to optimize the processing method for the beverage.

3.2.3 Storage studies

The best composition of the beverage selected on the basis of sensory scores was processed at the optimized conditions and evaluated for storage stability. The following parameters were studied during the storage period.

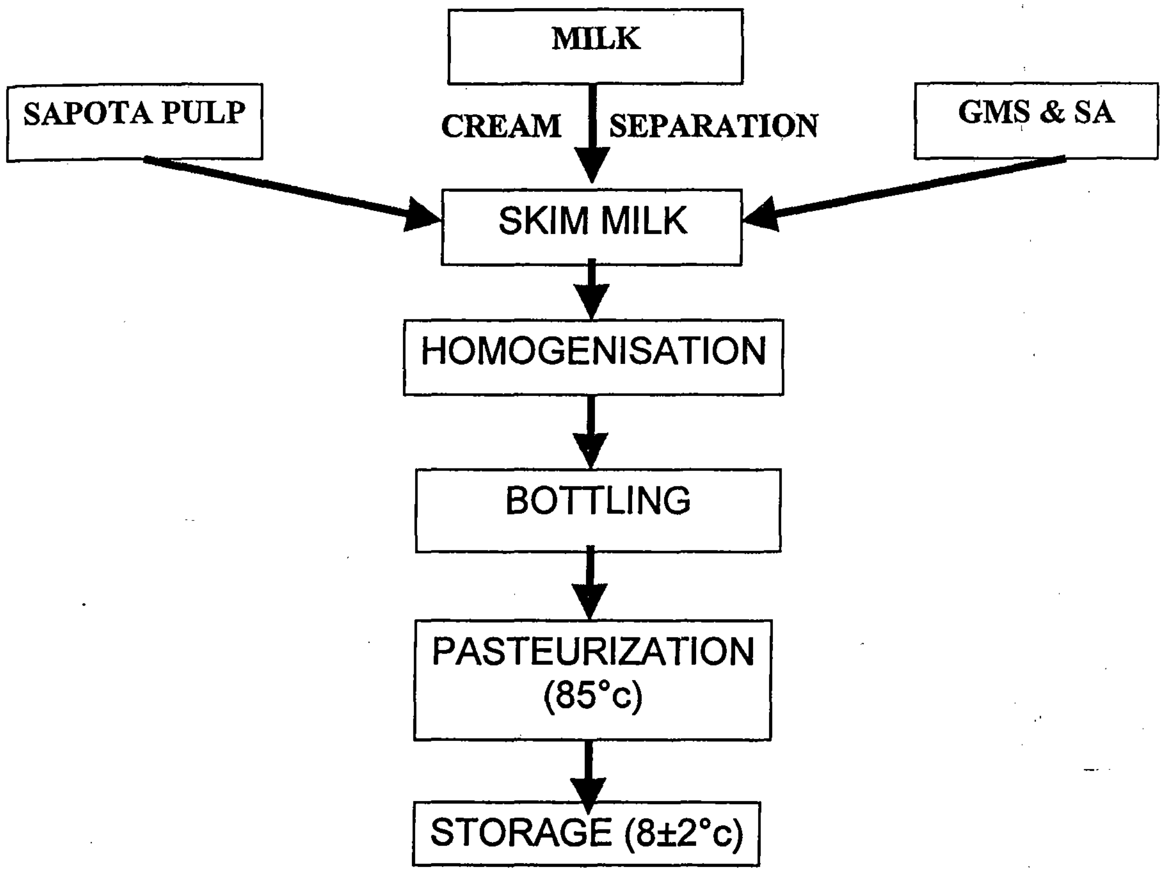


Fig. 3.6. Preparation of ready-to-drink sapota-milk beverage

3.2.3.1 TSS

TSS of the beverage was observed using a hand refractometer (Erma hand refractometer).

3.2.3.2 p^H

pH was directly read using digital p^H meter (ELICO L1 612 p^H analyser, Elico Limited, Hyderabad).

3.2.3.3 Acidity

Titrable acidity was estimated as per AOAC (1975) method and expressed as percentage of citric acid.

3.2.3.4 Microbiology

Procedure described under 3.1.7.1 was followed.

3.2.3.5 Sensory evaluation

The stored product was evaluated by a panel of 15 members on 10 point hedonic scale for various quality parameters (Appendix-IV).

3.2.3.6 Cost of production

Economics of production of 100 bottles of ready-to-drink bottled sapota-milk beverage was worked out as per methods described under 3.1.5.24

3.3 MARKETABILITY OF VALUE ADDED PRODUCTS

Marketability of instant sapota-milk beverage powder and bottled sapota-milk beverage powder was assessed by obtaining consumer response towards these products. A sample of 50 consumers was selected randomly from staff and students of College of Horticulture for the study and their attitude towards instant beverages and sapota-milk shake was assessed by administering a questionnaire (Appendix V).

The products viz. instant beverage powder and ready-to-drink bottled beverage were also served and their response viz. liking for the products, price expectation and readiness to buy the product were obtained in the same questionnaire.

3.4 STATISTICAL ANALYSIS

Observations under each experiment were tabulated and analysed statistically in a completely randomised design (CRD) or factorial CRD wherever appropriate as proposed by Panse and Sukhatme (1976). Treatment comparisons were done by Duncan's Multiple Range Test (DMRT). Scores of organoleptic evaluation were analysed by Krushkal-Wallis one-way analysis of variance (Siegel, 1956).

Results

4. RESULT

Results of the present study on "Value addition in sapota [*Manilkara achras* (Mill.) Fosberg]" are presented under the following three major headings viz.

1. Development of technology for instant sapota-milk beverage powder
2. Development of technology for bottled sapota-milk beverage
3. Marketability of value added products

4.1 DEVELOPMENT OF TECHNOLOGY FOR INSTANT SAPOTA-MILK BEVERAGE POWDER

The results on spray, roller and cabinet drying experiments to study the feasibility of preparing instant sapota-milk beverage powder are presented below. In all the drying experiments, strained sapota pulp was used, recovery of which was 70.75 per cent (Fig. 4.1).

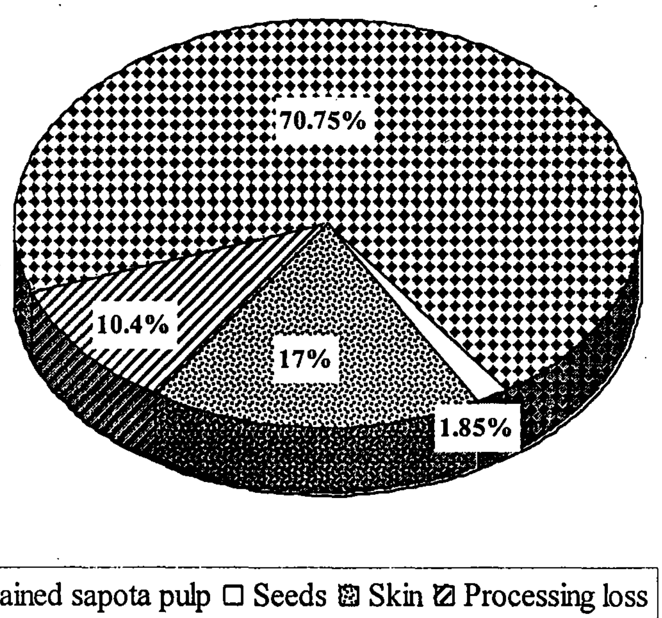


Fig. 4.1. Recovery of strained sapota pulp

4.1.1 Experiments on spray drying

The inlet air temperature of the spray drier and composition of the beverage mix were varied to standardise technology for producing spray dried sapota-milk beverage powder.

4.1.1.1 Effect of inlet air temperature

The effect of inlet air temperature of spray drier on drying is given in Table 4.1. At inlet temperatures 145 and 165°C, the powder obtained was moist and caked while at temperature 185°C and above, free flowing powder was obtained. However at 205°C, the product showed slight browning and started sticking on to the inner surface of the drier. Hence it was inferred that the ideal inlet air temperature was 185°C and for further experiments the inlet air temperature of the spray drier was fixed and maintained at 185°C.

Table 4.1. Effect of inlet air temperature on spray dried sapota-milk beverage powder

Sl. No.	Inlet air temperature (°C)	Product characteristics	Remarks on drying characteristics
1	145	Wet	Incomplete drying, product did not come out of the chamber
2	165	Sticky	Only partial drying, caking of the product
3	185	Free flowing	Complete drying with good output
4	205	Free flowing	Complete drying, product started sticking to the drier chamber.

4.1.1.2 Effect of composition of beverage mix

Sapota-milk beverage mix composition was varied with different proportion of sapota to milk solids, maintaining the inlet air temperature at 185°C and outlet air temperature at 90°C in the spray drier. Table 4.2 gives the effect of varied beverage mix composition on the quality of the finished product. The milky flavour was dominant in the finished products with ratios 1:2.0 and above. Beverage mixes with lower ratios (1:1 and 1:1.5) gave products with a balanced flavour of sapota and milk.

Table 4.2. Effect of beverage composition on quality of spray dried sapota-milk beverage powder

Treatment	Sapota:Milk (solids basis)	Product quality of the beverage powder		
		Colour	Dominant flavour	Flowability
S_1	1 : 3.0	White	Milk	Good
S_2	1 : 2.5	White	Milk	Good
S_3	1 : 2.0	White	Milk	Good
S_4	1 : 1.5	Off white	Milk and sapota	Good
S_5	1 : 1.0	Light brown	Milk and sapota	Good

The results of organoleptic evaluation of reconstituted sapota-milk beverage powder (SMBP) from different mix composition presented in Table 4.3 revealed that the beverage prepared using equal proportion of fruit and milk solids (S_5) was ranked top for all the quality parameters viz. colour, flavour, consistency and overall acceptability.

Table 4.3. Effect of beverage composition on sensory quality of spray dried sapota-milk beverage powder

Treatment	Mean sensory score values			
	Colour	Flavour	Consistency	Overall acceptability
S_1	1.27 (243)	3.00 (375)	1.60 (322.5)	1.33 (217.5)
S_2	1.33 (262)	3.00 (375)	1.67 (345)	1.47 (247.5)
S_3	2.40 (556)	3.00 (375)	1.73 (367.5)	3.20 (645)
S_4	3.80 (813)	4.38 (787)	1.73 (907.5)	3.60 (750)
S_5	5.00 (975)	5.00 (937)	4.00 (907.5)	4.67 (990)
Kruskalwallis Test Statistic	63.80**	61.22**	61.83**	65.10**

** Significant at 1% level

Values in parenthesis denote sum of ranks

4.1.2 Experiments on roller drying

The results on varied steam pressure inside the drum, drum speed and composition of the mix in roller drying experiments are presented hereunder.

4.1.2.1 Steam pressure

The effect of varying the steam pressure inside the drum on drying and product characteristics are given in Table 4.4. Roller dried SMBP prepared by maintaining the inside steam pressure at 4 kg cm^{-2} retained good sapota flavour with less browning (0.28 OD) as against 5 kg cm^{-2} which yielded dark brown product with a caramelized flavour, masking the mild flavour of sapota. Hence steam pressure inside the drum for all further experiments was fixed and maintained at 4 kg cm^{-2}.

Table 4.4. Effect of steam pressure on roller dried sapota-milk beverage powder

Sl. No.	Steam pressure (kg cm^{-2})	Moisture (%)	Colour of the product (OD at 420 nm)	Remarks
1	4.0	3.56^a	0.28^b	Light brown coloured flakes with good sapota flavour
2	5.0	3.32^b	0.30^a	Dark brown coloured flakes with charred flavour masking the mild sapota flavour

*Values with different superscripts differ significantly at 5% level

4.1.2.2 Drum speed

The effect of drum speed on product quality of roller dried SMBP presented in Table 4.5 revealed that even though product obtained with 7 rpm was slightly dark coloured, minimum moisture content was observed with this drum speed. Since this yielded quality product with good flavour and minimum moisture content, further studies were undertaken with 7 rpm drum speed.

Table 4.5. Effect of drum speed on roller dried sapota-milk beverage powder

Sl. No.	Drum speed (rpm)	Moisture (%)	Colour (OD at 420 nm)
1	7	3.38^b	0.28^a
2	10	3.51^a	0.23^b

*Values with different superscripts differ significantly at 5% level

4.1.2.3 Composition

The proportion of fruit to milk solids was varied to determine the optimum level of milk solids to be added to the mix. The characteristics of the product obtained for different beverage compositions are presented hereunder.

Table 4.6. Effect of beverage composition on quality of roller dried sapota-milk beverage powder

Treatment	Sapota : Milk (solids basis)	Beverage powder characteristics		
		Colour	Dominant flavour	Flowability
R_1	1 : 2.0	Creamish brown	Milk	Good
R_2	1 : 1.5	Creamish brown	Milk	Good
R_3	1 : 1.0	Light brown	Milk	Good
R_4	1 : 0.5	Light brown	Sapota and milk	Good
R_5^*	1 : 0.5	Creamish brown	Sapota and milk	Good
R_6^{**}	1: 0.5	Creamish brown	Milk	Good

* Milk with 1% fat
** Milk with 2% fat

It was observed that the ratio 1:0.5 (using skim milk) gave a product with dominant sapota flavour. However, sapota added to milk with one per cent fat in the ratio 1:0.5, upon reconstitution was judged as the best product with a mean score of 4.87 for overall acceptability (Table 4.7).

Table 4.7. Effect of beverage composition on sensory quality of roller dried sapota-milk beverage powder

Treatment	Colour	Flavour	Consistency	Overall acceptability
R_1	2.8 (352.5)	2.73 (267)	1.73 (345)	1.73 (186)
R_2	2.8 (3252.5)	2.87 (306)	1.73 (345)	2.27 (306)
R_3	4.2 (805.5)	4.67 (1035)	1.73 (345)	3.47 (623)
R_4	4.3 (847.7)	4.27 (882)	4.0 (1020)	4.53 (984.5)
R_5	4.33 (847.5)	4.8 (1086)	4.0 (1020)	4.87 (1117)
R_6	4.47 (889.5)	3.4 (519)	4.0 (1020)	4.27 (878.5)
Kruskal Walls Test Statistic	40.57**	72.10**	81.07**	74.56**

Values in parenthesis denote the sum of ranks
** Significant at 1% level

4.1.3 Experiments on cabinet drying

Experiments were conducted with varied drying temperature and beverage mix compositions to standardise technology for production of cabinet dried SMBP.

4.1.3.1 Temperature

The effect of temperature on cabinet drying of SMBP given in Table 4.8 revealed that cabinet drying at 70 and 80°C yielded good quality product, whereas at 60°C, it yielded a leathery product which was difficult to powder. Since drying was completed in a minimum time period of 4.5 h at 80°C, this temperature was acknowledged to be the best. Hence further experiments on cabinet drying were carried out with this standardised temperature.

Table 4.8. Effect of temperature on cabinet dried sapota-milk beverage powder

Sl.No.	Drying temperature (°C)	Drying time (h)	Product
1	60	7	Difficult to powder
2	70	5.0	Easy to powder
3	80	4.5	Easy to powder

4.1.3.2 Composition of the beverage mix

The proportion of sapota to skim milk solids was varied to determine the best beverage mix composition for cabinet drying. It was observed that the ratio 1:0.5 (fruit : milk) yielded a product with balanced flavour of sapota and milk (Table 4.9).

Table 4.9. Effect of beverage composition on quality of cabinet dried sapota-milk beverage powder

Sl.No.	Treatment	Fruit : Milk solids ratio	Colour	Dominant flavour	Flowability
1	C_1	1 : 2.0	Brownish cream	Milk	Good
2	C_2	1 : 1.5	Brownish cream	Milk	Good
3	C_3	1 : 1.0	Brownish cream	Milk	Good
4	C_4	1 : 0.5	Creamish brown	Sapota and milk	Good

This was further confirmed by organoleptic evaluation of the reconstituted beverage powder where in the 1:0.5 ratio of fruit to milk solids obtained the highest score rating for colour, flavour, consistency and overall acceptability (Table 4.10).

Table 4.10. Effect of beverage composition on sensory quality of cabinet dried sapota-milk beverage powder

Treatment	Colour	Flavour	Consistency	Overall acceptability
C_1	4.4 (360)	3.0 (345)	2.00 (270)	1.0 (120)
C_2	4.4 (360)	3.0 (345)	2.00 (270)	2.0 (345)
C_3	4.67 (480)	3.0 (345)	3.33 (570)	3.0 (570)
C_4	5.0 (630)	5.0 (795)	4.00 (720)	5.0 (795)
Kruskal Walls Test Statistic	15.18**	59.00**	45.51**	59.00**

Values in parenthesis denote the sum of ranks

** Significant at 1% level

4.1.4 Comparison of spray dried, roller dried and cabinet dried sapota-milk beverage powder

Sapota-milk beverage powder (SMBP) developed through spray drying, roller drying and cabinet drying under the standardised processing conditions were compared for various physico-chemical and organoleptic characters and cost of production, to suggest appropriate technology for production of best quality SMBP (Table 4.11).

Table 4.11. Physical characteristics of spray, roller and cabinet dried sapota-milk beverage powder

Physical characters	Spray dried SMBP	Roller dried SMBP	Cabinet dried SMBP
Moisture (%)	3.515[c]	3.546[b]	4.088[a]
Bulk density (g ml^{-1})	0.593[c]	0.631[b]	0.648[a]
Average particle density (g ml^{-1})	1.298[b]	1.341[a]	1.345[a]
Percentage volume occupied by the powder particles	45.71[c]	47.50[b]	48.19[a]
Solubility percent	85.99[a]	58.28[c]	67.66[b]
Soluble solids (%)	65.42[a]	50.80[c]	56.62[b]
Dispersed solids (%)	29.26[c]	41.72[a]	34.34[b]
Dispersibility (%)	94.60[a]	92.49[b]	91.58[b]
Sinkability (% T) - 2 min	79.44[b]	79.72[b]	84.72[a]
4 min	82.18[b]	83.92[b]	87.58[a]
6 min	83.16[b]	86.84[a]	89.18[a]
Specific gravity (g ml^{-1})	1.051[c]	1.055[b]	1.062[a]
Relative viscosity	11.01[c]	13.76[b]	38.82[a]

*Values with different superscripts differ significantly at 5% level

4.1.4.1 Moisture

Spray dried sapota-milk beverage powder possessed the lowest moisture content (3.515%) which was comparable with that of roller dried SMBP (3.546%), while cabinet dried SMBP recorded the highest (4.088%) moisture content.

4.1.4.2 Bulk density (BD), average particle density (APD) and percentage volume occupied by powder particles (PVPP)

Minimum bulk density was observed in the spray dried (0.593 g ml^{-1}) whereas the maximum was observed in cabinet dried product (0.648 g ml^{-1}). Average particle density of both roller and cabinet dried products were comparable whereas spray dried product recorded the lowest APD (1.298 g ml^{-1}). Similarly the lowest value for PVPP was also observed with spray dried product.

4.1.4.3 Solubility percent

Spray dried product recorded the maximum solubility percent (85.99%) followed by cabinet dried and the minimum was recorded with roller dried SMBP. Higher solubility, the preferred character for instant powder shows the superior quality of spray dried product.

4.1.4.4 Soluble solids and dispersed solids

Significant difference in soluble solids was observed in the beverage powders with the maximum in spray dried (65.42%) and the minimum in roller dried product (50.80%). Dispersed solids were the highest in roller dried product (41.72%) and the lowest was recorded in spray dried product (29.26%).

4.1.4.5 Dispersibility

Dispersibility of spray dried SMBP was the maximum (94.59%) and was significantly different from roller and cabinet dried products. Higher dispersibility confirms the better quality of spray dried product.

4.1.4.6 Sinkability

Sinkability, an index of sedimentation rate was the highest in cabinet dried product (89.18% T) after sixth minute, whereas the lowest was observed in spray dried product (83.16% T), reflecting the quality of spray dried SMBP.

4.1.4.7 Specific gravity and relative viscosity

The products when reconstituted, the cabinet dried SMBP showed the maximum specific gravity (1.062 g ml^{-1}) and relative viscosity (38.822) and spray dried product recorded the minimum.

4.1.4.8 Hunter colour values

The colour of the products when estimated using Hunter Lab Colour measuring system revealed that spray dried product showed maximum value for lightness (L) and yellowness (b) and minimum deviation from the standard (DE), indicating the bright colour of the spray dried product. Maximum value for redness (a) was observed with roller dried SMBP. Higher the redness value, darker is the product explaining the least preference for roller drying product (Table 4.12).

Table 4.12. Hunter colour values of spray, roller and cabinet dried sapota-milk beverage powder

Dried Product	Hunter colour values			
	L	a	b	DE
Spray dried SMBP	67.23[a]	3.58[c]	20.98[a]	31.42[c]
Roller dried SMBP	52.58[c]	6.35[a]	17.69[b]	42.43[a]
Cabinet dried SMBP	57.79[b]	3.94[b]	16.80[c]	37.04[b]

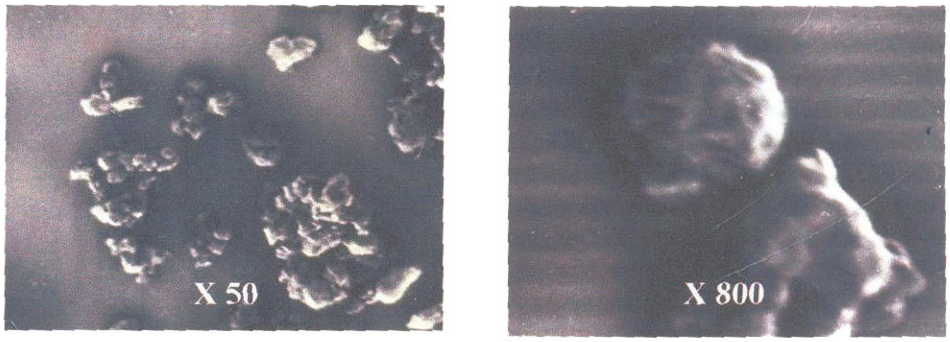
*Values with different superscripts differ significantly at 5%level

4.1.4.9 Microstructure

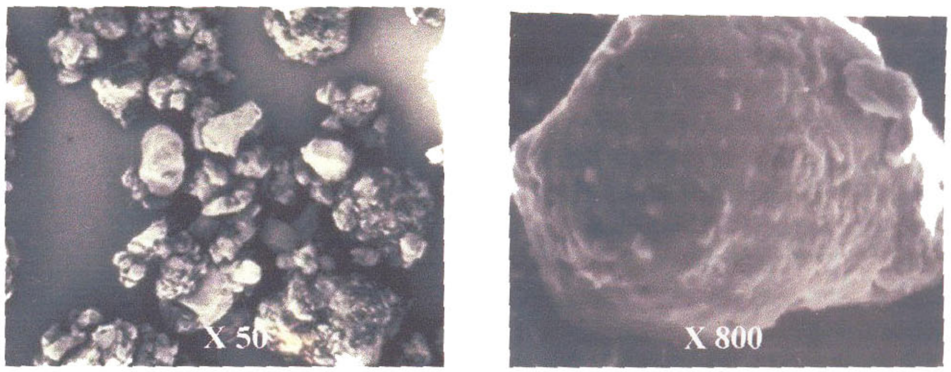
Microstructure of the products when observed under scanning electron microscope revealed that spray dried particles possessed a slightly distorted spherical shape, with a few shallow depressions on the surface. The diameter of the particles ranged from 25 to 50 μm. Roller dried particles appeared larger measuring 33 to 98 μm in diameter. They were irregularly elongated and the surface was rough with numerous blobs and protuberances. Whereas cabinet dried samples possessed elongated oval shape with very shallow depressions and few protuberances on the surface and the diameter ranged between 33 to 66 μm. In all the samples non-uniform distribution of the particles were observed and the particles were grouped together (Plate 4).

4.1.4.10 Chemical characteristics

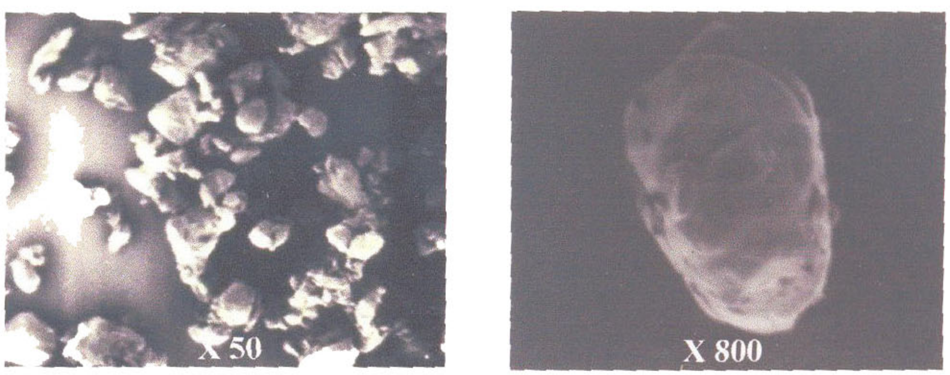
Spray dried SMBP recorded the highest protein (12.36%) whereas the roller dried SMBP possessed the highest fat (3.76%) content. Free fat content of the products varied significantly with the maximum in roller dried (1.85%) and minimum



a) Spray dried SMBP



b) Roller dried SMBP



a) Cabinet dried SMBP

Plate 4. Microstructure of spray, roller and cabinet dried sapota-milk beverage powder

in spray dried product (0.22%). Protein and fat content of the cabinet dried product was the lowest, but it contained maximum amount of carbohydrate (77.98%) which was on par with roller dried product (77.80%) (Table 4.13).

Table 4.13. Chemical characteristics of spray, roller and cabinet dried sapota-milk beverage powder

Chemical characters	Spray dried SMBP	Roller dried SMBP	Cabinet dried SMBP
Protein (%)	12.36[a]	7.82[c]	8.71[b]
Fat (%)	3.42[b]	3.76[a]	1.77[c]
Free fat (%)	0.22[c]	1.85[a]	0.48[b]
Total carbohydrate (%)	75.1[b]	77.8[a]	77.98[a]
Ash (%)	4.67[a]	3.09[b]	3.35[b]
Crude fibre (%)	3.99[b]	4.11[a]	4.36[a]
p^H	6.44[c]	6.50[a]	6.44[b]
Acidity (%)	0.64[a]	0.25[c]	0.25[b]
NEB (OD at 420 nm)	0.22[c]	0.24[c]	0.23[b]
Reducing sugar (%)	44.41[a]	40.54[b]	40.10[a]
Total sugar (%)	66.52[b]	67.98[a]	68.25[a]
Energy value (kcal/100 g)	362.2[a]	359.3[b]	344.2[c]

*Values with different superscripts differ significantly at 5%level
* Represent mean of five replications

The higher percentage of ash was observed in spray dried SMBP (4.67%) whereas crude fibre content was the highest in cabinet dried SMBP (4.36%) and was comparable with roller dried product (4.11%). Maximum acidity (0.64%) as well as the lowest p^H (6.43%) was also observed with the same sample.

Reducing and total sugar content was the maximum in cabinet dried product and the lowest total sugar content was observed in the roller dried product. Minimum non-enzymatic browning was observed in spray dried product (0.22 OD) whereas maximum was observed in roller dried SMBP (0.24 OD).

Total energy content of 100 g beverage powder was the highest in spray dried sapota-milk beverage powder (362.2 kcal), followed by roller dried (359.3 kcal) and the lowest was recorded in cabinet dried product (344.2 kcal).

4.1.4.11 Anthocyanidins

Anthocyanidins formed in dehydrated products on comparison showed that the TLC profile of roller and cabinet dried samples contained two spots with Rf values 0.23 and 0.52, but only one spot of Rf 0.52 could be detected in spray dried samples (Table 4.14).

Table 4.14. TLC profile of anthocyanidins

Sl. No.	Spot characterisation		Area under the spot (cm^2)		
	Rf value	Colour	SD	RD	CD
1	0.23	Dull blue	0	2.2	0.8
2	0.52	Bright blue	0.3	3.96	2.8

4.1.4.12 Flavanoids

The TLC profile of flavanoids of dehydrated products expressed a group of spots and the spot size was found to vary between different products. When the dehydrated products were compared with fresh sapota it was observed that two spots of Rf 0.46 and 0.94 observed in fresh sample were totally absent in the dehydrated products (Table 4.15).

Table 4.15. TLC profile of flavanoids

Sl. No.	Spot characterisation		Area under the spot (cm^2)			
	Rf value	Colour	Fresh	SD	RD	CD
1	0.29	Dull brownish green	1.44	0.66	1.30	1.44
2	0.36	Bright bluish purple	1.20	0.75	0.52	0.70
3	0.46	Greenish yellow	1.00	0	0	0
4	0.84	Bright greenish blue	2.50	1.92	1.50	1.76
5	0.94	Dull orange-brown	0.60	0	0	0

4.1.4.13 Organoleptic characters

Organoleptic evaluation of spray, roller and cabinet dried products for colour, flavour, consistency and overall acceptability showed that spray dried product recorded the maximum score for all the characters except in the case of consistency, where the cabinet dried product outscored other methods of drying (Table 4.16).

Table 4.16. Organoleptic characters of spray, roller and cabinet dried sapota-milk beverage powder

Organoleptic characters	Spray dried SMBP	Roller dried SMBP	Cabinet dried SMBP	Kruskal Wallis Test Statistic
Colour	4.94 (3592)	3.69 (1720)	4.08 (1947)	50.32
Flavour	4.19 (2822)	3.56 (1959)	4.13 (2479)	9.11
Consistency	3.38 (1961)	3.55 (2525)	3.68 (2773)	7.89
Overall acceptability	3.1 (2679.5)	2.56 (1949)	3.07 (2631.5)	7.64

The values represent mean of 40 scores
The values in parenthesis represent sum of ranks

4.1.4.14 Cost of production

Beverage powders from different drying methods when compared for its cost of production per 100 g was worked out to be Rs 18.80, Rs 16.90 and Rs 15.40 for spray, roller and cabinet drying respectively (Table 4.17).

Table 4.17. Comparative cost of production of spray, roller and cabinet dried SMBP

Sl. No.	Item	Spray dried	Roller dried	Cabinet dried
I	Working capital			
	a. Raw material	513.23	451.63	468.28
	b. Fuel	186.00	177.00	51.00
	c. Labour	150.00	150.00	200.00
	Total	849.23	778.63	719.28
II	Interest on working capital (@ 12%)	0.28	0.26	0.24
III	Depreciation of machineries (@ 10%)	21.61	10.42	3.77
IV	Interest on fixed cost (@ 12%)	26.21	12.50	4.52
V	Cost of production of 5 kg SMBP	897.32	801.8	727.80
VI	Cost of 100 g beverage powder	17.95	16.04	14.56
VII	Cost of packaging	0.85	0.85	0.85
VIII	Cost of unit pack (100 g)	8.80	16.90	15.40

Raw material cost was the highest in spray dried product followed by cabinet dried beverage powder (Table 4.18). Among the different components of total cost, raw material alone accounted for 57.2, 56.3 and 64.3 per cent respectively in spray, roller and cabinet drying methods. Raw material cost in spray drying was 13 and 9.6 per cent higher than roller and cabinet drying respectively.

Table 4.18. Cost of raw material for the production of spray, roller, cabinet dried SMBP (5 kg)

Drying method	Raw material	Quantity for 5 kg powder	Unit cost (Rs)	Cost	
				(Rs)	%
Spray drying	Sapota	8.745 kg	20/kg	174.900	34.08
	Milk	23.8 l	13/litre	309.400	60.29
	Additives	38.476 g	0.25/kg	9.619	1.87
	Sugar	1.207 kg	16/kg	19.312	3.76
Total				513.231	100.00
Roller drying	Sapota	11.68 kg	20/kg	233.605	51.72
	Milk	14.535 litre	13/litre	188.950	41.82
	Additives	38.545 g	0.25/kg	9.636	2.13
	Sugar	1.215 kg	16/kg	19.434	4.33
Total				451.625	100.00
Cabinet drying	Sapota	11.68 kg	20	233.600	49.89
	Skim milk powder	1.285 kg	160	205.600	43.90
	Additives	38.54 g	250	9.635	2.06
	Sugar	1.215 kg	16	19.440	4.15
Total				468.275	100.00

4.1.5 Moisture sorption behaviour

Spray dried SMBP

The moisture sorption behaviour of spray dried SMBP at ambient temperature on exposure to different relative humidity between 12 and 94 per cent is given in Table 4.19. Samples kept at 12 per cent RH showed desorption behaviour till fourth day and thereafter stabilized to a constant weight (Fig. 4.2). Moisture absorption was noticed in all the samples kept at 33 per cent RH from the very first day onwards. The product was free flowing when RH was maintained below 33 per cent. On the contrary caking was observed in samples exposed to RH above 33 per cent.

Table 4.19. Moisture sorption kinetics of spray dried SMBP at different relative humidities

RH %	Percentage change in weight									
	1 DAS	2 DAS	3 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS	9 DAS	10 DAS
12	-1.591	-1.889	-1.889	-1.939	-1.939	-1.939	-1.939	-1.939	-1.939	-1.939
22	0	0	0	0	-0.0487	-0.0487	-0.0487	-0.0487	-0.0487	-0.0487
33	0.896	1.194	1.244	1.343	1.343	1.343	1.493	1.493	1.493	1.493
40	2.537	2.886	2.886	2.886	2.786	2.786	2.786	2.786	2.786	2.786
46.6	2.495	2.994	2.944	2.944	2.944	2.794	2.794	2.794	2.794	2.794
53	4.065	4.363	4.561	4.561	4.561	4.660	4.660	4.660	4.660	4.660
64	6.832	7.920	8.564	8.564	8.762	8.861	8.861	8.910	8.910	8.910
75	14.750	17.770	19.620	20.590	21.129	21.518	21.859	22.250	22.250	22.250
84.3	14.399	19.730	24.065	26.756	28.950	30.343	32.884	33.034		
94	18.540	27.540	34.133	38.230	42.328	45.127	52.370			

DAS - Days after storage
Values represent mean of three replications

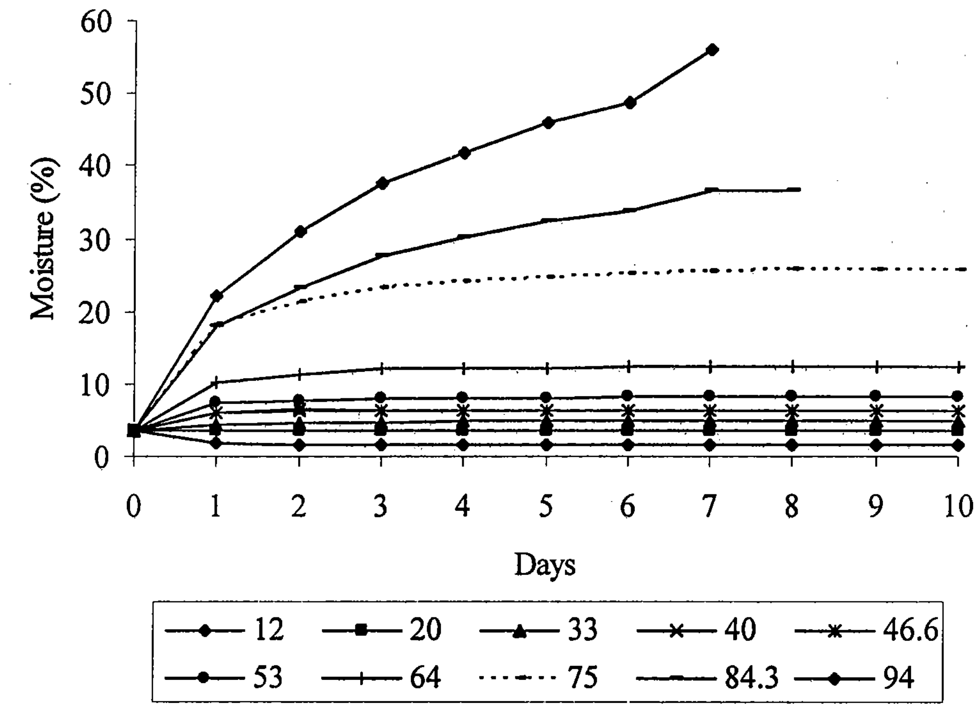


Fig. 4.2. Moisture sorption kinetics of spray dried SMBP

Colour deterioration of the product was noticed at 64 per cent RH (Plate 5) and mould growth observed after nine and seven days in the samples kept at 84.3 and 94 per cent RH respectively (Table 4.20).

Table 4.20. Equilibrium relative humidity data for spray dried sapota-milk beverage powder

Equilibrium relative humidity (ERH) %	Equilibrium moisture content (EMC) %	Physical observation
12.0	1.657	Product free flowing, no colour and flavour defect
22.0	3.609	Product free flowering, no colour and flavour defect
33.0	4.980	Slight caking starts after 3 days, slight colour change
40.0	6.130	Fully caked, sticky, slight brown colour
46.6	6.138	Fully caked, sticky, slight brown colour
53.0	7.811	Fully caked, slight brown colour
64.0	11.409	Fully caked, deep brown colour, off flavour developed
75.0	21.075	Fully caked and wet, deep brown colour
84.3	27.473	Fully caked and wet visual mould growth after 9 days
94.0	36.679	Fully caked and wet, visual mould growth after 7 days

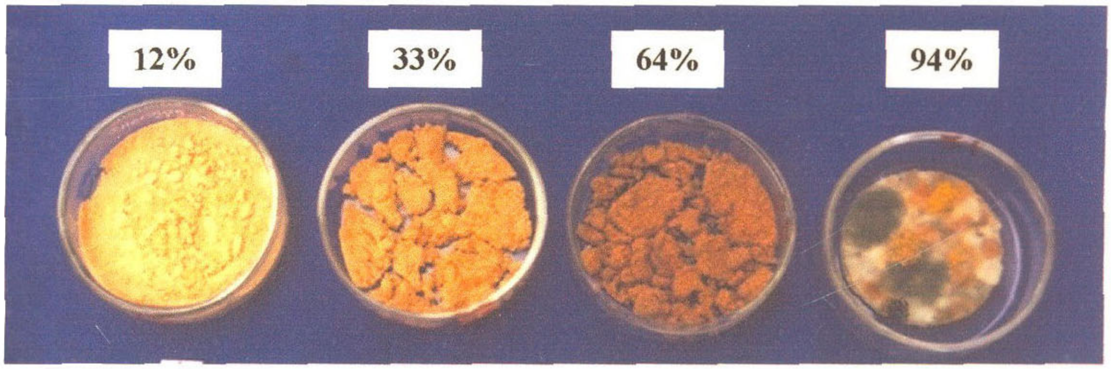


Plate 5. Spray dried sapota-milk beverage powder at different relative humidity

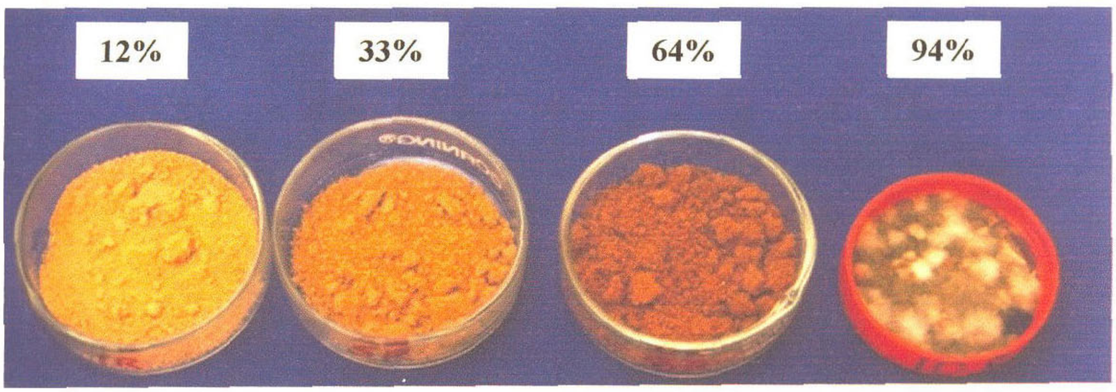


Plate 6. Roller dried sapota-milk beverage powder at different relative humidity

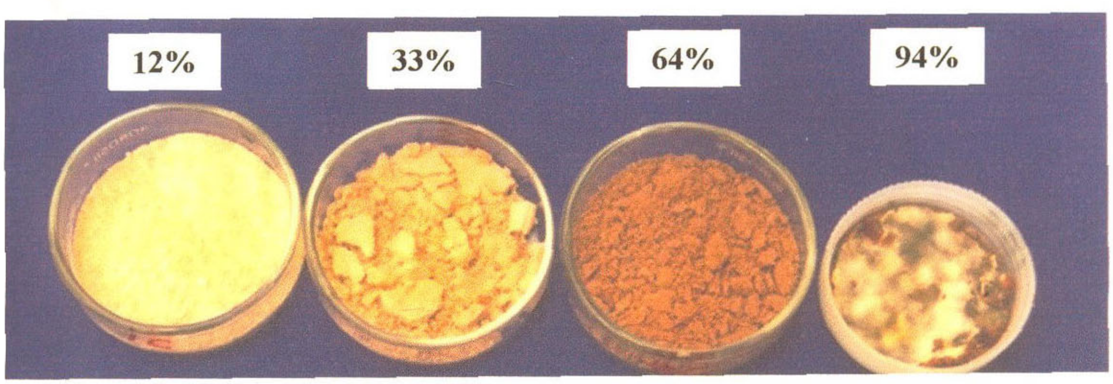
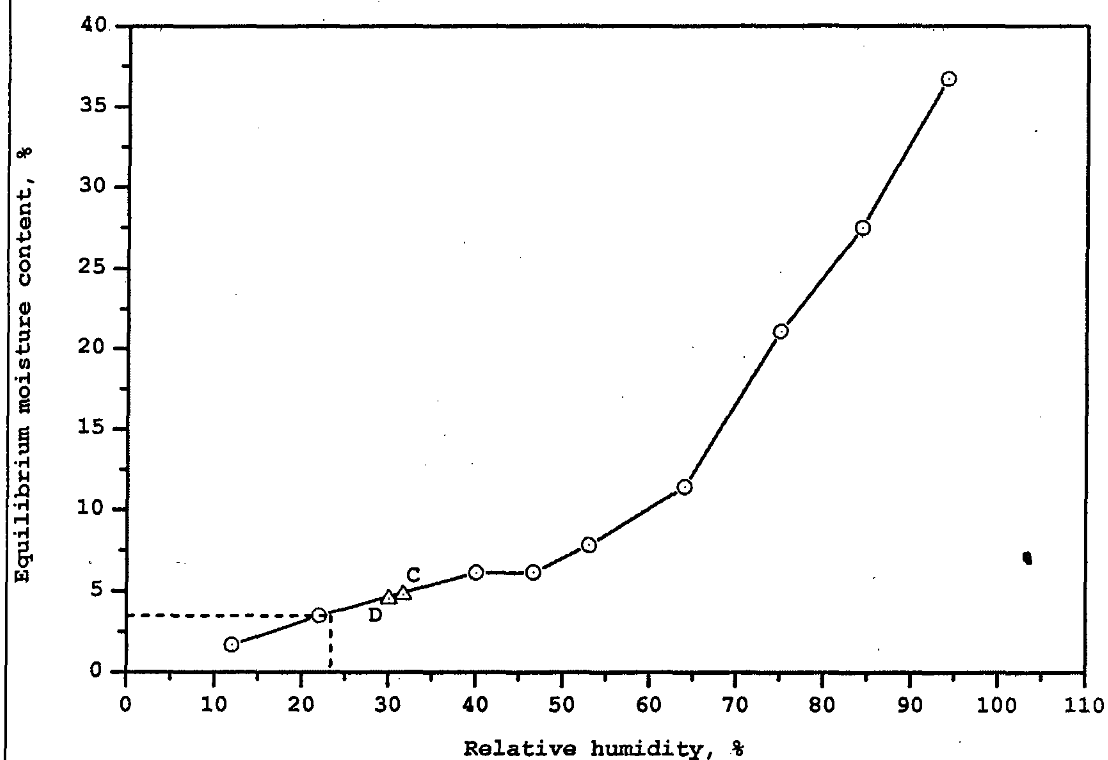


Plate 7. Cabinet dried sapota-milk beverage powder at different relative humidity

From moisture sorption isotherm of spray dried beverage powder it was observed that equilibrium relative humidity (ERH) of the product with of 3.515 per cent moisture content was 23.3 per cent (Fig. 4.3). The product has a moisture content of 4.521 and relative humidity of 31.98 as critical points for storage.



C - Critical Point (4.759)
D - Danger Point (4.521)
ERH - 23.30%

Fig. 4.3. Sorption isotherm of spray dried sapota beverage powder at 28°C

Roller dried SMBP

Moisture sorption characteristics of roller dried SMBP with an initial moisture content of 3.546 per cent on exposure to different relative humidities (RH) between 12 and 94 per cent is given in Table 4.21. Samples kept at 12 and 20 per cent RH showed desorption behaviour and attained constant weight after seven and five days respectively whereas those exposed to 33 per cent RH and above showed moisture absorption. Samples exposed to 75 per cent RH and above showed more than 15 per cent weight increase in a period of 24 hours (Fig. 4.4).

Table 4.21. Moisture sorption kinetics of roller dried SMBP at different relative humidities

RH (%)	Percentage change in weight over number of days									
	1 DAS	2 DAS	3 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS	9 DAS	10 DAS
12	-1.290	-1.639	-1.639	-1.639	-1.589	-1.739	-1.689	-1.689	-1.739	-1.689
22	-0.099	-0.099	-0.099	-0.099	-0.049	-0.049	-0.049	-0.049	-0.049	-0.049
33	0.844	0.745	0.943	1.124	1.142	1.290	1.142	1.192	1.290	1.390
40	2.190	2.597	2.690	2.789	2.789	2.789	2.897	2.897	2.897	2.897
46.6	2.290	2.640	2.897	2.890	2.890	2.897	2.938	3.03	3.03	3.03
53	3.768	4.412	4.810	4.810	4.810	4.809	4.810	4.810	4.809	4.810
64	7.000	8.400	9.140	9.190	9.290	9.340	9.239	9.289	9.290	9.29
75	15.350	17.730	18.850	19.200	19.500	19.650	19.700	19.75	19.95	19.9
84.3	14.410	19.240	22.480	24.430	26.120	27.270	29.310	29.46	28.92	-
94	19.000	26.770	30.995	35.270	38.410	40.500	44.427	-	-	-

DAS - Days after storage

'-' indicates reduction in weight

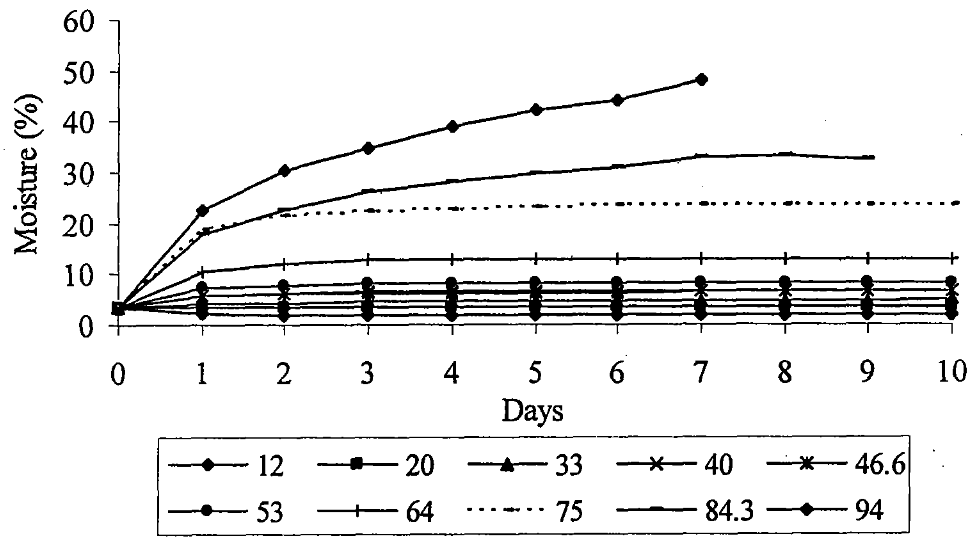


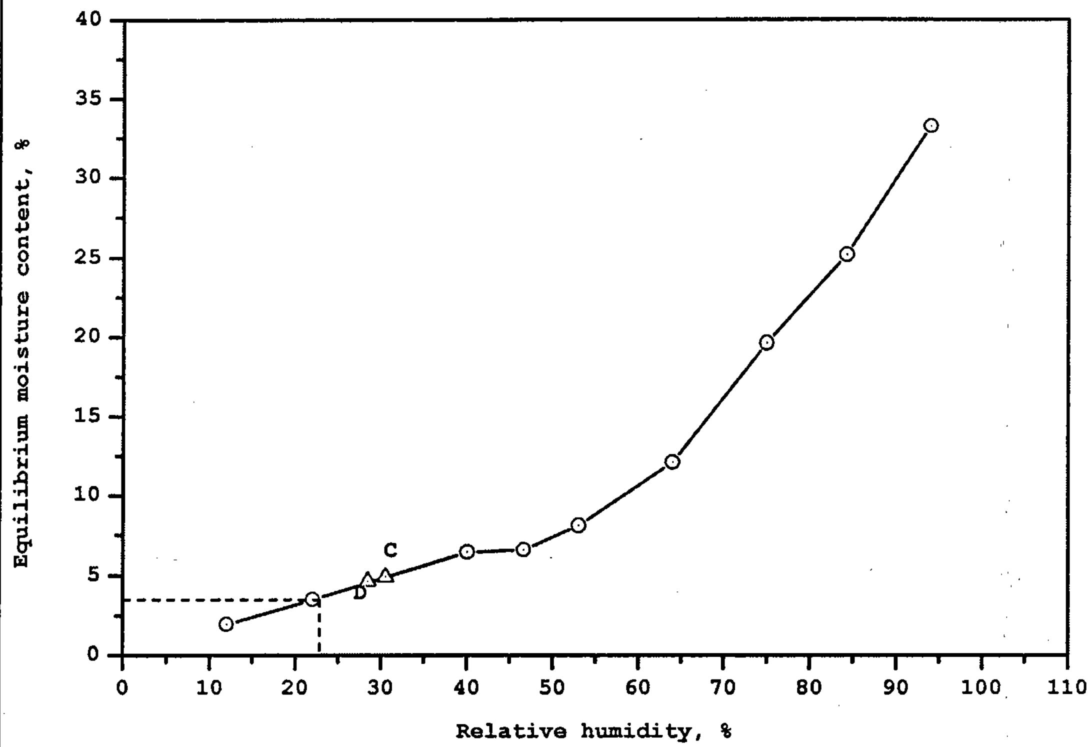
Fig. 4.4. Moisture sorption kinetics of roller dried SMBP

The product was free flowing below 33 per cent RH and caking was observed on exposure to 33 per cent RH (Plate 6). Browning and rancid flavour was noticed at 64 per cent RH whereas mould growth was observed in samples kept at 84.3 and 94 per cent RH after nine and seven days respectively (Table 4.22).

Table 4.22. Equilibrium relative humidity data for roller dried sapota-milk beverage powder

Equilibrium relative humidity (ERH) %	Equilibrium moisture content (EMC) %)	Physical observation
12.0	2.835	Product free flowing with neither colour nor flavour defects
22.0	3.945	Product free flowering, neither colour nor flavour defects observed
33.0	5.826	Slight caking starts after 8 days, no colour and flavour defects
40.0	7.222	Slight caking starts after 3 days, no colour and flavour defects
46.6	7.238	Slight caking starts after 3 days, no colour and flavour defects
53.0	8.736	Slight caking after 2 days, slight colour change, no flavour defect
64.0	12.318	Fully caked, deep brown colour, off flavour developed
75.0	20.634	Fully caked and wet, deep brown colour and off flavour developed
84.3	27.1618	Fully caked, wet and visual mould growth after 9 days
94.0	34.635	Fully caked, wet and visual mould growth after 7 days

From moisture sorption isotherm of roller dried SMBP at 28 ± 2°C it was found equilibrium relative humidity (ERH) of the product was 23.31 per cent (Fig. 4.5). The product has a moisture content of 4.594 and relative humidity of 30.55 as critical points for storage.



C - Critical Point (4.836)
D - Danger Point (4.594)
ERH - 23.31 %

Fig. 45. Sorption isotherm of roller dried sapota beverage powder at 28°C

Cabinet dried SMBP

Cabinet dried SMBP when exposed to varying relative humidity between 12 and 94 per cent, continuous moisture desorption was observed at 12 per cent RH for seven days whereas at 20 per cent RH no change in weight was observed for the first four days (Table 4.23). Moisture absorption was observed in all the samples exposed to 33 per cent RH and above (Fig. 4.6).

Table 4.23. Moisture sorption kinetics of cabinet dried SMBP at different relative humidities

RH (%)	Percentage change in weight over number of days									
	1DAS	2 DAS	3 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS	9 DAS	10 DAS
12	-0.940	-0.940	-1.290	-1.190	-0.890	-0.999	-1.340	-1.340	-1.340	-1.340
22	0	0	0	0	0	0	0.050	0.050	0.050	0.050
33	1.297	1.347	1.697	1.697	1.697	1.546	1.747	1.846	1.846	1.846
40	2.747	3.147	3.197	3.279	3.279	3.297	3.328	3.328	3.328	3.328
46.6	2.832	3.179	3.279	3.296	3.296	3.296	3.396	3.396	3.396	3.396
53	4.253	4.946	5.143	5.242	5.242	5.242	5.093	5.093	5.093	5.093
64	7.411	8.794	9.240	9.337	9.437	9.437	9.387	9.387	9.387	9.387
75	14.663	17.756	19.551	20.199	20.499	20.499	20.748	20.848	20.847	20.847
84.3	14.598	19.860	23.490	25.77	27.46	28.599	31.032	31.529	31.678	
94	18.653	26.334	32.319	35.810	39.200	42.190	46.733			

DAS - Days after storage

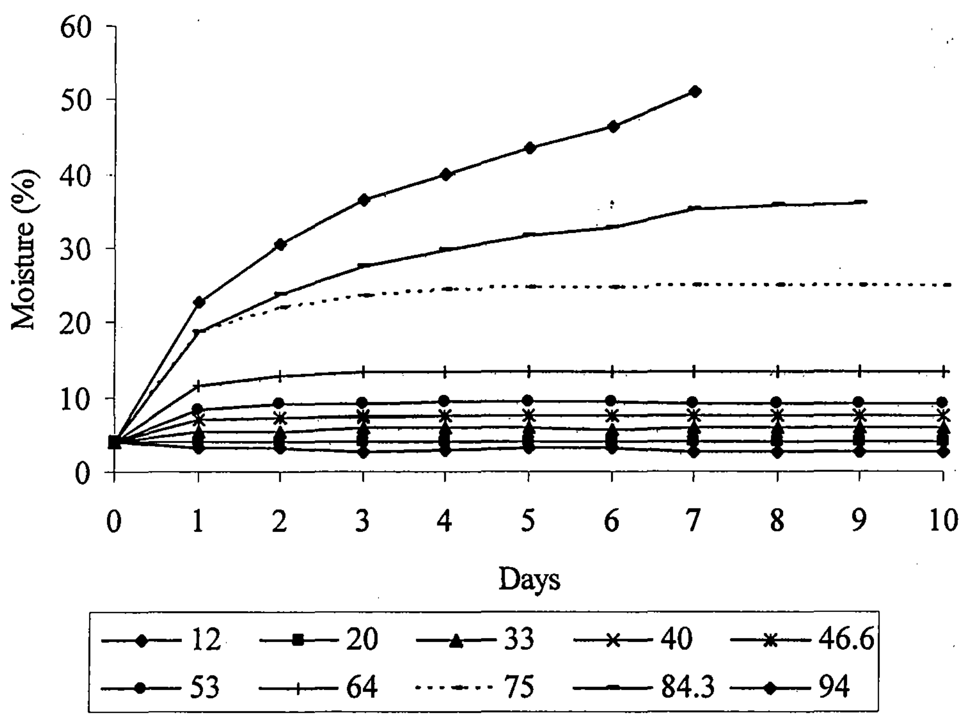


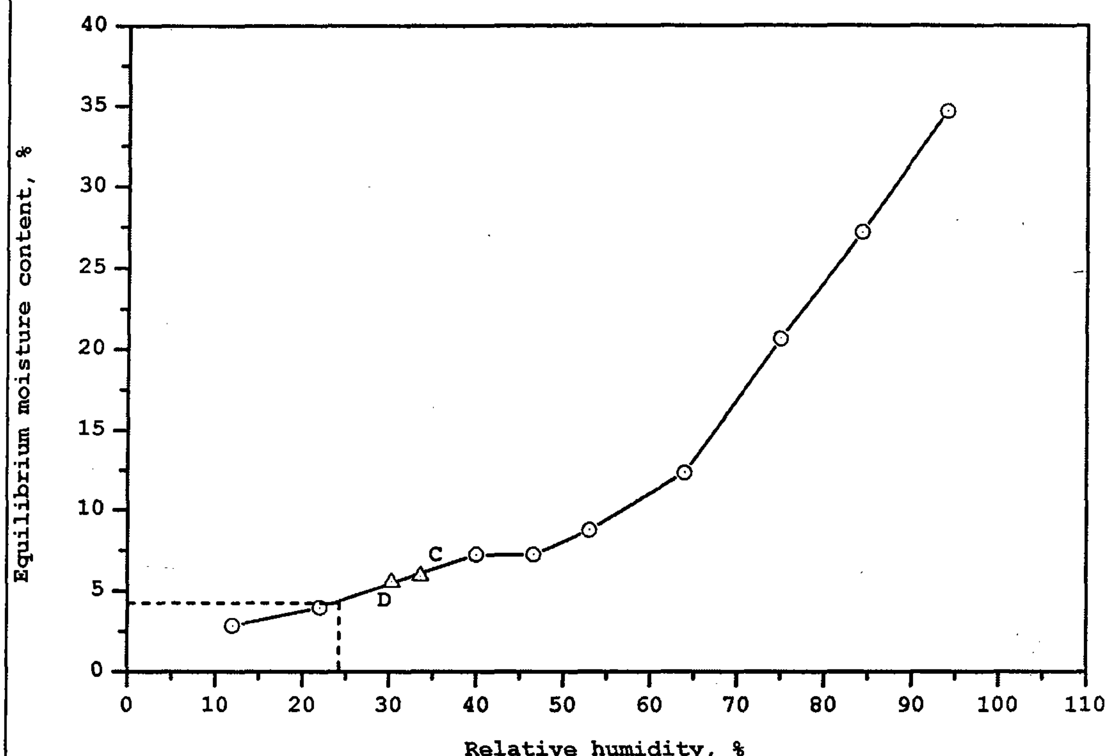
Fig. 4.6. Moisture sorption kinetics of cabinet dried SMBP

The product was free flowing at 40 per cent RH and below whereas browning of the product was observed at 64 per cent RH (Plate 7) and mould growth was observed in samples exposed to 84.3 and 94 per cent RH (Table 4.24).

Table 4.24. Equilibrium relative humidity data for cabinet dried sapota-milk beverage powder

Equilibrium relative humidity (ERH) %	Equilibrium moisture content (EMC) %)	Physical observation
12.0	1.938	Product free flowing with neither colour nor flavour defects
22.0	3.498	Product free flowing with neither colour nor flavour defects
33.0	5.008	Slight caking observed after 8 days, no colour change
40.0	6.435	Slight caking observed after 3 days, slight colour change
46.6	6.579	Slight caking observed after 3 days, slight colour change
53.0	8.102	Fully caked and sticky, slight colour change
64.0	12.064	Fully caked and wet; deep brown colour, varied flavour
75.0	19.622	Fully caked and wet deep colour, varied flavour
84.3	25.179	Fully caked and wet visual mould growth after 9 days
94.0	33.217	Fully caked and wet visual mould growth after 7 days

From the moisture sorption isotherm of cabinet dried SMBP (Fig. 4.7) it was found that equillibrium relative humidity of the product with an initial moisture content of 4.088 was 24.25 per cent. The product has a moisture content of 5.496 and relative humidity of 33.63 as critical points for storage.



C - Critical Point (5.785)
D - Danger Point (5.496)
ERH - 24.25%

Fig. 4.7. Sorption isotherm of cabinet dried sapota beverage powder at 28°C

4.1.6 Storage studies

Spray, roller and cabinet dried sapota-milk beverage powder was packed with N_2, CO_2, vacuum and air (control) in metallised polyester laminated pouches were evaluated for the changes during storage and results are presented hereunder.

Spray dried SMBP

Irrespective of the treatments, moisture, non-enzymatic browning (NEB), free fat, acidity and microbial load of the spray dried SMBP progressively increased throughout the storage period whereas p^H of the beverage powder decreased.

The lowest moisture content was observed in vacuum packed samples (6.843%) while the control recorded the highest (8.084%) after a period of six months. However no significant difference could be detected between the treatments. Vacuum and nitrogen packed samples recorded minimum non-enzymatic browning of 0.328 and 0.372 optical density respectively whereas control samples recorded the maximum (Table 4.25).

Minimum free fat was observed with carbon dioxide (0.90%) and it was on par with nitrogen and vacuum packed samples, while the control samples recorded the maximum (1.223%). Even though p^H declined progressively in all the samples, there was no significant difference between the treatments up to four months. Minimum and maximum acidity was recorded in vacuum packed (1.064%) and control samples (1.142%) respectively. However no significant difference was observed between the treatments.

Initially the powder recorded 25,000 cfu g^{-1} bacterial count which increased to 3,15,000 cfu g^{-1} in control samples within six months and the minimum increase was observed in vacuum packed samples (95,000 cfu g^{-1}). Maximum fungal population was also present in control sample (1750 cfu g^{-1}) whereas the minimum was present in carbon dioxide packed sample (1000 cfu g^{-1}) which was on par with nitrogen and vacuum packed (1250 cfu g^{-1}) samples (Table 4.26).

The spray dried SMBP was reconstituted with water and sensory evaluation of the samples stored under different techniques was done. The sensory score values presented in Table 4.27 showed that all the treatments except control were acceptable up to four months but afterwards it showed a drastic decline. Texture of the vacuum packed samples was affected after two months, and hence reduced its overall acceptability (Fig. 4.8).

Table 4.25. Physico-chemical changes during storage of spray dried SMBP under ambient conditions

Packaging techniques	Moisture (%)^{NS}				NEB (OD at 420 nm)				Free fat (%)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	3.515	4.350	6.207	8.084	0.218^{i}	0.252^{h}	0.321^{de}	0.372^{c}	0.218^{f}	0.385^{ef}	0.751^{cd}	0.908^{bc}
Carbon dioxide	,,	4.165	5.907	7.737	,,	0.291^{f}	0.370^{c}	0.394^{b}	,,	0.282^{ef}	0.628^{d}	0.900^{bc}
Vacuum	,,	3.940	5.452	6.843	,,	0.275^{g}	0.312^{e}	0.328^{d}	,,	0.367^{ef}	0.699^{d}	0.947^{b}
Control	,,	4.275	6.163	8.337	,,	0.318^{de}	0.393^{b}	0.428^{a}	,,	0.447^{e}	0.971^{b}	1.223^{a}

Contd.

Table 4.25. Continued

Packaging techniques	pH				Acidity (%)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	6.436^{a}	6.407^{bc}	6.384^{d}	6.374^{d}	0.641^{b}	0.762^{b}	0.900^{ab}	1.064^{a}
Carbon dioxide	,,	6.433^{a}	6.424^{a}	6.372^{d}	,,	0.762^{b}	0.918^{ab}	1.116^{a}
Vacuum	,,	6.421^{ab}	6.403^{c}	6.372^{d}	,,	0.762^{b}	0.918^{ab}	1.090^{a}
Control	,,	6.407^{bc}	6.400^{c}	6.371^{d}	,,	0.762^{b}	0.918^{ab}	1.142^{a}

*Values with different superscripts differ significantly at 5%level

Table 4.26. Changes in microbial status during storage of spray dried SMBP under ambient conditions

Packaging techniques	Bacteria (x 10^4 cfu/g)				Fungi (x 10^3 cfu/g)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	2.50^{e} (4.345)	8.50^{c} (4.882)	10.50^{c} (5.015)	11.00^{c} (5.015)	0.50^{b} (1.50)	0.50^{b} (1.50)	1.25^{a} (3.076)	1.25^{a} (3.076)
Carbon dioxide	,,	8.75^{c} (4.345)	10.00^{c} (4.913)	13.00^{bc} (5.008)	,,	0.50^{b} (1.50)	1.00^{ab} (2.326)	1.00^{ab} (2.326)
Vacuum	,,	4.75^{d} (4.435)	8.00^{c} (4.575)	9.50^{c} (4.857)	,,	0.50^{b} (1.50)	1.00^{ab} (2.326)	1.25^{ab} (2.401)
Control	,,	19.5^{ab} (4.435)	29.50^{a} (5.252)	31.50^{a} (5.414)	,,	0.50^{b} (1.50)	1.50^{a} (3.151)	1.75^{a} (3.226)

(Values in parenthesis denote the transformed values)
MAS - Months after storage ; *Values with different superscripts differ significantly at 5% level

Table 4.27. Sensory score values of spray dried SMBP stored under different techniques

Packaging techniques	Colour			Flavour			Texture			Overall acceptability		
	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	4.8 (204)	4.0 (186)	2.9 (174)	4.8 (189)	3.7 (159)	2.7 (106)	4.799 (210)	4.0 (180)	3.85 (171)	4.9 (183)	4.0 (170)	2.65 (120)
Carbon dioxide	4.8 (204)	4.0 (186)	2.9 (174)	4.8 (189)	3.7 (159)	2.7 (106)	4.700 (195)	4.0 (180)	1.50 (60)	4.7 (165)	3.8 (150)	2.05 (113)
Vacuum	4.8 (204)	4.0 (186)	2.9 (174)	4.8 (189)	3.7 (159)	2.7 (106)	2.600 (130)	2.3 (111)	1.50 (60)	3.8 (150)	3.8 (150)	2.85 (132)
Control	4.8 (204)	2.4 (102)	1.7 (63)	4.8 (189)	3.4 (138)	1.9 (68)	4.900 (220)	3.15 (148)	3.00 (140)	4.9 (186)	2.9 (133)	1.05 (60)
Kendall's coefficient	0.0143	0.8127	0.5189	0.1541	0.30	0.508	0.8826	0.9758	0.9757	0.7671	0.864	0.9126

MAS - Months after storage

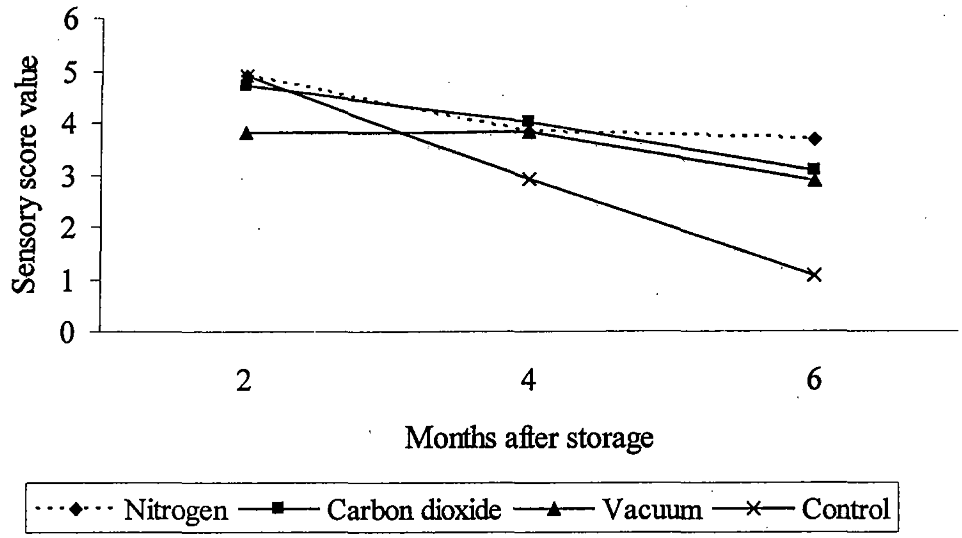


Fig. 4.8. Effect of packaging methods on overall acceptability of spray dried SMBP stored at ambient temperature

Roller dried SMBP

Results of storage studies of roller dried SMBP under different packaging methods is given in Table 4.28. Throughout storage similar to spray dried product the control samples recorded higher values for moisture, non-enzymatic browning, free fat, acidity and microbial load.

Minimum moisture ingression was observed in vacuum packed (5.782%) samples after six months and which was on par with nitrogen and carbon dioxide packed samples. Non-enzymatic browning was the least in carbon dioxide packed samples (0.410 OD) which was on par with those packed with vacuum (0.412 OD).The highest p^H after sixth month was observed with vacuum packed samples (5.885). Even if the lowest value for acidity was observed with vacuum, it was not significantly different from other treatments.

Table 4.28. Physico-chemical changes during storage of roller dried SMBP under ambient conditions

Packaging techniques	Moisture (%)				NEB (OD at 420 nm)				Free fat (%)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	3.546^{i}	4.479^{gh}	5.479^{ef}	6.567^{b}	0.239^{g}	0.283^{f}	0.330^{f}	0.410^{a}	1.845^{f}	2.045^{e}	2.170^{dc}	3.072^{c}
Carbon dioxide	,,	4.680^{g}	5.832^{de}	6.290^{bc}	,,	0.290^{f}	0.350^{d}	0.427^{b}	,,	2.058^{e}	2.241^{d}	3.403^{b}
Vacuum	,,	4.240^{h}	4.754^{g}	5.782^{de}	,,	0.290^{f}	0.345^{d}	0.412^{b}	,,	2.080^{e}	2.193^{de}	3.405^{b}
Control	,,	5.358^{f}	6.106^{cd}	7.186^{a}	,,	0.292^{f}	0.367^{c}	0.434^{a}	,,	2.288^{d}	2.945^{c}	3.969^{a}

Contd.

Table 4.28. Continued

Packaging techniques	pH				Acidity (%)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	6.501^{a}	6.066^{b}	5.955^{c}	5.876^{d}	0.246	0.246^{a}	0.271^{b}	0.270^{b}
Carbon dioxide	,,	6.066^{b}	5.955^{c}	5.880^{d}	,,	0.246	0.271^{b}	0.271^{b}
Vacuum	,,	6.066^{b}	5.956^{c}	5.952^{c}	,,	0.246^{a}	0.259^{ab}	0.271^{b}
Control	,,	6.066^{b}	5.951^{c}	5.811^{e}	,,	0.246^{a}	0.271^{b}	0.271^{b}

*Values with different superscripts differ significantly at 5%level

Bacterial count was minimum in vacuum packed samples up to two months, then onwards no significant difference were observed between treatments. Fungal count in nitrogen, carbon dioxide and vacuum packed samples were statistically at par with each other (Table 4.29). Sensory evaluation of the samples stored under different techniques showed that nitrogen packing was the best treatment (Fig. 4.9). However none of the treatments could extent shelf-life beyond four months (Table 4.30).

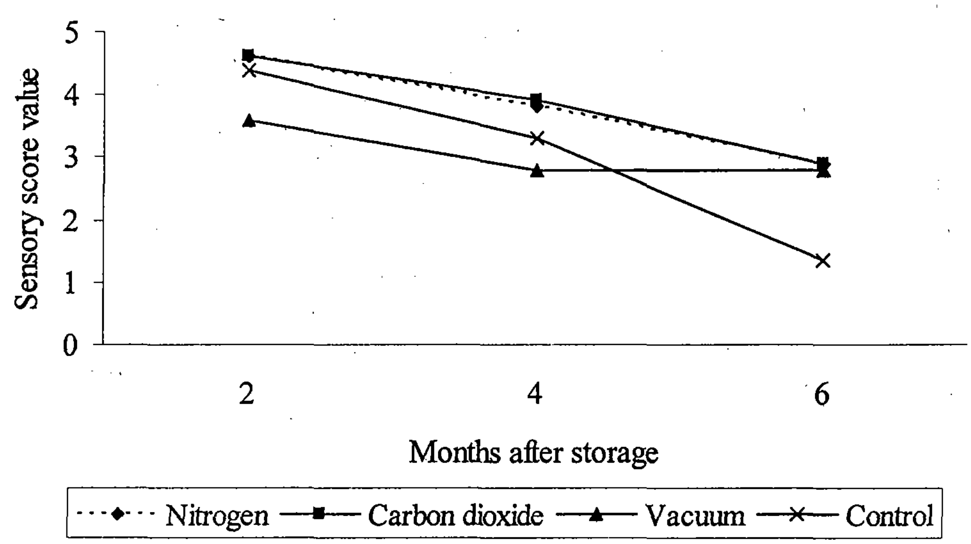


Fig. 4.9. Effect of packaging methods on overall acceptability of roller dried SMBP stored at ambient temperature

Cabinet dried SMBP

Storage of cabinet dried SMBP with nitrogen, carbon dioxide, vacuum and air (control) showed that after six months of storage the lowest moisture content (4.612%) was observed in carbon dioxide packed samples (Table 4.31). Non-enzymatic browning and percentage free fat was maximum in control samples.

Non-enzymatic browning in N_2, CO_2 and vacuum packed samples were at par with each other, but showed significant difference from the control. Free fat content was the lowest when the beverage powder was packed with nitrogen. No

Table 4.29. Changes in microbial status during storage of roller dried SMBP under ambient conditions

Packaging techniques	Bacteria (x 10^4 cfu/g)				Fungi (x 10^3 cfu/g)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	1.50^{c} (3.195)	3.25^{ab} (4.476)	8.50^{ab} (4.92)	12.00^{ab} (5.078)	0.25^{c} (0.75)	0.75^{abc} (2.25)	0.50^{bc} (1.50)	1.50^{ab} (2.401)
Carbon dioxide	,,	4.00^{ab} (4.564)	8.00^{ab} (4.896)	11.00^{ab} (5.04)	,,	0.50^{bc} (1.50)	0.50^{bc} (1.50)	1.00^{abc} (2.326)
Vacuum	,,	1.50^{c} (3.195)	2.25^{b} (4.25)	8.75^{ab} (4.898)	,,	0.50^{bc} (1.50)	0.50^{bc} (1.50)	0.50^{bc} (1.50)
Control	,,	9.50^{ab} (4.964)	14.50^{ab} (5.146)	20.75^{a} (5.315)	,,	1.50^{a} (3.12)	2.00^{a} (3.226)	3.50^{a} (3.509)

Values in parenthesis denote transformed values MAS - Months after storage ;
*Values with different superscripts differ significantly at 5% level

Table 4.30. Changes in sensory score values of roller dried SMBP stored under different packaging techniques

Packaging techniques	Colour			Flavour			Texture			Overall acceptability		
	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	4.9 (183)	3.8 (177)	2.9 (162)	4.9 (183)	3.7 (165)	2.9 (144)	5.0 (213)	4.0 (192)	3.65 (168)	4.6 (180)	3.9 (165)	2.90 (138)
Carbon dioxide	4.7 (174)	3.8 (174)	2.9 (162)	4.7 (172)	3.7 (165)	2.9 (144)	4.7 (200)	3.9 (185)	1.50 (64)	4.6 (180)	3.8 (172)	2.90 (138)
Vacuum	4.8 (174)	3.8 (174)	2.9 (162)	4.8 (174)	3.7 (165)	2.9 (144)	3.8 (190)	2.4 (111)	1.75 (72)	3.6 (160)	2.8 (138)	2.80 (138)
Control	4.9 (183)	2.7 (112)	1.7 (102)	4.9 (183)	3.2 (105)	1.3 (90)	4.9 (201)	3.10 (140)	3.00 (132)	4.4 (175)	3.3 (156)	1.35 (84)
Kendall's coefficient	0.6970^{NS}	0.6095	0.5189	0.0647^{NS}	0.5	0.5084	0.7954	0.9361	0.9759	0.5375^{NS}	0.5590	0.9129

MAS - Months after storage

Table 4.31. Physico-chemical changes during storage of cabinet dried SMBP under ambient conditions

Packaging techniques	Moisture (%)				NEB (OD at 420 nm)				Free fat (%)			
	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	4.088^{h}	4.780^{d}	5.885^{b}	6.499^{a}	0.232^{f}	0.249^{e}	0.285^{cd}	0.302^{b}	0.475^{k}	0.567^{j}	0.810^{i}	0.992^{e}
Carbon dioxide	,,	4.295^{gh}	4.403^{fg}	5.288^{c}	,,	0.248^{e}	0.282^{d}	0.300^{bc}	,,	0.568^{j}	0.894^{g}	1.035^{d}
Vacuum	,,	4.518^{efg}	4.735^{de}	4.612^{def}	,,	0.248^{e}	0.286^{cd}	0.288^{bcd}	,,	0.840^{h}	0.962^{f}	1.219^{b}
Control	,,	4.745^{de}	5.955^{b}	6.705^{a}	,,	0.255^{e}	0.297^{bcd}	0.386^{a}	,,	0.991^{e}	1.158^{e}	1.349^{a}

Contd.

Table 4.31. Continued

Packaging techniques	pH				Acidity (%)			
	0MAS	2 MAS	4 MAS	6 MAS	0 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	6.443^{a}	6.118^{b}	6.044^{c}	5.800^{fg}	0.254	0.254^{c}	0.265^{bc}	0.271^{ab}
Carbon dioxide	,,	6.131^{b}	6.037^{c}	5.806^{f}	,,	0.254^{c}	0.265^{bc}	0.271^{ab}
Vacuum	,,	6.143^{b}	6.055^{c}	5.885^{e}	,,	0.254^{c}	0.265^{bc}	0.271^{ab}
Control	,,	6.122^{b}	5.986^{d}	5.755^{g}	,,	0.254^{c}	0.269^{abc}	0.283^{a}

significant difference was observed in p^H, acidity, microbial load and sensory quality between the treatments after six months of storage (Table 4.32). No significant difference could be observed between different packaging methods (Table 4.33). However, the sensory score values also showed that all the treatments were acceptable up to four months (Fig. 4.10).

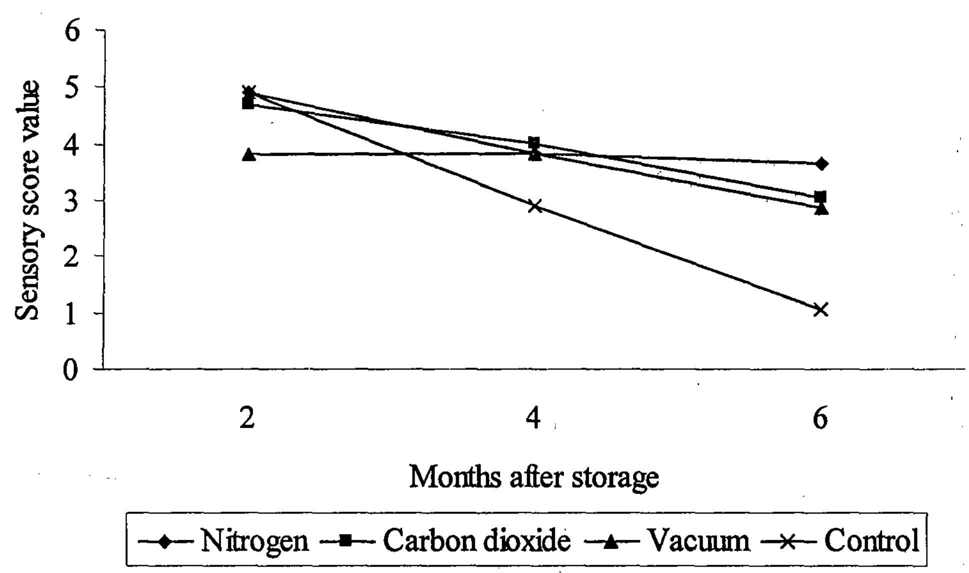


Fig. 4.10. Effect of packaging methods on overall acceptability of cabinet dried SMBP stored at ambient temperature

4.2 DEVELOPMENT OF TECHNOLOGY FOR BOTTLED SAPOTA-MILK BEVERAGE

Experiments were carried out to formulate bottled ready-to-drink sapota-milk beverage and to evaluate processing time and storage stability.

4.2.1 Composition

The proportion of sapota and skim milk was varied to standardise the composition of sapota-milk beverage. The scores obtained for the various organoleptic characters in different proportion of sapota and milk are given in Table 4.34.

Table 4.32. Changes in microbial status during storage of cabinet dried SMBP under ambient conditions

Packaging techniques	Bacteria (x 10^4 cfu/g)^{NS}				Fungi (x 10^3 cfu/g)^{NS}			
	0MAS	2 MAS	4 MAS	6 MAS	0MAS	2 MAS	4 MAS	6 MAS
Nitrogen	1.25 (4.075)	1.25 (4.075)	1.5 (4.151)	2.25 (4.314)	0.5 (4.075)	0.5 (4.075)	0.75 (2.25)	0.75 (2.25)
Carbon dioxide	,,	1.25 (4.075)	1.5 (4.151)	2.00 (4.239)	,,	0.5 (4.075)	0.75 (2.25)	0.75 (2.25)
Vacuum	,,	1.25 (4.075)	1.25 (4.075)	1.25 (4.075)	,,	0.5 (4.075)	0.75 (2.25)	0.75 (2.25)
Control	,,	1.75 (4.195)	2.0 (4.27)	2.25 (4.314)	,,	0.5 (4.075)	1.00 (3.0)	1.25 (2.401)

(Values in parenthesis denote the transformed values) ; MAS - Months after storage

Table 4.33. Sensory score values of cabinet dried SMBP stored under different techniques

Treatment	Colour			Flavour			Texture			Overall acceptability		
	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS	2 MAS	4 MAS	6 MAS
Nitrogen	4.8 (177)	3.8 (171)	2.9 (162)	4.9 (175)	3.7 (165)	2.95 (144)	5.0 (213)	4.0 (192)	3.65 (168)	4.9 (183)	3.0 (156)	2.95 (132)
Carbon dioxide	4.6 (174)	3.8 (162)	2.9 (147)	4.6 (160)	3.7 (160)	2.95 (144)	4.7 (204)	3.9 (159)	1.55 (60)	4.7 (165)	3.0 (144)	2.95 (132)
Vacuum	4.3 (162)	3.8 (111)	2.9 (107)	4.7 (165)	3.7 (160)	2.75 (130)	3.8 (72)	2.4 (69)	1.55 (60)	3.8 (66)	3.0 (144)	2.75 (126)
Control	4.8 (171)	2.7 (102)	1.3 (72)	4.9 (175)	3.2 (105)	1.35 (84)	4.9 (180)	3.0 (111)	3.25 (138)	4.9 (186)	3.0 (147)	1.35 (72)
Kendall's coefficient	0.2913	0.6095	0.5189	0.1421	0.50	0.716	0.7954	0.9361	0.8786	0.7671	0.0094	0.6393

MAS - Months after storage

Table 4.34. Organoleptic score values for various compositions of sapota-milk beverage

Composition	Sensory score values			Overall acceptance
	Colour	Flavour	Consistency	
T_1	6.73 (451)	6.33 (295)	1.73 (120)	4.4 (285)
T_2	8.47 (1430.5)	6.67 (440)	7.6 (1494.5)	4.47 (305)
T_3	7.53 (867)	6.73 (467)	7.47 (1361)	5.13 (478)
T_4	6.53 (373)	7.53 (889)	3.93 (355)	8.33 (1440)
T_5	8.67 (1555)	8.73 (1578.5)	8.67 (1815)	8.67 (1627.5)
T_6	8.27 (1306)	8.73 (1578.5)	6.53 (944.5)	8.33 (1440)
T_7	6.33 (295)	7.60 (927)	6.53 (944.5)	8.33 (1440)
T_8	8.53 (1472)	8.60 (1501.5)	7.87 (1515.5)	8.47 (1515)
T_9	8.467 (1430.5)	8.60 (1501.5)	5.67 (630)	6.467 (762)
Kruskalwallis Test Statistic	26.18	27.74	53.26	39.99

Values in parenthesis denote sum of ranks

The results revealed that there was a preponderant preference for the beverage containing 40 per cent sapota and 20 per cent skim milk (T_5). It was noticed that compositions with 15 per cent skim milk was the least preferred beverage, but when the pulp percentage was increased to 60 percentage, it affected consistency scores adversely.

4.2.2 Processing

The best combination (T_5) selected on the basis of sensory scores was further subjected to three different methods of processing viz., sterilization at 15 psi for 20 minutes, pasteurization at 85°C for 20 minutes and pasteurization at 85°C for 30 minutes. Sterilization was not found suitable for sapota-milk beverage as the product colour turned pink-red. The effect of pasteurization time on microbial load, p^H and acidity are given in Fig. 4.11.

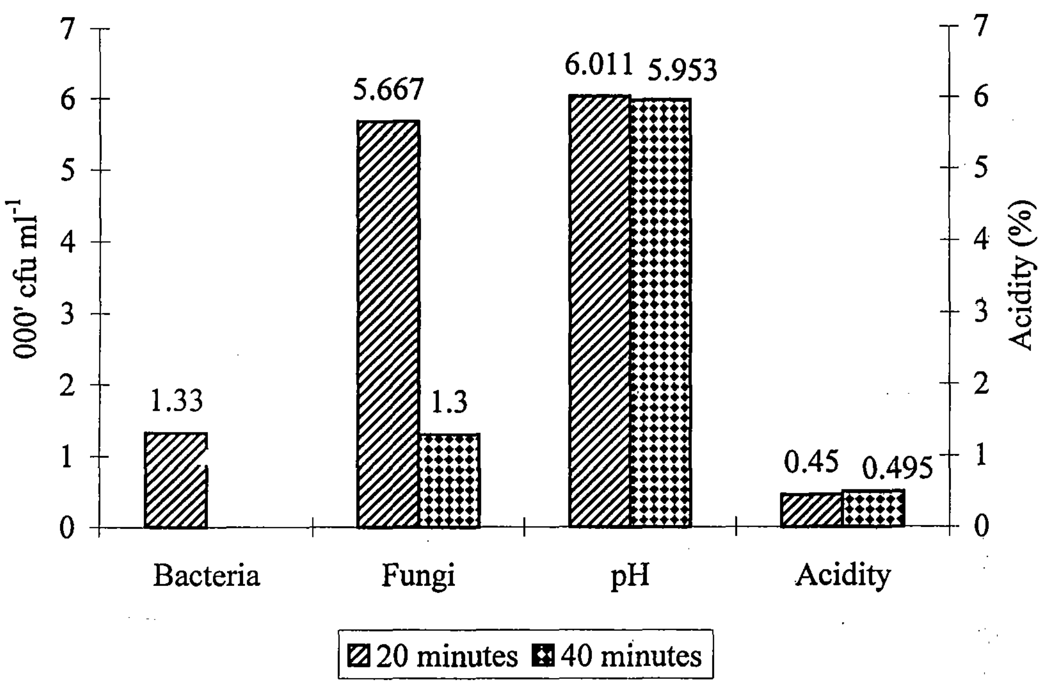


Fig. 4.11. Effect of pasturisation time on qulaity of sapota-milk beverge

Bacterial population was not observed in beverage pasteurized for 30 minutes whereas the product pasteurized for 20 minutes contained 1330 cfu ml^{-1}. Similarly fungal count was only 1300 cfu ml^{-1} in beverage pasteurized for 30 minutes as against 5667 cfu ml^{-1} in the beverage pasteurized for 20 minutes. With increase in pasteurization time, the acidity increased and consequently decreased the p^H.

The effect of pasteurization on organoleptic scores of the beverages is given in Table 4.35. It was observed that colour, flavour, consistency and overall acceptability were improved by longer period of pasteurization.

Table 4.35. Effect of pasteurization on organoleptic qualities of sapota-milk beverage

Organoleptic qualities	Duration of pasteurisation		Kruskal Wallis Test Static
	20 minutes	30 minutes	
Colour	6.67 (120)	8.53 (345)	23.471
Flavour	7.533 (136)	8.73 (329)	18.310
Consistency	8.667 (210)	8.87 (255)	1.621
Overall acceptability	6.73 (120)	8.53 (345)	23.721

4.2.3 Storage

Bottled sapota-milk beverage pasteurized for 30 minutes at 85°C were stored both at ambient (28±2°C) and refrigerated condition (8±2°C). The beverage stored at ambient condition got coagulated and turned totally unacceptable after a day of storage.

TSS and p^H of the beverage stored under refrigerated condition showed a progressive decline whereas acidity and microbial status increased during storage (Table 4.36).

Table 4.36. Effect of storage on chemical and microbial qualities of bottled sapota-milk beverage under refrigerated conditions

Months after storage (MAS)	TSS °Brix	p^H	Acidity (%)	Bacteria (10^4 cfu ml^{-1})	Fungi (10^2 cfu ml^{-1})
0	19.92^a	6.05^a	0.456^c	0.0^e (0)	4.5^c (1.2)
1	19.88^a	5.98^a	0.463^c	5.4^d (4.692)	10.2^b (2.025)
2	19.68^b	5.76^b	0.469^{bc}	24.0^c (5.376)	14.0^{ab} (2.581)
3	19.14^e	5.73^c	0.480^{ab}	65.0^b (5.811)	21.0^{ab} (3.323)
4	18.86^d	5.53^d	0.491^a	97.6^a (5.989)	26.0^a (3.356)

*Values with different superscripts differ significantly at 5% level
Values in paranthesis denote transformed values

Examination of initial microbial status of the beverage showed that it contained only fungi (450 cfu ml^{-1}). But the bacterial population increased to 5400 and 9,76,000 cfu ml^{-1} after first and fourth month of storage respectively.

Even though organoleptic scores showed a progressive decline during storage, the product remained acceptable even after four months of storage (Table 4.37).

Table 4.37. Effect of storage on organoleptic qualities of bottled sapota-milk beverage under refrigerated conditions

Organoleptic qualities	Initial value	Mean score values				Kruskal Wallis Test statistic
		1 MAS	2 MAS	3 MAS	4 MAS	
Colour	8.6 (487.5)	8.6 (487.5)	8.6 (487.5)	8.467 (427.5)	8.467 (427.5)	1.054^{NS}
Flavour	8.8 (544)	8.73 (540)	8.6 (480)	8.47 (420)	8.4 (390)	3.907^{NS}
Consistency	8.8 (547)	8.6 (468)	8.4 (457.5)	8.33 (427.5)	8.27 (397.5)	3.824^{NS}
Overall acceptability	8.8 (551)	8.73 (547.5)	8.67 (517.5)	8.53 (457.5)	8.2 (307.5)	10.009

*Values in paranthesis denote sum of scores
NS – Non-significant

4.2.4 Cost of production

Cost of production of one bottle of ready-to-drink sapota-milk beverage was worked out to be Rs 4.35 (Table 4.38).

Table 4.38. Cost of production of 100 bottles of ready-to-drink sapota-milk beverage

Sl. No.	Item	Quantity	Unit cost (Rs)	Total cost (Rs)
I	Raw material			
a	Sapota pulp	8.00 kg	20/kg	160.0
b	Milk	4.16 kg	13/litre	54.08
c	Sugar	1.90 kg	16/kg	30.40
d	Stabilizer and emulsifier	20.0 g	250/kg	5.00

Contd.

Sl. No.	Item	Quantity	Unit cost (Rs)	Total cost (Rs)
II	Fuel	75 p / kg of beverage		15.00
III	Labour			
a	Skilled labour	4 h	200/8 h	100.00
b	Attendant (Woman)	4 h	100/8 h	50.00
	Total working capital			414.48
IV	Interest on working capital (@12%)			0.14
V	Interest on fixed capital (@12%)			6.50
VI	Depreciation of machineries and accessories (@10%)			5.50
VII	Total cost of production			426.62
VIII	Processing loss (2%)	0.40 kg (2 bottles)		
IX	Actual quantity of beverage	19.60kg (98 bottles)		
X	Cost per bottle			4.35

4.3 MARKETABILITY OF VALUE ADDED PRODUCTS

Preconsumption behaviour of the consumers revealed that 70 per cent were habituated with instant beverages. Among this, majority (68.75%) preferred to take such beverages once or twice a week, while 16 per cent were in the habit of taking it only once or twice a month (Table 4.39). Almost 94 per cent of the respondents were found to have a strong preference for natural beverages over synthetic ones.

Table 4.39. Preconsumption behaviour pattern of the respondents towards instant beverages

Factor	Response	Respondents	
		Number	Percentage
Habit of using instant beverages	Positive	35	70
	Negative	15	30
Frequency of usage	Weekly 1-2 times	24	48
	Weekly 3-4 times	3	6
	Monthly 1-2 times	8	16
Preference on one type of beverage	Natural	47	94
	Synthetic	1	2
	Neutral	2	4

Among the respondents 42 per cent of the respondents evaluated were exposed to sapota-milk beverage ("chikku shake") previously from juice parlours. Majority of the respondents expressed moderate liking for the product while 14 per cent liked the beverage very much (Table 4.40).

Table 4.40. Attitude of respondents towards sapota-milk beverage

Factor	Response	Respondents	
		Number	Percentage
Prior exposure to Sapota-milk beverage	Positive	21	42
	Negative	29	58
Attitude towards sapota-milk beverage	Liked extremely	3	14.3
	Liked moderately	13	61.9
	Just liked	5	23.8
	Disliked	0	-

Almost 42 per cent of the respondents expressed a moderate preference for sapota-milk beverage powder while 14 per cent liked it very much. It was observed that almost 46 per cent of the consumers expected the price above Rs 20, while 42 per cent expected it to range between Rs 15-20 per 100 g pouch. However, large majority (76%) was ready to buy the product if available in the market at Rs 20 per 100 g pouch (Table 4.41).

Table 4.41. Consumer response towards newly developed instant sapota-milk beverage powder

Factor	Response	Number of Respondents	
		Number	Percentage
Liking for the product	Liked very much	7	14
	Liked moderately	21	42
	Just liked	22	44
	Disliked	-	-
Price expectation about the product (Rs /100 g)	10-15	6	12
	15-20	21	42
	20-25	20	40
	25-30	3	6
Readiness to buy the product @ Rs 20/100 g	Positive	38	76
	Negative	12	24

In the case of bottled beverage 52 per cent expressed a moderate preference while 12 per cent liked it very much. The price expectation was ranging between Rs 8-10 per bottle in most cases of respondents and almost 90 per cent were ready to buy the product at Rs 10 per bottle (Table 4.42).

Table 4.42. Consumer response towards newly developed bottled sapota-milk beverage

Factor	Response	Number of Respondents	
		Number	Percentage
Liking for the product	Liked very much	6	12
	Liked moderately	26	52
	Just liked	17	34
	Disliked	1	2
Price expectation about the product (Rs per bottle)	<8	6	12
	8-10	33	66
	>10	11	22
Readiness to buy the product @ Rs 10 per bottle	Positive	45	45
	Negative	5	10

Discussion

5. DISCUSSION

Sapota being highly perishable, technologies for value added products have to be developed that will ensure minimum postharvest loss, better returns and fair price stability. Sapota-milk shake, a blend of two natural products, sapota and milk, is a highly delicious beverage popular throughout India. But the fruits being seasonal, availability of this beverage throughout the year is limited. In order to ensure the availability of this beverage, any time any where, an attempt has been made to standardise technology for sapota-milk beverage as an instant powder and as a bottled ready-to-drink product.

5.1 TECHNOLOGY FOR PRODUCTION OF INSTANT SAPOTA-MILK BEVERAGE POWDER

Experiments on spray, roller and cabinet drying were conducted to develop appropriate technology for production of sapota-milk beverage powder and the results are discussed hereunder.

5.1.1 Experiments on spray drying

Among the different inlet air temperatures experimented, 185°C yielded a free flowing spray dried powder with balanced flavour of sapota and milk. Stickiness of the product observed at inlet air temperatures above and below 185°C, is a frequently encountered phenomenon during spray drying of products containing low molecular weight components.

Sticky point, the temperature at which caking is instantaneous, decreases with decrease in molecular weight. Sapota contains high amount of monosaccharides viz. glucose and fructose, which have very low glass transition temperatures and sticky points. It is the reason for sticky problems faced during spray drying.

Glass transition temperature (Tg) is the temperature at which a hard, solid, amorphous sugar undergoes transformation to a soft, rubbery liquid phase. Anhydrous fructose, glucose, sucrose and lactose have Tg values at 5, 31, 62 and 101°C respectively (Bhandari and Hower, 1999). Water is the major component responsible for depressing the Tg of food materials as water has a very low Tg of -135°C (Johari *et al.*, 1987). Roos and Karel (1991a) reported that products with low Tg have sticky points at low temperature and with increase in either moisture or temperature, the sticky point temperature of the products also decline.

Heavy wall deposit encountered with inlet air temperature above 185°C revealed that product temperature has definitely crossed this critical temperature. Normally maximum temperature that the product attains in spray drying is only those of outlet air. But on collision with walls of the chamber, the temperature of the powder could have increased. To avoid this, drier wall temperature should be kept below Tg of the product.

Roose and Karel (1991b) and Bhandari *et al.* (1997) also have reported that temperature of surface of the product as well as wall temperature should not cross 10-20°C above Tg of the product. However addition of high molecular weight molecules such as malto-dextrin and starch which have high Tg value, reduces the sticky point of the product. Hence Dacosta and Cal-Vidal (1988) added high corn starch (15-20%) in coconut milk and Rao and Mathur (1987b) added malto-dextrin in infant formula for successful spray drying at higher inlet temperatures above 200°C. Low yield and heavy wall deposit was also observed by Brennan *et al.* (1971) when concentrated orange juice was spray dried at lower temperatures viz. 130, 140 and 150°C.

Equal proportion of sapota and milk solids in the beverage mix gave the best beverage powder with dominant sapota flavour (Fig. 5.1). Coulter and Breene (1967) also reported that 50:50 ratio of skim milk to plant solids such as bananas, pumpkin and peas, gave adequately dried products with characteristic flavour in conventional spray drier.

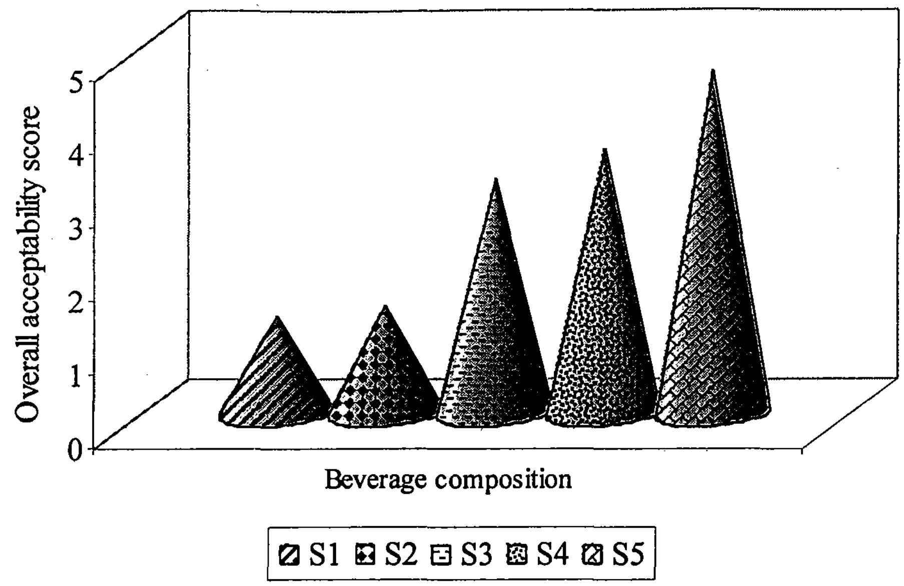


Fig. 5.1. Effect of beverage composition on overall acceptability of spray dried SMBP

Hence beverage mix composition of 1:1 fruit to milk solids and inlet air temperature of 185°C was acknowledged as the optimum for production of spray dried sapota-milk beverage powder. The material and process flow chart thus standardized for spray dried SMBP is given in Fig.5.2.

5.1.2 Experiments on roller drying

Sapota-milk beverage mix on roller drying with 4 kg cm^{-2} steam pressure inside the drum and 7 rpm drum speed yielded quality product with good colour and sapota flavour. Higher steam pressure (5 kg cm^{-2}) discoloured the finished product due to the high drum surface temperature (Fig.5.3).

The products obtained with 7 and 10 rpm drum speed were qualitatively similar. The moisture content was the lowest when drum speed was kept minimum (7 rpm), as it retained the product on hot drum surface for a few more seconds (Fig.5.4).

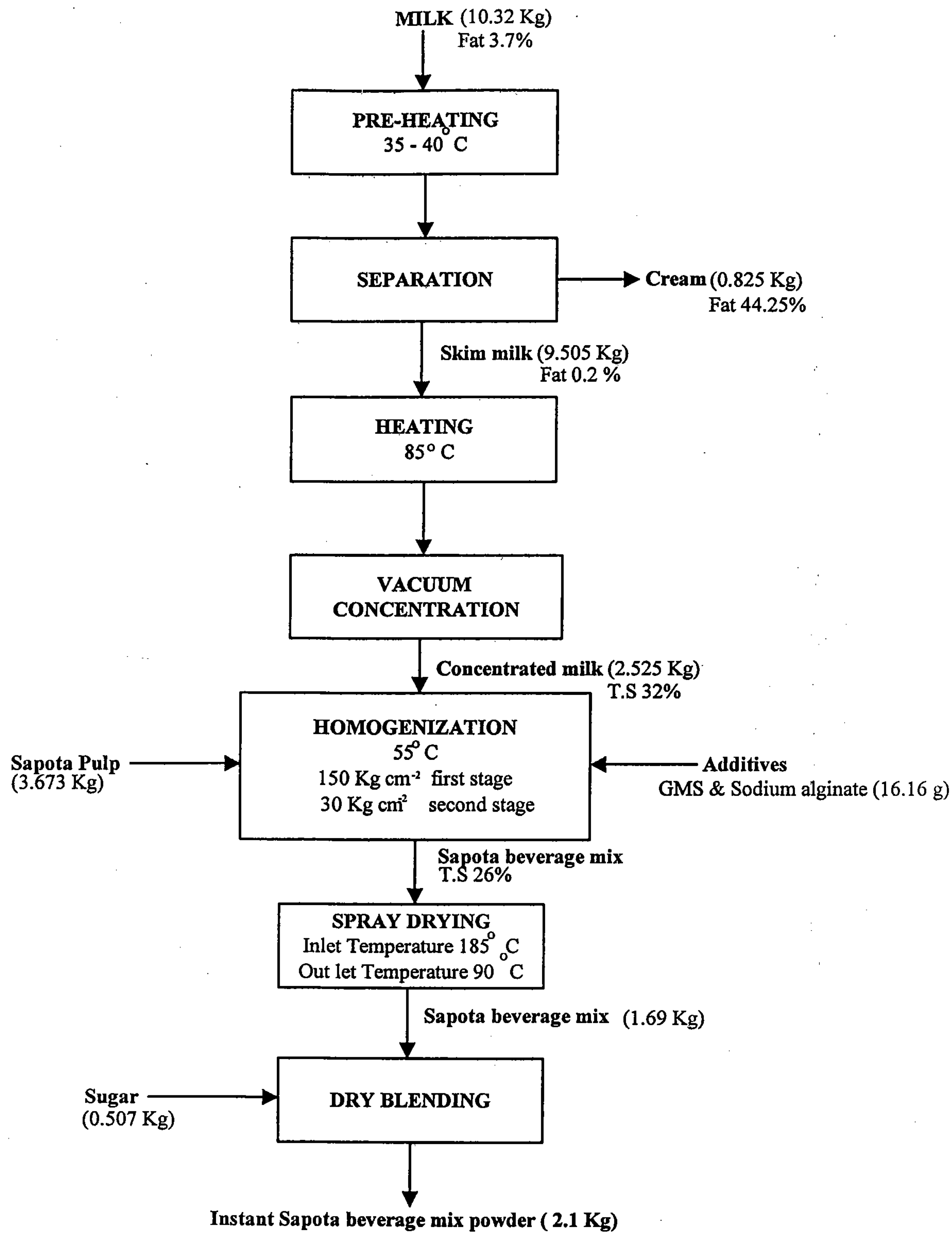


Fig. 5.2. Material and process flow chart for spray dried sapota-milk beverage powder

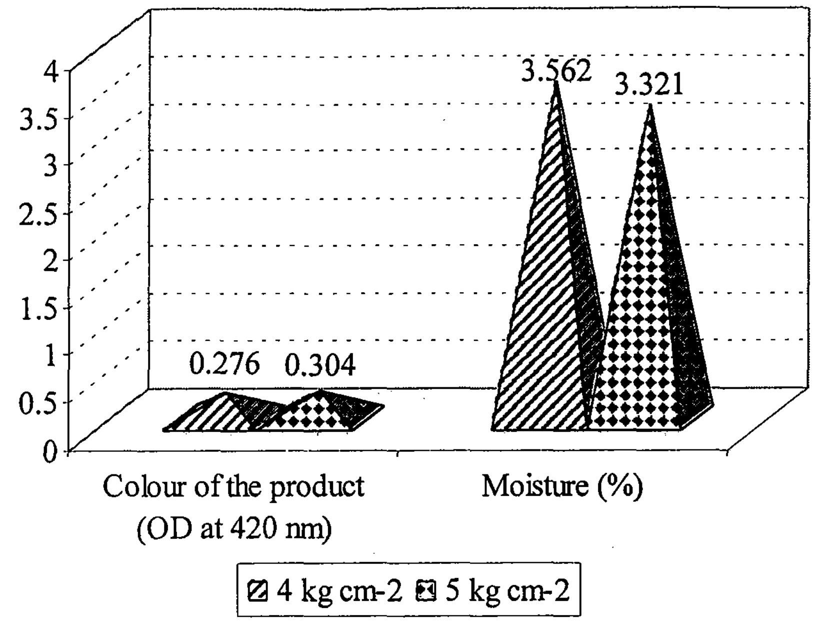


Fig. 5.3. Effect of steam pressure on roller drying of sapota-milk beverage powder

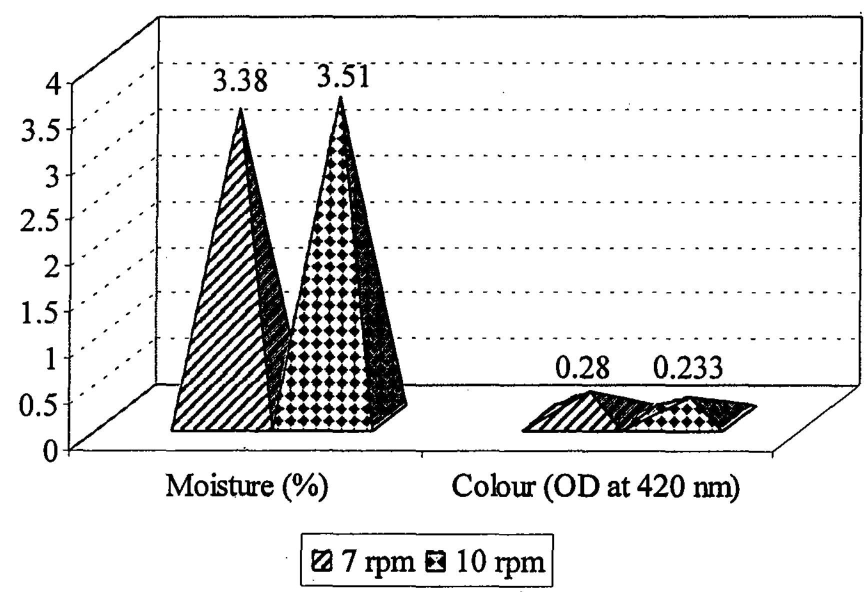


Fig. 5.4. Effect of drum speed on roller drying of sapota-milk beverage

Kalpalathika (1984) also observed that low drum speed resulted in low moisture content in the roller dried carrot baby food. Since minimum moisture content is the preferred character for storage, 7 rpm drum speed was selected as the best.

Ideal steam pressure and drum speed reported for roller dried goat milk was 5.25 kg cm^2 and 18 rpm respectively (Prakash *et al.*, 1990). The fruit pulp even after blending with milk was highly viscous. Hence for uniform spread on the drum surface and easy removal of moisture from the highly hygroscopic fruit solids, a lesser drum speed. Since the thermo-labile colour and flavour of sapota fruit is lost at high temperature unlike milk products, the sapota-milk beverage mix should be dried with low steam pressure (4 kg cm^{-2}) and drum speed (7 rpm).

The roller dried SMBP contained only 3.38 per cent moisture, whereas it was 12 per cent in apricot pulp drum dried with 3-4 rpm (Padival and Srinivasan, 1966) and 5-7 per cent in tomato flakes produced with 3.3 rpm (Lazar and Meirs, 1971), showing the superior quality of the product obtained in the present study.

The product obtained with the lowest proportion of milk solids added to sapota pulp was organoleptically rated superior because of dominant sapota flavour in the product (Fig.5.5). However skim milk when used did not retained good milky flavour in the finished product. When the fat content of the milk was increased to one cent, the product was relished very high. However, at two per cent fat level, due to high amount of free fat developed in the product due to drum drying, a thin oily film on the reconstituted beverage surface was observed. Identical report has been made by De (1980) who confirmed that 85-95 per cent of the fat in drum dried whole milk powder exists in free stage.

However the product obtained with 1:0.5 ratio with milk containing 2 per cent fat possessed a typical milk candy taste and there is the possibility of milk candy production from sapota that is worth being investigated.

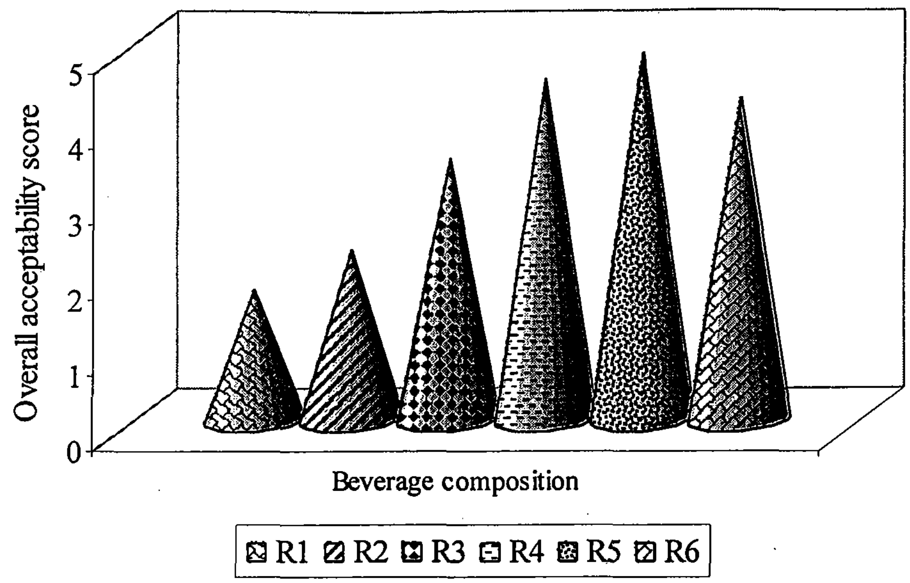


Fig. 5.5. Effect of beverage composition on overall acceptability of roller dried SMBP

Based on the response of the sensory panel and in the light of discussions, it can be confirmed that the ratio 1:0.5 sapota to milk (1% fat) was the best composition for roller drying. The materials and process flow chart for roller drying of SMBP mix thus developed is given in Fig.5.6.

5.1.3 Experiments on cabinet drying

Free flowing good quality powder could be obtained with 70 or 80°C. But it was found that drying occurred at a faster rate at 80°C, with no deleterious effect on colour and flavour. This shows that 80°C is not detrimental to the thermo-labile colour and flavour components of sapota fruit. However lower temperature (60°C) was found inadequate for satisfactory drying and hence yielded a leathery product.

Srivastav *et al.* (2002) reported that fully ripe bael pulp could not be dried to the desired level even after 30 hours at 60°C in cabinet drier. Results of the study conducted by Rakhi *et al.* (2002) in mushroom also gave identical results. She reported that 12 h was required for dehydrating mushroom soup powder at 60 ± 2°C using a cabinet drier.

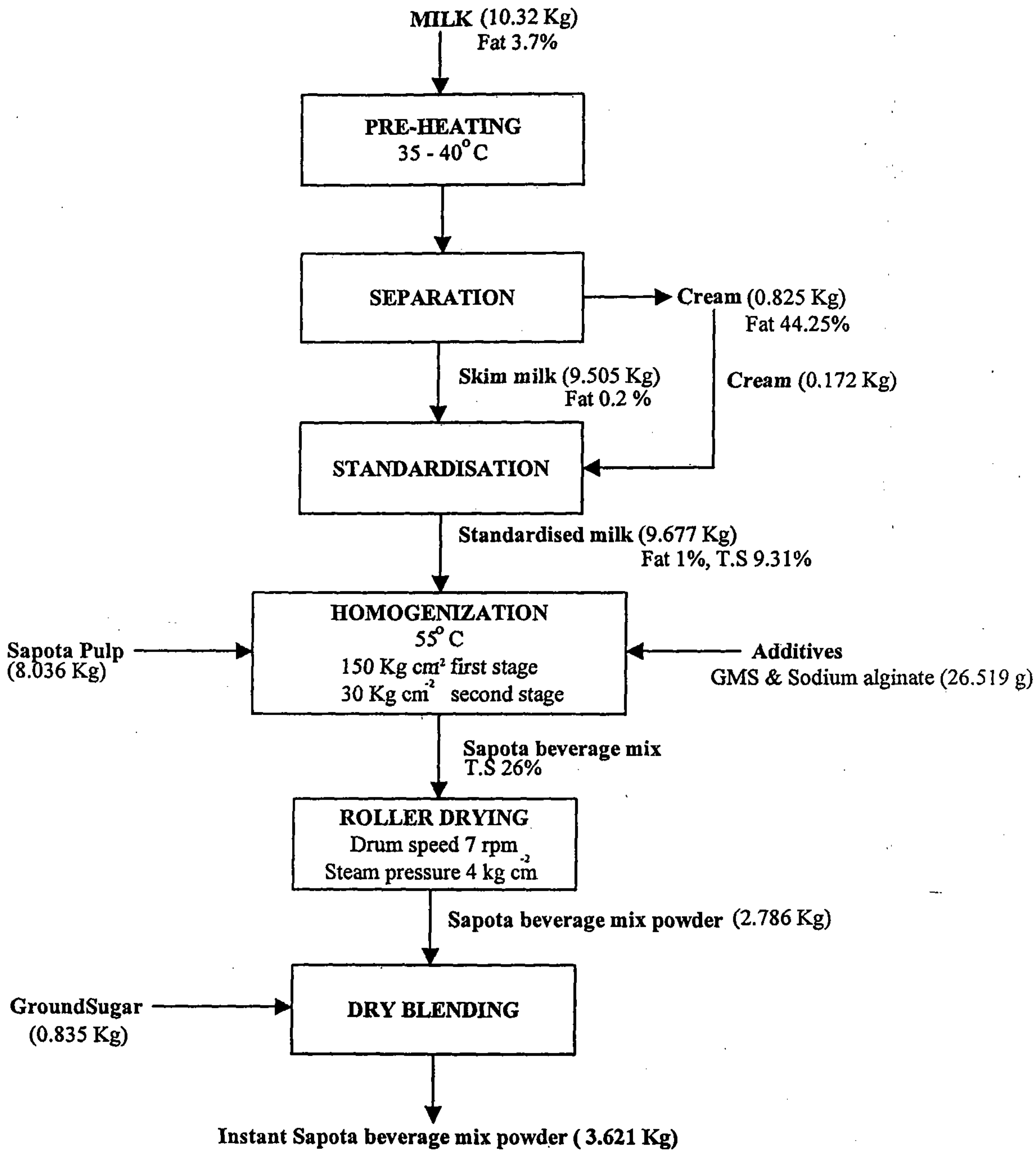


Fig. 5.6. Material and process flow chart for roller dried sapota-milk beverage powder

Beverage powder with 1:0.5 ratio of fruit and milk solids was preferred by the sensory panel owing to high concentration of fruit solids in the product (Fig.5.7). The materials and process flowchart for cabinet drying thus developed is given in the Fig.5.8.

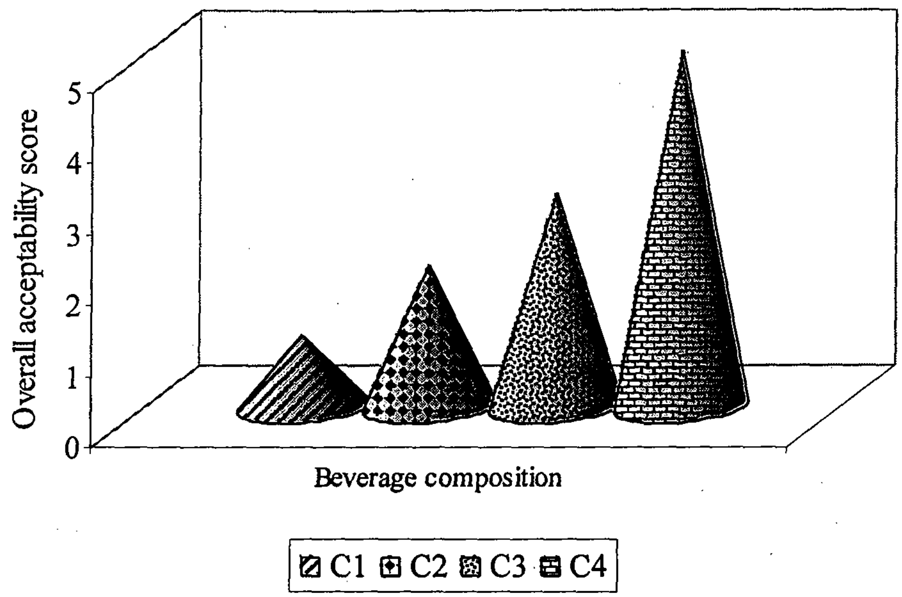


Fig. 5.7. Effect of beverage composition on overall acceptability of cabinet dried SMBP

5.1.4 Spray dried, roller dried and cabinet dried sapota-milk beverage powder - a comparison

Fruits are sensitive to prolonged heat treatment as it results in loss of delicate flavour, colour and reduced acceptability of the product (Nanjundaswamy and Setty, 1989) and it is difficult to promote any product in the market unless it closely resembles the quality of fresh product. Various physico-chemical and organoleptic characters of the SMBP developed through different drying methods varied and are discussed here under.

5.1.4.1 Moisture

Moisture content of beverage powder immediately after production is the most important factor as it determines the various deteriorative changes that would

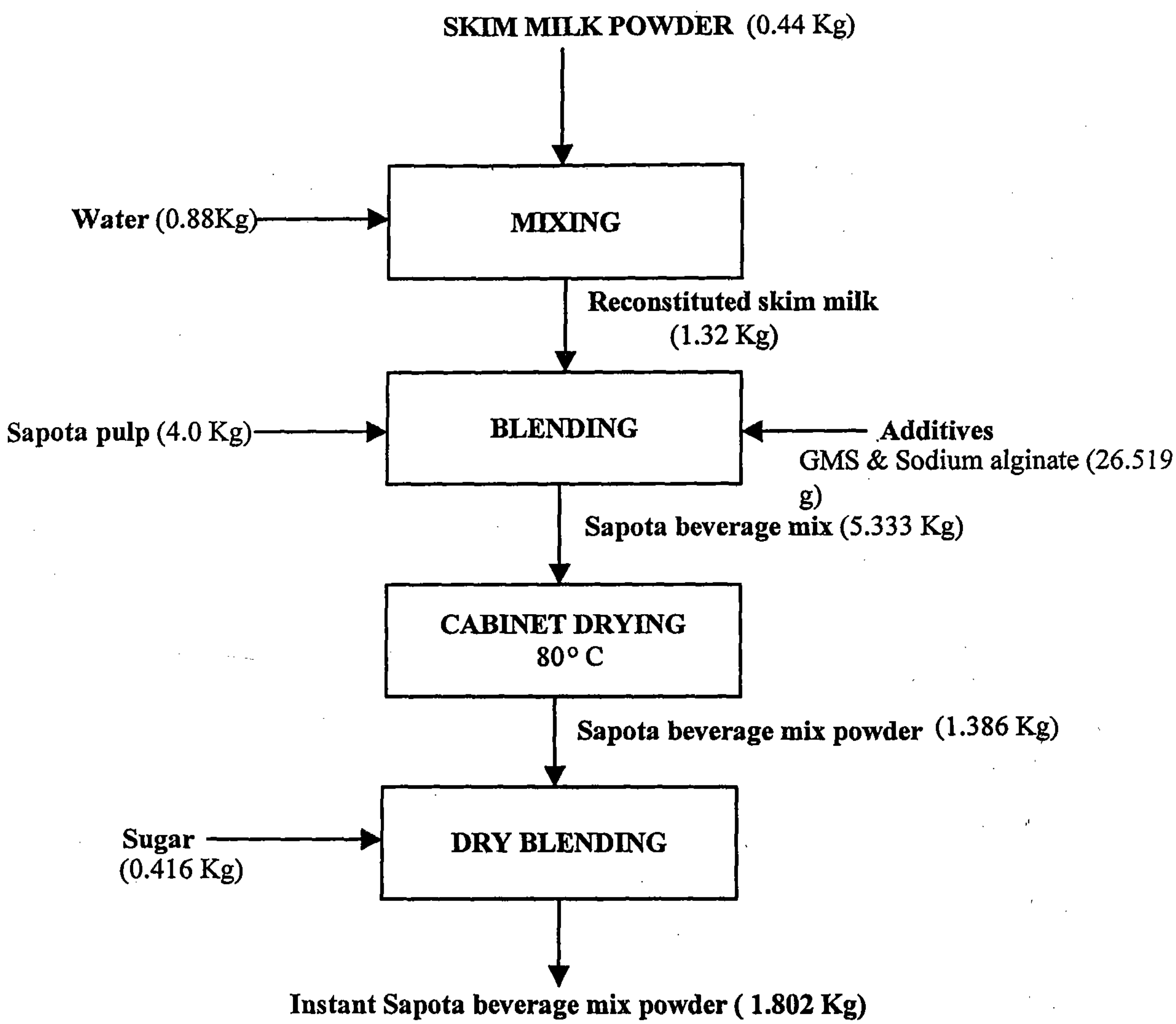


Fig. 5.8. Material and process flow chart for cabinet dried sapota-milk beverage powder

occur in storage viz. hydrolytic reactions, non-enzymatic browning, lipid oxidation, enzyme activity, microbial growth etc.

The lowest moisture content was observed in spray dried SMBP which was comparable with roller dried SMBP. The temperature employed for sapota-milk beverage powder production in spray, roller and cabinet drying were 185, 145 and 80°C respectively. Higher the temperature involved in drying, lower was the moisture content of the finished product, thus explaining the difference in residual moisture levels in these products. Results of the study conducted by Kumar and Venugopal (1991) and Prakash *et al.* (1990) also revealed that spray dried product contained less moisture than roller dried product.

5.1.4.2 Bulk density, average particle density and percentage volume occupied by the powder particles

Low bulk density is an important part of powder production influencing the instant characteristics (Pisecky, 1980) and producers are also interested in products with low bulk density, so as to supply optically larger amounts of powder in the market.

The lowest bulk density SMBP was obtained with spray drying (0.593 g ml^{-1}) and the value falls within the range of spray dried milk powder as suggested by Hall and Hedrick (1971). They opined that normal bulk density of spray dried milk powder varied between 0.5 to 0.6 g ml^{-1} and that of roller dried varied between 0.3 to 0.5 g ml^{-1}. High amount of air entrapped during atomisation may have resulted in lower bulk density observed in the spray dried product. The compaction resulting from pulverization resulted in higher bulk density in roller and cabinet dried SMBP. According to Aruna *et al.* (1998) bulk density of cereal-based papaya powder ranged between 0.67-0.69 g ml^{-1} whereas the product developed in the present study through cabinet drying recorded a lower value of 0.648 g ml^{-1} showing that the better quality of the SMBP developed.

Lower particle density is the preferred character for instant powders and the lowest value was observed in spray dried SMBP. Hall and Hedrick (1971) opined that the amount of entrapped air influenced the particle density significantly.

5.1.4.3 Solubility percentage

Maximum value for solubility percentage, the preferred character for instant powder was observed in spray dried SMBP (85.94). The major soluble components in the product are sugars, non-denatured serum milk protein and some of the salts. The values observed here is in confirmation with the solubility percentage of banana milk-shake powder (83.47-87.49) as reported by Lakshminarayana *et al.* (1997). Higher temperature as well as longer duration of heat treatment resulted-in denaturation of milk protein, and thus reduced solubility of roller dried and cabinet dried products. Prakash *et al.* (1990) also reported higher insolubility observed in roller dried goat milk powder over spray dried product.

5.1.4.4 Soluble solids and dispersed solids

Higher quantities of dispersed solids with roller and cabinet dried product may be attributed to higher fibre content of the product due to high proportion of fruit solids used in both these products when compared to spray dried SMBP. Moreover due to high temperature involved in the roller and cabinet drying methods, majority of the solids remained in a dispersed state rather than in a soluble state. In spray dried SMBP 65.42 per cent of the solids were soluble, giving it the instant nature and 29.26 per cent solids were in dispersed stage, giving it the desired mouth feel.

5.1.4.5 Dispersibility

Even after 24 hours of reconstitution only 5.40 per cent of the total solids settled giving a dispersibility of 94.60 per cent for spray dried SMBP. Higher dispersibility, the desired character for beverage powder reflects lower sedimentation in the spray dried product upon reconstitution. This is due to low particle density of the spray dried product.

5.1.4.6 Sinkability

Sinkability at the second, fourth and sixth minute gave an idea about the rate of sedimentation in the beverage (Fig 5.9). Particle density was the highest in cabinet dried SMBP, which caused high sedimentation. Higher density particles sink rapidly and take long time to dissolve. Hall and Hedrick (1971) reported that higher the occluded air in the particle, lower is the sinkability of the milk powder.

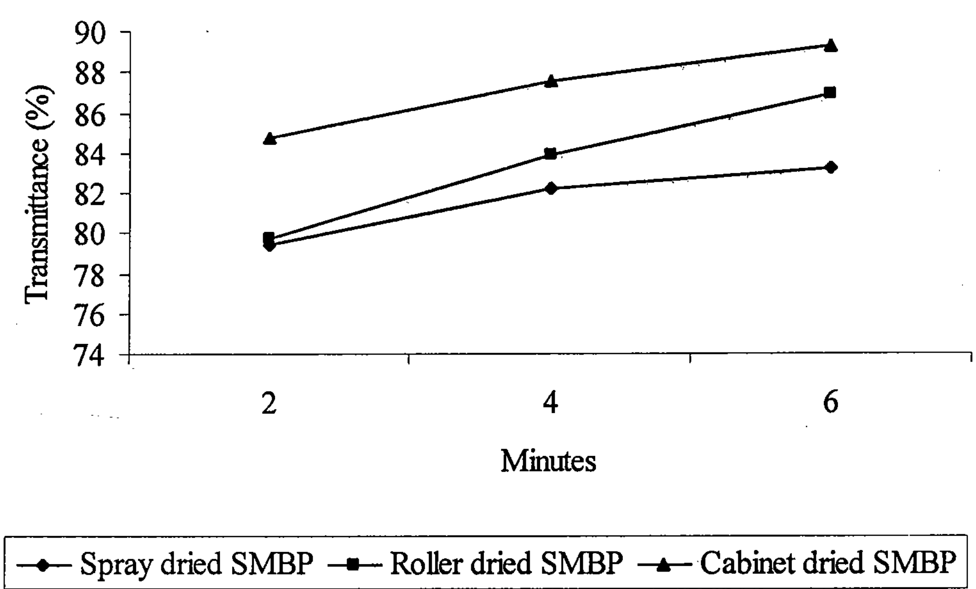


Fig. 5.9. Sinkability of spray, roller and cabinet dried SMBP

5.1.4.7 Specific gravity and relative viscosity

The results showed that specific gravity showed a similar pattern as that of APD with the lowest value in spray dried SMBP (1.051) and the highest value in cabinet dried SMBP. Geevargheese (1996) also reported similar values for specific gravity (1.051-1.055) in spray dried kera ice cream mix.

Relative viscosity, a function of specific gravity, also showed similar pattern as that of specific gravity and it was observed that spray dried product possessed very low viscosity of 11.005. Geevargheese (1996) also reported that upon reconstitution the viscosity of kera ice-cream mix was lowered and it ranged between 8.331 and 8.408.

5.1.4.8 Hunter colour values

Maximum value for lightness (L) and least deviation (DE) from the standard as well as the lowest redness value (a) indicate that the spray dried product has the lowest colour degradation. It is evident from the result that the inlet air temperature as high as 185°C was not detrimental to the colour of the product. This is due to the fact that owing to evaporative cooling and fast removal of moisture from the product, maximum temperature that the particles will attain is only that of outlet air (90°C) and that too only for 3-4 seconds.

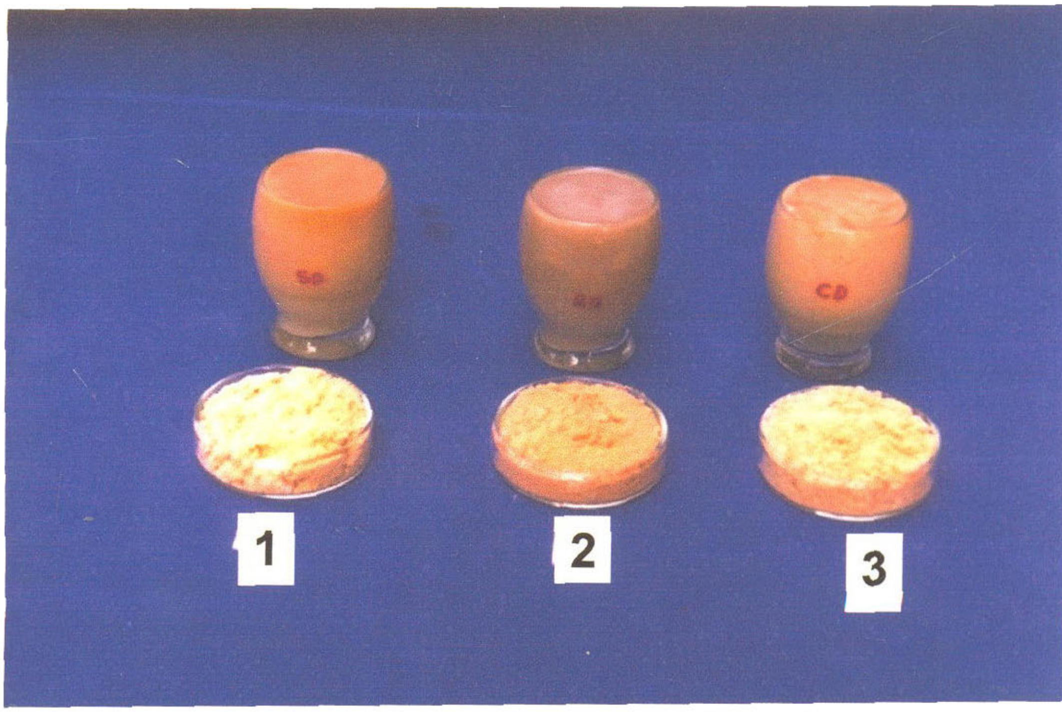
Higher proportion of milk and lower temperature used in spray drying could have resulted in a product with high content of β-carotene compared to other two dried products and hence showed higher values for yellowness (Plate 8). The redness (a) value was the highest in roller dried product and it can be inferred that the product was darker in colour due exposure to high temperature during dehydration.

5.1.4.9 Microstructure

The spray dried particles were of spherical shape with almost smooth surface against highly distorted and rough surface of roller dried particles as presented in Plate 4. Larger temperature gradient between the particles and hot air, during drying resulted in increased roughness or wrinkles on the particle surface and it may be the reason for rougher surface in the roller dried particles obtained in the present study. Bhandari *et al.* (1984) observed that in normal ice-cream powder particle size varied from 27 to 90 μm in diameter and this is in conformation with the size of particles (25-50 μm) observed in the present study. Spray dried skim milk powder used could be the reason for smaller sized particles obtained in the cabinet dried product.

5.1.4.10 Chemical characters

Composition of beverage mix standardized in different methods of drying were different and consequently the chemical characters of these products also showed variation.



1 - Spray dried 2 - Roller dried 3 - Cabinet dried

Plate 8. Sapota-milk beverage powder before and after reconstitution

1 - Stored at room temperature;
2 - Pasteurized at 85°C for 20 minutes
3 - Pasteurized at 85°C for 30 minutes
4 - Sterilized at 15 psi for 30 minutes

Plate 9. Bottled sapota-milk beverage

High carbohydrate and fibre content in cabinet dried and roller dried products is the result of high proportion of fruit solids used in drying. High temperature in roller drying might have resulted in caramellisation of sugar and thus reduced the total sugar content in the product. Whereas higher proportion of milk solids (1:1 ratio of sapota to skim milk solids) resulted in high protein content in the spray dried product.

Roller dried product contained the highest fat since it was developed using cow milk containing one per cent fat. In spray dried SMBP only 6.38 per cent of total fat was present in free stage whereas 49.12 per cent fat in roller dried SMBP was present as free fat. This high free fat content could be the result of fat globule membrane rupture caused by high temperature of the drum as well as scraping action of knife while removing the film from the drum surface as suggested by De (1980). Pulverisation increased the free fat content of cabinet and roller dried product further.

The measurement of alcohol soluble colour at 420 nm indicates the degree of non-enzymatic browning. Minimum non-enzymatic browning was observed in spray dried product due to less severe heat treatment whereas high temperature of the drum resulted in maximum NEB in roller dried SMBP. De (1980) reported that development of brown colour in milk products is objectionable and higher the intensity of heating, greater is the tendency for browning, the result of interaction between amino compounds and sugar (Maillard-type browning).

High proportion of milk used resulted in higher ash and acidity content in spray dried SMBP. The total energy value as estimated by bomb calorimeter was maximum (362.2 kcal/100 g) in spray dried product. Higher protein content of spray dried product might be the reason for high energy content of the product. Thus it can be concluded that spray-dried product was superior in terms of protein content, colour, free fat and calorific value.

5.1.4.11 Anthocyanidins

In the spray dried product only one small spot could be detected with an Rf value 0.52 confirming lower quantity of anthocyanidin formed in the product. It is because of low temperature and small retention time in spray drying. Another spot with Rf 0.23 in other two methods of drying shows the formation of an additional anthocyanidin compound. It may be inferred that higher temperature is required for the formation of this compound from the parent leuco-anthocyanidin compound. Spot size gives an idea about the quantity of this degraded compound in each product. It was observed that maximum anthocyanidins were formed in the roller dried product and the minimum in spray dried product revealing the superior quality of spray dried product. However, only quantitative analysis can give a correct picture.

Rege and Pai (1990) have reported that higher the temperature in processing, maximum is the conversion of leuco-anthocyanidins present in sapota fruit to anthocyanidins, which impart a pink-red colour to the product. They have observed three anthocyanidin compounds viz. dephinidin, cyanidin and pelargonin with Rf values 0.4, 0.56 and 0.7 respectively in paper chromatography of thermally processed sapota pulp.

5.1.4.12 Flavanoids

Flavanoid compounds detected were same in all the three dehydrated products, but the spot size showed marked variation. The spot size was maximum in spray dried SMBP for compounds with Rf values 0.36 and 0.84. However, two spots corresponding to Rf values 0.46 and 0.94 observed in fresh sapota were lacking in all the dehydrated products, showing that these two compounds are highly volatile/thermolabile. Further studies on this aspect are required.

5.1.4.13 Organoleptic characters

Spray dried sapota-milk beverage powder was preponderantly preferred by the respondents and it scored maximum values for all the characters assessed except consistency. Lower concentration of fruit pulp used in spray drying could have resulted in low consistency score rating. However, even with lower concentration of fruit pulp, the flavour was retained maximum in spray dried product.

High acceptability of spray dried product can be well related to superior physico-chemical characteristics of the product compared to roller dried and cabinet dried products. This is again due to low time and temperature employed in spray drying. Perusal of physico-chemical and organoleptic qualities revealed that quality was the best in spray dried sapota-milk beverage powder followed by the cabinet dried product

5.1.4.14 Cost of production

Cost of production worked out for 100 g pack of beverage powder was the highest for the spray dried product and it was 11 and 22 per cent higher than the cost of roller and cabinet dried products respectively. The difference in cost of production is mainly attributed to variation in the proportion of milk solids utilized for different methods of drying, which alone contributed 60.8 per cent of the total cost. Again costlier and sophisticated machineries viz. spray drier and vacuum evaporator employed in the production of spray dried product increased the capital investment in spray drying plant. Even through spray dried product is little more costly, it was rated superior both for physico-chemical and sensory qualities. A superior quality product always commands a better market price and hence the difference is compensated.

Economics for a pilot plant producing 1000 kg spray dried sapota-milk beverage powder is given in Appendix-VI.

5.1.4.15 Moisture sorption behaviour

Moisture sorption is the major factor limiting shelf-life of dehydrated products. Sorption isotherm of spray, roller and cabinet dried products were sigmoid in shape (Fig. 5.10). Brunauer *et al.* (1938) categorised sigmoid shaped curves under Type II and the products exhibiting such curves under medium hygroscopic products.

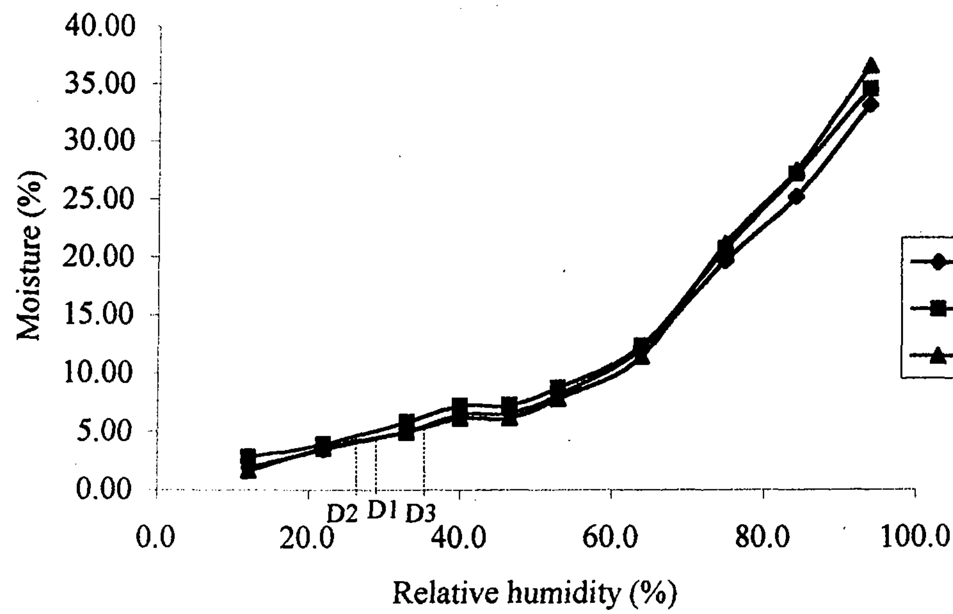


Fig. 5. 10. Moisture sorption isotherms for dehydrated products

Moisture sorption isotherms of spray dried orange juice (Brennan, 1971), freeze dried pineapple juice powder (Kumar *et al.*, 1981) and spray and roller dried buffalo milk based infant milk food (Kumar and Venugopal, 1991) were also sigmoid shaped.

According to Labuza (1984) the sorption isotherm can be divided into three regions. In the first region where water activity is below 0.2, moisture is bound with the material by chemi-sorption and adsorption. Above this in the second region, hydrophilic macromolecular components adsorb moisture, thus increasing the equilibrium moisture content and in the third region, moisture fills up the pores with in the material structure.

Cabinet dried product recorded highest equillibrium moisture content (EMC) upto 64 per cent RH while spray dried product recorded the lowest. But above 64 per cent relative humidity, spray dried product showed the highest EMC. Since the cabinet dried SMBP possessed the highest sugar content, the sugar molecules adsorbed more moisture resulting in higher EMC below 75 per cent RH. But above 75 per cent RH, moisture fills up the pores with in the material structure. Hence more porous structure that spray dried particles possess may be the reason for exhibiting higher EMC above 75 per cent RH.

A moisture content of 4.521 and 4.594 per cent and relative humidity of 31.98 and 30.55 were critical for storage of spray and roller dried product respectively whereas cabinet dried product showed a higher critical moisture per cent of 5.496 and RH of 33.63. Danger point (D) represents a relative humidity five per cent below the critical point, at which the product becomes lumpy, loosing its free flowing property. The packaging material selected should not permit the product to reach this danger point, so that there is a safe margin of error. The danger points of spray (D_1), roller (D_2) and cabinet dried (D_3) products are 30.08, 28.47 and 30.32 per cent respectively.

It was observed that all the three samples were susceptible to mould growth at 83 and 94 per cent relative humidity. Richard-Mollard *et al.* (1985) also have reported that food products when equilibrated to RH above 70 per cent generally showed mould growth.

5.1.4.16 Storage studies

Spray, roller and cabinet dried sapota-milk beverage powder were packed with N_2, CO_2, vacuum and air (control) in metallised polyester low density polyethylene laminated pouches and the changes in storage were observed.

The moisture content of beverage powder plays a significant role in the keeping quality of the product. Moisture ingress was the maximum in air packed samples and consequently non-enzymatic browning also showed the highest value in the same. Hall and Hedrick (1971) reported that discolouration will progress rapidly if the moisture content of the powder is high and similar was the result in the present storage studies.

Higher moisture content observed in nitrogen and carbon dioxide packed samples over vacuum packed samples may be due to small amounts of moisture inherent with the gas. Browning during storage is attributed to the reaction between free amino groups and reducing sugar and to delay this reaction the moisture ingress should be kept the minimum.

The fat when released from the lipo-protein membrane is referred to as free fat and has significant role in promoting oxidation. Free fat formed during storage was the minimum in nitrogen packed samples showing that N_2 has some inhibitory action on release of free fat. Love and Dugan (1978) reported that below the monolayer value (a_w 0.11) greater lipid oxidation occurred in neutral lipids and phospholipids of air packed samples than in N_2 packed samples with loss of soluble proteins and reducing sugars in instant navy bean powder stored at accelerated temperture.

Similar to the results obtained in the present study, Sharma *et al.* (1974) also reported that with increase in storage period more and more coalescence of the fat took place which resulted in the liberation of the fat in free form in stored mango-milk powder. Mahajan *et al.* (1979) justified it by stating that increase in free fat during storage may be due to the expansion of dispersed air cells in the dried particles which resulted in rupture of already weakened fat globule membrane. Mrithyunjaya and Bhanumurthi (1987) attributed this to storage temperature and opined that increase in free fat was observed as some of the low melting glycerides would be in a liquid state at room temperature (30 ± 1°C). This increase in free fat content on storage is one aspect that needs detailed investigation. Again the profound influence of nitrogen packing is to be probed at length.

Rancid flavour was developed after a storage period of four months irrespective of the packaging method employed. According to Buma (1971) development of oxidized flavour during storage, lack of dispersibility and scum formation upon reconstitution of milk powder are the results of high free fat content.

Even though, there was no significant difference in p^H, acidity and microbial load between nitrogen, carbon dioxide and vacuum packed samples, the change in p^H was the minimum in vacuum packed samples. This may be due to minimum moisture content in vacuum packed samples.

The panel preferences showed that N_2 packed product was preponderantly preferred over other two products and this could be due to lower free fat present in N_2 packed samples as well as better appearance of the packed product. Guadagni and Dunlap (1975) also reported that N_2 packing effectively delayed the onset of deteriorative auto-oxidation reactions in commercially prepared pinto bean powder. However after four months the sensory score values showed a drastic decline, irrespective of the packaging methods employed.

To ensure better storage life for the sapota-milk beverage powder, along with nitrogen flushing, the product should be given stringent packaging with materials having very high moisture and oxygen barrier properties.

5.2 DEVELOPMENT OF TECHNOLOGY FOR BOTTLED SAPOTA-MILK BEVERAGE

Results of formulation, processing and storage of ready-to-drink bottled sapota-milk beverage are discussed hereunder.

5.2.1 Composition

In the experiment with varied fruit and milk proportions, the maximum organoleptic score value was observed with beverage containing 20 per cent skim milk and 40 per cent sapota pulp (Fig.5.11). Increase in pulp content increased the viscosity and thus affected its free flowing nature. Higher concentration of skim milk also (25%) adversely affected its consistency. Hassan and Ahammed (1998a) also reported that mango-milk beverage lost its flow-behaviour and showed high viscosity with increase in pulp content.

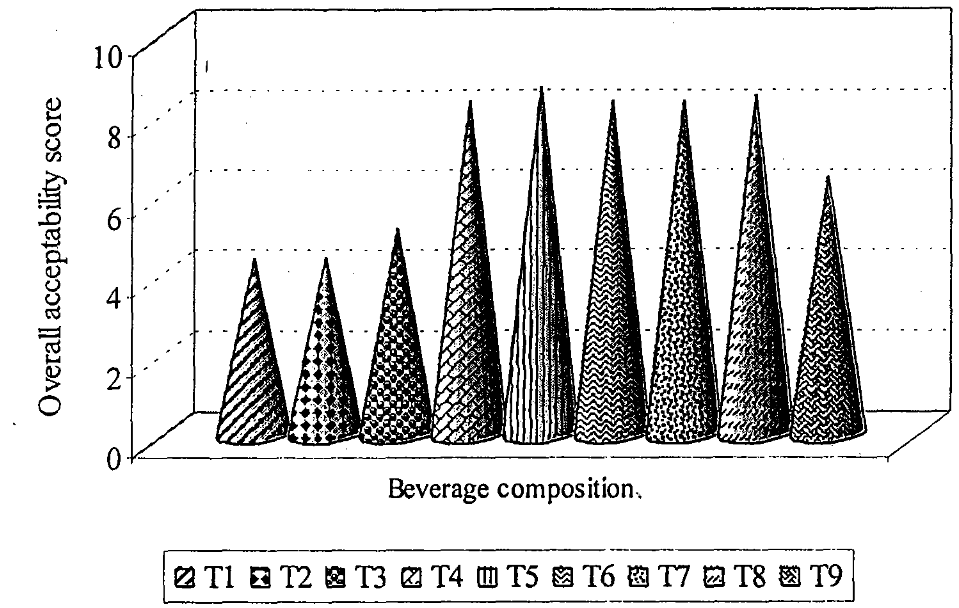


Fig. 5.11. Effect of beverage composition on overall acceptability of bottled sapota-milk beverage

5.2.2 Processing

Sapota-milk beverage with 40 per cent fruit pulp and 20 per cent skim milk was subjected to pasteurization and sterilization. The product pasteurized for 30 minutes at 85°C and stored at ambient temperature coagulated showing that high temperature treatment / sterilization as in the case of flavoured milk is necessary to make the product shelf-stable at room temperature.

But sterilization of the product at 15 psi for 20 minutes produced pink-red coloured anthocyanidin pigment making the product totally unacceptable (Plate 9). This observation is in accordance with Rege and Pai (1996) who reported that thermal processing of sapota lead to the conversion of leuco-anthocyanidins present in the fruit to anthocyanidins and rendered the product unsuitable for consumption on account of pink-red colouration and an astringent taste formation.

Pasteurization for 30 minutes at 85°C was selected as the best as the minimum microbial load was noticed in this compared to the product pasteurized for

20 minutes. Higher duration of pasteurization resulted in slight brown colour and increased sweetness, and these characters made the product organoleptically superior to the beverage pasteurized for 20 minutes. Sodium alginate added as stabilizer increased the viscosity of the beverage upon prolonged heat treatment and resulted in thicker product.

Similar to the reports of Singh and Bains (1988) increase in acidity of the beverage as well as decrease in p^H was observed in the beverage processed for 30 minutes. This could be due to release of acids from the bound form or due to chemical reaction between sugars and milk (Maillard reaction), which produced organic acids.

5.2.3 Storage

TSS and p^H of the bottled sapota-milk beverage declined and acidity increased during storage. This could be due to microbial action or due to chemical reactions between sugars and milk leading to the production of organic acids. Such a result has been reported by Hassan and Ahammed (1998a). They reported that p^H of mango-milk beverage decreased from 4.8 to 4.3 and TSS from 18 to 16.5 whereas acidity increased from 0.3 to 0.32 after six months of storage.

The microbial status of the product showed a progressive increase, but it did not show any relationship with overall acceptability. The beverage remained acceptable even after four months. Similarly, Cromie and Dommett (1989) also reported that there existed no relationship between microbial counts and flavour acceptability of stored pasteurized milk. They could neither correlate free fatty acid concentration, nor p^H with overall acceptability. According to Shroeder and Bland (1984) shelf-life of pasteurized milk is the time taken for bacterial count to reach 1×10^6 cfu ml^{-1}. In the sapota-milk beverage stored for four months the bacterial count was only about 0.9×10^6 cfu ml^{-1}. Hence it can be concluded that this pasteurized beverage under refrigerated temperature possess a shelf-life of four months.

5.3 MARKETABILITY OF VALUE ADDED PRODUCTS

The encouraging response received during the marketability study is due to the consumer preference for quality product with cheaper price, newer taste and convenience. The newly formulated sapota-milk beverage powder when put for market response study showed a wider preference even with a price of Rs.6 per 30 g pack, the quantity required to make one glass of drink.

Read-to-drink bottled product also responded positively even when priced Rs.10.00 per bottle. As pasteurized bottled beverage is very close to the fresh product unlike UHT treated beverages, it will have a good market positioning. However, the difficulty met is to handle it under cold chain. Therefore it is confirmed that this beverage, a blend of two natural, highly nutritious products, sapota and milk, without any addition of synthetic flavour or colour, will be a promise for tomorrow's health conscious consumers.

Summary

6. SUMMARY

The present investigation on "Value addition in sapota [*Manilkara achras* (Mill.) Fosberg] was undertaken at the department of Processing Technology, College of Horticulture, Vellanikkara during the period 2000-2004 and utilizing the facilities of KAU Dairy Plant, Mannuthy. The objectives were to develop appropriate production technology for instant sapota-milk beverage powder and bottled ready-to-drink sapota-milk beverage and to assess its storage stability, economics and marketability.

Technology for spray, roller and cabinet dried sapota-milk beverage powder were standardised in the drying experiments. Spray drying of the beverage mix containing 1:1 ratio of fruit and milk solids at an inlet air temperature of 185°C and maintaining the outlet air temperature at 90°C yielded best quality sapota-milk beverage powder.

Good quality sapota-milk beverage powders were obtained from roller drying of beverage mix containing sapota and milk (1% fat) in the ratio 1:0.5 with 7 rpm drum speed and 4 kg cm^{-2} steam pressure and by cabinet drying of a mix having 1:0.5 ratio of fruit to milk solids at 80°C for 4.5 hours

Spray dried product possessed superior physico-chemical and organoleptic qualities as a ready-to-reconstitute product. The product was very hygroscopic with 23.30 per cent ERH and packing in metallised low density polyethylene pouch with nitrogen flushing offered a shelf-life of four months under ambient conditions.

To make one glass of thick foamy beverage, 30 g beverage powder has to be mixed well (using mixer/blender) with chilled water. Production cost for 30 g beverage powder was worked out to be Rs 3.50 only. Even when the product was priced Rs.6 per 30 g and put for market response study a wider preference among the respondents was observed.

Technology for bottled ready-to-drink sapota-milk beverage with 20°Brix containing 40 per cent sapota and 20 per cent skim milk was also standardised in the present study. The bottled drink pasteurized at 85°C for 30 minutes possessed a shelf-life of four months under refrigerated conditions. The cost per bottle of beverage was worked out to be Rs.4.50 and in the marketability study, 90 per cent of the respondents were found ready to buy the product even at a selling price of Rs.10 per bottle.

The "natural" value added products developed here offers a great potential for industrial processing, thus ensuring price stability for sapota fruits and better returns to farmers. Moreover the beverage powder can be successfully produced in conventional milk drying plants in India without any additional investment and this natural product, with delicate sapota flavour is sure to command a better domestic as well as export market.

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 Processing Preservation* 15: 31-43

Al-Haq, M.I. and Mahyuddin, G. 1992. Commercial manufacturing of pasteurized mango fruit flavoured milk based beverages. *Pakist. J. sci. ind. Res.* 35: 420-424

Al-Haq, M.I., Mahyuddin, G., Zaidi, S.K.R. and Nassar-Abbas, S.M. 1996. Manufacture of exotic fruit flavoured milk beverage by employing UHT technique. *Pakist. J. sci. ind. Res.* 39: 1-4

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

* Andrushchenko, V.P. and Kashurin, A.N. 1990. Drying of sugar containing products by spraying. *Izvestiya-Vysshikh-Uchebnykh-Zavedenii-Pisbehevaya-Tekhnologiya* 4: 77-78

AOAC, 1975. *Official Methods of analysis.* Twelth edition. Association of Official Analytical Chemists, Washington, p.1021

AOAC, 1990. *Official Methods of Analysis.* Fifteenth edition. Association of Official Analytical Chemists, Virginia, p.850

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

Babu, D.R. and Gupta, D.K.D. 2002. Development of milk and lassi powders containg pineapple juice. Fifteenth Indian Convention of Food Scientists and Technologists, 12-13 December 2002. Central Food Technological Research Institute, Mysore. *Abstract*: 137

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

Baudach, G. 1983. Milk-shake and a process for producing it as well as a milk-shake base. *German Federal Republic Patent Application 1983* DE 30 31 254 A1

* 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, Kopenhagen. *Abstract*: 913-920

Bhandari, B.R. and Hower, T. 1999. Implication of glass transition for the drying and stability of dried foods. *J. Fd Engng* 40: 71-79

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

Bhandari, V. and Balachandran, R. 1984. Reconstitution characteristics of spray dried ice cream mix containing sodium alginate as stabilizer. Fourth Indian Convention of Food Scientists and Technologists, 7-9 June 1984. Central Food Technological Research Institute, Mysore. *Abstract*: 154

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

Bhanumurthy, J.L. 1987. Status of infant milk based foods in India. *Indian Fd Ind.* 5: 71-73

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

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

Bradly, R.L. 1995. Moisture and total solids analysis. *Introduction to Chemical Analysis of Foods* (ed. Nielsen, S.S.). Boston Jones and Barlett Publishers, England, pp.93-111

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.* 71: 295-307

Brunauer, S.P., Emmett, P.H. and Teller, E. 1938. Adsorption of gases in multimolecular layers. *J. Am. chem. Soc.* 60: 309-311

Buma, T.J. 1971. Free fat in spray dried whole milk: 1- General introduction and brief review of literature. *Neth. Milk Dairy J.* 25: 33-42

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

Bystrom, C. 1996. French counter attack against coca-cola. *NMI* 23: 175

Camacho, L., Vargas, E. and Sierra, C. 1989. Comparative nutritional and quality studies of drum drying of lupin imitation milk. *Nutr. Rep. Int.* 39: 593-603

Camacho, L., Vasquez, M., Leiva, M. and Vargas, E. 1988. Effect of processing and methionine addition on the sensory quality and nutritive value of spray dried lupin milk. *Int. J. Fd Sci. Technol.* 23: 233-240

Chadha, K.L. 1992. Strategy for optimisation of productivity and utilization of sapota [*Manilkara achras* (Mill.) Fosberg]. *Indian J. Hort.* 49: 1-17

Chandrasekhara, M.R., Aswathanarayan, S., Shurpaleskar, S.R. and Rao, B.H.S. 1969. Pilot plant production of infant food based on ground nut and milk solids. *J. Fd Sci. Technol.* 6: 267-271

Chandrasekhara, M.R., Shurpalekar, S.R., Subbarao, B.H., Kurien,S. and Shurpalekar, K.S. 1966. Development of infant foods based on soybean. *J. Fd Sci. Technol.* 3: 94-97

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

Chitra, P., Manimegalai, G. and Vennila, P. 2002. Formulation and evaluation of ready-to-use banana milk-shake powder. Fifteenth Indian Convention of Food Scientists and Technologists, 12-13 December 2002. Central Food Technological Research Institute, Mysore, *Abstract*: 48

Chopda, C.A. and Barret, D.M. 2001. Optimisation of guava juice and powder production. *J. Fd Processing Preservation* 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

Coulter, S.T. and Breene, W.M. 1967. Spray drying fruits and vegetables using skim milk as a carrier. *J. Dairy Sci.* 49: 762-767

Cromie, S.J. and Dommett, T.W. 1989. Relationships between bacterial counts and acceptability of refrigerated pasteurized milk. *Aust. J. Dairy Technol.* 44: 4-6

Dacosta, J.M.C. and Cal-Vidal, J. 1988. Caking degree of spray dried coconut milk. *Pre-concentration and drying of food materials* (ed. Bruin, S.). Elsevier Science Publishers, Amsterdam, pp.263-273

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

De, S. 1980. Outlines of Dairy Technology. Oxford University Press, New Delhi, p.539

Dengale, P.S., Kute, L.S. and Kadam, S.S. 1998. Influence of methods of extraction on recovery and quality of sapota pulp. *Bev. Fd Wld* 25: 23-24

El-shibiny, S., Abdou, S.M., El-Alfy, M.B. and Mansons, N. 1994. Preparation and properties of powdered beverage based on carrot juice and UF milk permeate. *Egyptian J. Dairy Sci.* 22: 307-317

Endres, K. and Renner, E. 1991. Studies on the optimal sugar content of shakes and driking yoghurt in the nutrition of children. *Lebensmittelindustrie-Und-Michwirtschaft* 112: 51-52

*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

Ganeshan, V. 1996. Investigations on production of coconut skim milk powder. Ph.D. thesis, Tamil Nadu Agricultural University, Coimbatore, p.104

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 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. *Abstract*: 158

Gautam, S.K. and Chundawat, B.S. 1998. Standardisation of technology of sapota wine making. *Indian Fd Packer* 52: 17-22

Geevarghese, P.I. 1996. Technological evaluation of kera ice cream. Ph.D. thesis, Kerala Agricultural University, Thrissur, p.211

George, L. 1983. Package design and shelf-life of whole milk powder in flexible packages. M.Sc. dessertation, Central Food Technological Research Institute, Mysore, p.112

Ghosh, S. and Singh, S. 1995. Development of whey based mushroom soup powder. Annual Convention of Food Scientists and Technologists (India), 7-9 September 1995. Central Food Technological Research Institute, Mysore. *Abstract*: 86

Gokavi, S.S. 2000. Physico-chemical and nutritional quality of malted cereals and milk based infant food. Ph.D. thesis, University of Mysore, Mysore, p.252

Grewal, K.S. and Jain, S.C. 1982. Studies on the feasibility of incorporating preserved mango pulp in the preparation of milk-mango shake. *Indian Fd Packer* 36: 95-97

Guadagni, O.G., Dunlap, C. and Kon, S. 1975. Effect of temperature and packaging atmosphere on stability of drum dried pinto bean powder. *J. Fd Sci.* 40: 681-683

Guleria, S.P. and Jain, S.C. 1978. Development of milk based fruit juice beverage using buffalo milk. First Indian Convention of Food Scientists and Technologists, 23-24 June 1978. Central Food Technological Research Institute, Mysore. *Abstract*: 85

Gutknecht, K.W. 1992. Healthier soft drinks. *Utah Sci.* 52: 163

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

Hassan, M. and Ahamed, J. 1998a. Physico-chemical and sensory characteristics of mango-milk beverage. *Indian Fd Packer.* 52: 32-37

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

Hayashi, H. and Kudo, N. 1989. *Effect of viscosity on spray drying of milk.* Report No.88, Technical Research Institute, Snow Brand Milk Products Company, Tokyo,p.59

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

Ibrahim, M.K.E., El-Abd, M.M., Mehriz, A.M. and Ramadan, F.A.M. 1993a. Preparation and properties of guava-milk beverage. *Egyptian J. Dairy Sci.* 21: 59-68

Ibrahim, M.K.E., El-Abd, M.M., Mebriz, A.M. and Ramadan, F.A.M. 1993b. Preparation and preservation of mango-milk beverage. *Egyptian J. Dairy Sci.* 21: 69-81

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

Ingle, G.S., Khedkar, D.M. and Dhabhade, R.S. 1981. Ripening studies in sapota fruits (*Achras sapota* L.). *Indian Fd Packer* 35: 42-45

Ingle, G.S., Khedkar, D.M. and Dhabhade, R.S. 1982. Physico-chemical changes during growth of sapota fruits (*Achras sapota* L.). *Indian Fd Packer* 36: 86-94

Jagtiani, D.J. 1988. *Fruit Preservation.* Vikas Publishing Company, New Delhi, p.274

Javalagi, A.M. and Vaidehi, M.P. 1986. Protein and energy content of acceptable beverages prepared with blends of soya, skim milk, sesame, coconut and malts from wheat, ragi and green gram. *Beverage Fd Wld 11*: 35-38

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

Jha, A. and Mann, R.S. 1995. Studies on the formulation of ready-to-reconstitute tea complete powder. *Indian J. Dairy Sci.* 48: 681-686

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

Kalpalathika, P.V.M. 1984. Studies on strained baby foods made from certain tropical fruits and vegetable pulp. Ph.D. thesis, University of Mysore, Mysore, p.308

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

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

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. *Abstract*: 87

Kulkarni, S. 1998. Scope and opportunities for processing of milk and milk products for domestic and export market. *Bev. Fd Wld* 23: 71-73

Kumar, H.S.P., Jayathilakan, K. and Vasundhara, T.S. 1981. Factors affecting the quality of freeze dried pineapple juice powder. *Indian Fd Packer* 45: 5-11

Kumar, K.R. and Venugopal, J.S. 1991. Moisture sorption behaviour of infant milk food formulations. *Indian J. Dairy Sci.* 44: 632-638

Labuza, T.P. 1984. *Moisture sorption: Practical Aspects of Isotherm Measurement and Use.* American Association of Cereal Chemists, St. Paul, p.82

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

Lazar, M.E. and Miers, J.C. 1971. Improved drum dried tomato flakes produced by a modified drum drier. *Fd Technol.* 25: 72-74

Lazar, M.E. and Morgan, A.I. 1965. Instant fruit flakes. *Fd Processing.* 26: 72-75

Lazar, M.E., Brown, A.H., Smith, G.S., Wong, F.F. and Lindquist, F.E. 1956. Experimental production of tomato powder by spray drying. *Fd Technol.* 17: 129-133

Lim, S.D., Kim, K.S., Park, D.J., Kang, T.S., Lee, N.H. 1994. Effect of packaging conditions on the quality of dried whole milk: Changes in physico-chemical properties during storage. *Korean J. Anim. Sci.* 36: 90-99

Love, M.H. and Dugan, L.R. 1978. Physico-chemical assessment of shortterm changes in the quality characteristics of stored instant navy bean powder. *J. Fd Sci.* 43: 89-91

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., Balasubrahmanyam, N., Indiramma, A.R., Raj, B. and Desikachur, S.R. 1989a. Packaging and storage studies on malted ragi and green gram based weaning food. *J. Fd Sci. Technol.* 26: 68-71

Malleshi, N.G., Daodu, M.A. and Chandrasekhar, A. 1989b. 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. ASAE, Saskatchevan, Canada, *Abstract*: 168

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

Mizrahi, S., Berk, Z. and Cogan, U. 1967. Isolated soybean protein as a banana spray drying aid. *Cereal Sci. Today* 12: 322-325

Mrithyunjaya, N. and Bhanumurthi, J.L. 1987. Shelf-life of laminate and tin packed whole milk powder. *Indian J. Dairy Sci.* 40: 78-81

Nanjundaswamy, A.M. and Sethy, G.R. 1989. Advances in dehydration process for fruits, vegetables and their products. *Trends in Food Science and Technology* (eds. Rao, M.R.R., Chandrasekhara, N. and Ranganath, K.A.). Proceedings of Second International Food Convention, 1-8 February 1988. Association of Food Scientists and Technologists (India), Mysore, pp.369-375

Nakaya, T., Karasawa, T., Kihara, N., Wada, Y. and Kiyota, M. 1991. Milk-shake and manufacturing thereof. *United States Patent 1991* US 4 988 529

Nanjundaswamy, A.M. 1984. Studies on preparation of dehydrated products from tropical fruits and their pulps. Ph.D. thesis, University of Mysore, Mysore, p.152

Negi, J.P. and Mitra, L. 2001. *Indian Horticulture Database.* National Horticulture Board, Guargon, p.155

Nishiyama, K. 1982. Method for making milk containing fruit juice. *Japanese Examined patent 1982* JP 57 38 220 B2

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

Pandurang, M.K. 1996. Recent developments in fruit juice powders. M.Sc. thesis, University of Mysore, Mysore, p.98

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

Patil, D.L. and Magar, N.G. 1976. A comparative study on chemical examination of banana powders prepared by different methods. *Indian J. Nutr. Dietetics.* 13: 218-225

Perez-Munoz, M.F. and Flores, R.A. 1998. Effect of storage time on solubility and colour of spray dried soy milk. *J. Fd Protection* 61: 231-234

Phahar, W.A. and Leung, H.K. 1985. Storage stability of dehydrated and soy fortified fermented maize meal. *J. Fd Sci.* 50: 182-184

Planovskii, A.A. and Golovach, V.P. 1988. Manufacture of dried skim milk with apple juice. *Molochnaya-I-Myasnaya-Promyshlennost* 3: 20-21

Piesecky, J. 1980. Bulk density of milk powders. *Australian J. Dairy Technol.* 33: 106-111

Plummer, D.T. 1979. *An Introduction to Practical Biochemistry.* Second edition. Tata Macgraw Hill Company, New Delhi, p.159

Prakash, O., Goyal, S.K. and Singh, J. 1990. Physico-chemical properties of spray dried and roller dried whole milk powders made from goat milk. *Indian J. Anim. Sci.* 60: 369-372

Rajorhia, G.S. 1989. Innovative technologies for the manufacture of khoa powder and gulabjamun mix. *Indian Dairyman* 41: 31-33

Rajorhia, G.S. and Pal, D. 1988. Influence of flexible packages on storage quality of gulabjamun mix powder. Second International Food Convention and Exhibition, 18-23 February 1988. Central Food Technological Research Institute, Mysore, *Abstract:* 147

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. *Abstract*: 49

Ramesh, K., Singh, J. and Goyal, G.K. 1993. Effect of stabilizers on heat stability of coffee flavoured drink during sterilization process. *Indian J. Anim. Sci.* 63: 785-786

Ranganna, S. 1986. *Manual of Analysis of Fruit and Vegetable Products.* Tata McGraw Hill Publishing Company, New Delhi, p.2240

Rao, B.V.R. and Mathur, B.N. 1987a. Development of a pre-term infant formula: Part I. Effect of forewarming temperature on physical characteristics. *Indian J. Dairy Sci.* 40: 249-253

Rao, B.V.R. and Mathur, B.N. 1987b. Processing changes during manufacture of a spray dried infant formula: Electrophoretic and ion exchange chromatographic behaviour of casein. *Indian J. Dairy Sci.* 40: 398-403

Rao, H.G.R. and Gupta, M.P. 2000. Development of spray dried orange juice blended skim milk powder. National Conference on Sustainable Food Production, 22 March 2000. College of Veterinary and Animal Sciences, Mannuthy. *Abstract*: 97

Rege, A.R. and Pai, J.S. 1999. Thermal processing of sapota. *Indian Fd Packer* 53: 37-42

Rehman, A., Al-Haq, M.I. and Mahyuddin, G. 1992. Development of pasteurised banana-milk based beverages using cow and buffalo milk. *Pakist. J. sci. ind. Res.* 35: 250-254

Renard, A.C. 1998. Milk with fruit juice: finding a good market positioning. *Revue Laitiere Francaise* 581: 12-13

Richard-Mollard, D., Lesage, L. and Cahagnier, B. 1985. Effect of water activity on mold growth and mycotoxin production. *Properties of Water in Foods*, (eds. Simalos, D. and Multon, J.L.). Martinus Nijoff Publishers, Boston. pp.273-292

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

Roos, Y. and Karel, M. 1991b. Water and molecular weight effects onglass transitions in amorphous carbohydrates and carbohydrate solutions. *J. Fd Sci.* 56: 1676-1681

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

Sadasivam, S. and Manickam, A. 1996. *Biochemical Methods*. Second edition. New Age International Limited, New Delhi, p.256

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

Salooja, M.K. and Balachandran, R. 1988. Physical properties of spray dried malted milk powder. *Indian J. Dairy Sci.* 41: 456-461

Samah, B.N., Goyal, G.K. and Singh, J. 1989. Influence of atmospheric and vacuum roller drying systems on the physico-chemical properties of buffalo whole milk powder. *Egyptian J. Dairy Sci.* 17: 359-372

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

Selvaraj, Y. and Pal, D.K. 1984. Changes in chemical composition and enzyme activity of the sapodilla (*Manilkara zapota* L.) cultivars during development and ripening. *J. hort. Sci.* 59: 275-281

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, *Abstract*:87

Shah, R.K., Prajapati, J.B. and Dave, J.M. 1987. Packaging materials to store a spray dried acidophilus malt preparation. *Indian J. Dairy Sci.* 40: 287

Sharma, A., Shulka, F.C. 1998. Development of a beverage using milk byproducts and fruit juices. Fourth International Convention of Food Scientists and Technologists, 23-27 November 1998. Central Food Technological Research Institute, Mysore. *Abstract*: 195

Sharma, A.K. and Gupta, S.K. 1978. Manufacture of milk-shake. *Indian Dairyman* 30: 585-586

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

Shikamony, S.D. and Sudha, M. 2003. Lucrative export possibilities. *Survey of Indian Agriculture 2004* (ed. Ram, N.). National Press, Chennai, pp.122-125

Shroeder, M.J.A. and Bland, M.A. 1984. Effect of pasteurization on shelf life and sensory quality of asceptically packaged milk. *J. Dairy Res.* 51: 569-571

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

Siegel, S. 1956. *Non-parametric Statistics for Behavioural Sciences.* McGraw Hill Kogahusha Limited, New Delhi, p.193

Singh, S. and Singh, S. 1996. Effect of whey concentration on the quality of whey based mushroom soup powder. *Mushroom Res.* 5: 33-37

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. *Abstract*: 143

Singh, T. and Bains, G.S. 1982. A process for milk beverage incorporating grain extractives. First International Conference (Ahara-1982), Central Food Technological Research Institute, Mysore. *Abstract*: 88

Singh, T. and Bains, G.S. 1988. Grain extract-malt beverages, Processing and physico-chemical characteristics. *J. Fd Sci.* 53: 1387-1390

Singh, W. and Kapoor, C.M. 1993. Whey-jeera beverage. Third International Food Convention, 7-12 September 1993. Central Food Technological Research Institute, Mysore. *Abstract*: 80

Sommer, H.H. 1951. *Theory and Practice of Ice-cream Making.* Sixth edition. The Olsen Publishing Company. Wisconsin, p.364

Sood, V.C. and Srinivasan, M.R. 1975. Manufacture and freezing characteristics of spray dried ice cream mix. *J. Fd Sci. Technol.* 12: 15-18

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. *Abstract*: 102

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

Sulladmath, U.V. and Reddy, M.A.N. 1990. Sapota. *Fruits: Tropical and subtropical* (eds. Bose, T.K. and Mitra, S.K.). Naya Prokash, Calcutta, pp.565-591

Suryanarayana, V. and Goud, P.V. 1984. Effect of post-ethrel treatment on ripening of sapota fruits. *Andhra agric. J.* 31: 308-311

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

Thapa, M.J. 1980. Some studies on the osmotic dehydration of sapota - an investigation. M.Sc. dissertation, Central Food Technological Research Institute, Mysore, p.106

Tirumalesha, A. and Jayaprakash, H.M. 1997. Storage stability of spray dried ice cream mix prepared from the admixture of whey protein concentrate and butter milk solids. *Indian J. Dairy Biosci.* 8: 23-27

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 - A in Guatemala, *Nutr. Res.* 21: 61-70

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

Wewala, A.R. 1990. *Manipulatum of Water activity: An Important Aspect of Extending Shelf-life of Whole Milk Powder.* Report No. 82. New Zealand Dairy Research Institute, Palmerston North, New Zealand, p.16

Wheeler, R.J. and Gillies, A.J. 1973. Banana milk - A milk fruit food. *Aust. J. Dairy Technol.* 28: 96-99

Yousif, A.K., Alghani, A.S., Hamad, A. and Mustafa, A.I. 1996. Processing and evaluation of date juice-milk drink. *Egyptian J. Dairy Sci.* 24: 277-288

* Originals not seen

Appendices

APPENDIX-I

Sensory Score Card for Reconstituted Beverage Powder

Sample No.	Colour	Flavour	Consistency	Overall acceptability
1				
2				
3				
4				

You have been provided with reconstituted sapota beverage powder. Please do evaluate the drinks using the scores given below:

Colour

Quality parameters	Score
Creamish brown	5
Brown	4
Cream	3
Creamish white	2
Milky white	1

Flavour

Quality parameters	Score
Sapota with milk	5
Sapota	4
Milky	3
Cooked/caramelized	2
Flat	1

Consistency

Quality grades	Score
Thick milk-shake like	5
Thin milk-shake like	4
Fruit juice like	3
Milk like	2
Watery	1

Overall acceptability

Quality grades	Score
Highly acceptable	5
Moderately acceptable	4
Acceptable	3
Just acceptable	2
Not acceptable	1

Name:
Designation:

Signature:

APPENDIX-II

Sensory score card for stored sapota-milk beverage powder

Sample No.	Colour	Flavour	Texture	Overall acceptability

You have been provided with sapota-milk beverage powder. Please evaluate the product for various qualities using the scores as given below

Quality grade	**Score**
Highly acceptable	5
Moderately acceptable	4
Acceptable	3
Just acceptable	2
Not acceptable	1

Name: **Signature:**

APPENDIX-III

Machineries used in the production of spray, roller and cabinet dried SMBP

1. Spray drying

Sl. No.	Machinery	Cost (Rs)	Working time (min)	Depreciation (@ 10%)	Interest (@ 12%)
1	Spray drier (15 kg H_2O/hr)	15 lakhs	60	17.127	20.5524
2	Vacuum evaporator	2.5 lakhs	20	0.9515	1.418
3	Homogeniser	26,000	20	0.0990	0.1188
4	Cream separator	35,000	15	0.0999	0.1999
5	Steam processing vats	30,000	30	0.1713	0.2055
6	Steam boiler	2.5 lakhs	60	2.8545	3.425
7	Packaging machine	1,50,000	20	0.2855	0.3425
8	Mini pulveriser	10,000	10	0.0190	0.0228
			Total	21.6077	26.2049

2. Roller drying

Sl. No.	Machinery	Cost (Rs)	Working time (min)	Depreciation (@ 10%)	Interest (@ 12%)
1	Roller drier	5.5 lakhs	60	6.2799	7.5359
2	Homogeniser	26,000	20	0.0990	0.1188
3	Cream separator	35,000	15	0.0991	0.1200
4	Steam processing vats	30,000	30	0.1713	0.2055
5	Steam boiler	2.5 lakhs	60	2.8545	3.4254
6	Mini pulveriser	10,000	30	0.0571	0.0685
7	Packaging machine	1.5 lakhs	10	0.2855	0.3425
8	Hot air oven	50,000	60 min	0.5709	0.6851
			Total	10.4173	12.5017

3. Cabinet drying

Sl. No.	Machinery	Cost (Rs)	Working time (min)	Depreciation (@ 10%)	Interest (@ 12%)
1	Cabinet dryer	50,000	360	3.4254	4.11
2	Mini pulveriser	10,000	30	0.0571	0.0685
3	Packing machine	1.5 lakhs	10	0.2855	0.3425
			Total	3.7680	4.521

APPENDIX-IV

Sensory score card for ready-to-drink sapota-milk beverage

Sample No.	1	2	3	4
Colour				
Flavour				
Texture				
Overall acceptability				

Please do evaluate the product by giving the scores corresponding to the quality grades as given below

Quality grades	Score	Quality grades	Score
Like extremely	9	Dislike slightly	4
Like very much	8	Dislike moderately	3
Like moderately	7	Dislike very much	2
Like slightly	6	Dislike extremely	1
Neither like nor dislike	5		

Name: **Signature:**

APPENDIX-V

Questionnaire for Market Survey of Sapota-Milk Beverage Formulations

You have been provided with a newly developed sapota-milk beverage for assessing the acceptability. Kindly spare your valuable few minutes to answer the following questions. Please tick () mark against your answer.

1. Are you habituated with instant soft drinks / synthetic beverage / cool drinks …….. Yes / No
2. If so, how frequently …. Nos. … / day / week / month
3. Of which whether you prefer natural cold drinks / synthetic beverages
4. Have you any time tried sapota milk-shake from juice vents ….. Yes / No
5. If so how much you enjoyed ….. liked very much / moderately liked / just liked / never liked
6. How you rated the natural products provided before you?

   a) Instant sapota-milk beverage powder ……. Liked extremely / Liked moderately /Just liked / Disliked

   b) Bottled sapota-milk beverage ……… Liked extremely / Liked moderately / Just liked / Disliked

7. What is your price expectation of these products?

   a) Instant sapota-milk beverage powder ………..

   b) Bottled sapota-milk beverage ……….

8. If these natural products are available in the market at the following price, will you prefer to buy these items?

   a) Instant sapota-milk beverage powder @ Rs.20/100 g ……….Yes / No

   b) Bottled sapota-milk beverage @ Rs.10/200 ml bottle ……….Yes / No

Name:
Designation: Signature:

APPENDIX-VI

Economics for a pilot plant producing 1000 kg spray dried sapota-milk beverage powder
(Assuming that plant is working for 16 h continuously in two shifts)

Sl. No.	Item	Quantity	Rate (Rs.)	Amount (Rs.)	Total (Rs.)
I	Raw materials 1. Sapota pulp 2. Milk 3. Emulsifier & stabilizer 4. Sugar	 1749 kg 4760 kg 7.695 g 241.4 kg	 2.0/kg 13.0/litre 0.25/g 16/kg	 34980 61880 1923.75 3862.4	1,02,646.15
II	Fuel charges 1. Diesel 2. Electricity	 48 l 2000 units	 22/l 3/unit	 1056 6000	7056
III	Labour charge (per month) 1. Manager 2. Shift supervisor 3. Processing Associates 4. Unskilled labour 5. Administrative Assistant	 1 2 4 4 2	 9000 6000 5000 3000 3500	 9000 12000 20000 12000 7000	2000
IV	Land & Buildings			15 lakhs	
V	Machinery & Accessories			85.5 lakhs	
VI	Depreciation of machineries @10%*				1169.52
VII	Interest on fixed capital @12%				3304.12
VIII	Interest on working capital @ 12%				36.72
Total cost of production		116212.51			
Cost per 1 kg of spray dried product		116.20			

*Cost of machineries involved in spray drying

Sl. No.	Machinery	Cost (Rs.)
1	Spray drier (150kg H_2O/h)	50 lakhs
2	Vacuum evaporator	10 lakhs
3	Homogeniser	5 lakhs
4	Cream separator	50,000
5	Steam processing vats	3 lakhs
6	Steam boiler	5 lakhs
7	Packaging machine	1.5 lakhs
8	Mini pulveriser	50,000
	Total	85.5 lakhs

APPENDIX-VII

Cost of machinery used in sapota-milk beverage preparation

Sl. No.	Machinery	Cost (Rs.)
1	Cream separator	35,000
2	Top loading cooler	20,000
3	Crown cork sealing machine	2,000
4	Blender	5,000
5	Accessories	2,500
	Total	64,500

VALUE ADDITION IN SAPOTA
[*Manilkara achras* (*Mill.*) *Fosberg*]

By

T. MAYA

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Horticulture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Processing Technology

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2004

ABSTRACT

A study on "Value addition in sapota [*Manilkara achras* (Mill.) Fosberg] was conducted with an objective to develop appropriate production technology for instant sapota-milk beverage powder and bottled ready-to-drink sapota-milk beverage.

Technology for spray, roller and cabinet dried sapota-milk beverage powder was standardised in the drying experiments. Spray drying beverage mix containing 1:1 ratio of fruit and milk solids at an inlet air temperature of 185°C keeping the outlet at 90°C gave the best quality beverage powder, with superior physico-chemical and organoleptic qualities. The product was very hygroscopic with 31.3 per cent ERH, hence requiring stringent packaging. However, metallised low density polyethylene packs and nitrogen flushing assured a shelf-life of four months for the beverage powder under ambient conditions.

To make one glass pleasantly flavoured fruit-milk drink, 30 g beverage powder has to be mixed well with chilled water and for a thicker shake mixer/blender can be used. Cost of production per 30 g was worked out to be Rs.3.50. The beverage powder when put for market response study showed a wider preference even with Rs.6 per 30 g.

Technology for bottled ready-to-drink sapota-milk beverage with 20°Brix containing 40 per cent sapota and 20 per cent skim milk was standardised in the present study. The bottles when pasteurized at 85°C for 30 minutes possessed a good shelf-life of four months under refrigerated condition. The cost per bottle was worked out to be Rs.4.50 and almost 90 per cent consumers were found quite ready to buy the product even at a price of Rs.10 per bottle.

The “natural” value added products developed here offers a great potential for industrial processing, thus ensuring price stability for sapota fruits and better returns to farmers. The sapota-milk beverage powder can be successfully produced in conventional milk drying plants in India without any additional investment and this natural product, with delicate sapota flavour is sure to command a better domestic as well as export market. As the pasteurized bottled sapota-milk beverage is very close to the fresh product unlike UHT treated beverages, it will also have a good market positioning. However, the difficulty met is to handle the bottles under cold chain. Therefore it is confirmed that these natural, highly nutritious beverage formulations, without any addition of synthetic flavour or colour, will be a promise for tomorrow’s health conscious consumers.