DEVELOPMENT OF PROCESS PROTOCOL FOR BANANA FLOUR

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KERALA, INDIA

2014

DECLARATION

We hereby declare that this project report entitled “DEVELOPMENT OF PROCESS PROTOCOL FOR BANANA FLOUR” is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this project report, entitled, **"DEVELOPMENT OF PROCESS PROTOCOL FOR BANANA FLOUR"** is a record of project work done jointly by Ms. Dhanasree B, Ms. Sneha Sukumaran and Mr. Vithu Prabha under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, associateship or other similar title of any other University or Society.

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SYMBOLS AND ABBREVIATIONS

%	percentage
=	equal to
±	plus or minus
et al.,	and others
etc.	etcetera
FAOSTAT	Statics division of FAO
Fig.	figure
g	gram(s)
h	hour(s)
i.e.	that is
KCAET	Kelappaji College of Agricultural Engineering and Technology
KAU	Kerala Agricultural University
kg	kilogram
$kgcm^{-2}$	kilogram per square centimetre
mg	milligram
min	minute(s)
ml	millilitre
MT	metric tons
MT/ha	metric ton per hectare
NHB	National Horticulture Board
NIIR	National Institute of Industrial Research
^{o}B	degree Brix
^{o}C	degree Celsius
rev/min	revolutions per minute
RH	relative humidity
sec	second(s)

S	significant
SD	Standard Deviation
TSS	total soluble solids
USDA	United States Department of Agriculture
viz.	namely
w.b	wet basis
wt.	weight
w/w	weight by weight

Dedicated to our parents

And

The God Almighty...

CHAPTER 1
INTRODUCTION

Fruits and vegetables are important supplements to the human diet as they provide essential minerals, nutrients including vitamin C, vitamin K, foliate, thiamin, carotene, dietary fibre and antioxidant phyto-compounds required for maintaining health. They are easily digested and exercise a cleansing effect on the blood and digestive tract (Nirmala, 2010). In the recent years, demand for both fresh and processed fruits and vegetables have been substantial and this trend is likely to continue in future. The increasing demand can be regulated by either increasing their production or by adapting suitable processing techniques for its preservation.

Among the fruits, banana is the fifth largest agricultural commodity in the world. In India, banana holds the first position in production and productivity among fruits with 29780 MT and 35.9 MT/ha respectively (NHB, 2011). Banana covers 13% of the total area under total fruit area, contributing nearly one third of total fruit production in the country. The highest productivity noted was 65.8 MT/ha in Tamil Nadu followed by Maharashtra (52.5 MT/ha) in the year 2010-2011 (NHB, 2011).

Banana is a cheap source of carbohydrate and rich source of potassium, calcium, antioxidants and other micro nutrients. The greener, less ripe bananas contain higher levels of starch and, consequently, have a "starchier" taste. The sugar rich and low fat bananas have varied uses as infant food, functional food, dessert, carbohydrate based staple food and many more diversified food or feed uses (Mohapatra *et al*., 2009). But this fruit is highly perishable owing to its higher water content and it is susceptible to many diseases, especially fungal infection. It has many health benefits; its high potassium serves as electrolytes, which regulate heart functions, blood pressure and maintains fluid balance. Potassium also protects the body against strokes and heart diseases. Banana’s soluble fibre known as pectin, helps the body maintain healthy bowel movements, reduces peptic ulcers, and helps lower cholesterol.

In many places there is significant loss of the food value of banana due to improper post-harvest management practices that causes huge economic loss. Post production losses of banana can be reduced by adopting various post-harvest management practices like cleaning, sorting, pre-storage treatments etc. that are currently in practice all over the world to prolong its shelf life. About 20-30% fruits can be utilized for flour processing, which is going to waste during the handling. By appropriate post-harvest technological tools we can reduce losses and increase the income of farmer's producing banana for utilization of banana production as well as profitable farming in our country. To avoid wastage, the surplus commodity should be processed and preserved properly. The selection of proper food processing technique plays a significant role in increasing the shelf life of the commodity while maintaining its nutritional aspects.

Drying, a preservation technique reduces the moisture content of banana thus prevents its spoilage. In the drying process it is essential to consider two important criteria like product characteristics and drying conditions. Product quality is of great importance in food drying. The first objective in drying is to remove moisture from the product and to stabilize it. But in food drying many other changes may occur like physico-chemical modifications that modify the overall quality of the final product. Thus, drying of banana must also preserve various quality criteria, like nutritional factors (vitamin, minerals), colour, shape and texture.

Banana flour is a powder made from processed bananas. The plantain flour has a good potential for use as a functional agent in bakery products on account of its high water absorption capacity, the banana flour contains low gluten, so it could not be used as main material. It is used as a component for production of milk shakes and baby foods, cakes, biscuits etc. Banana flour contains high per cent of starch hence it is used for the formulation of nutritious weaning mixes and supplementary foods. For the preparation of banana flour, unripe bananas are used. The fruits are harvested at three-quarters the full ripe stage and are processed within 24 h prior to the onset of ripening. If less mature fruits are used, the flour may taste slightly astringent and bitter due to the tannin content (Dauty, 1995).

Banana powder, because of its high concentration of banana essence, has been found to be a "major source of carbohydrate and calories". While it is generally low as a source of protein, the beneficial ingredients of the powder are still "markedly superior to that of other fruits". The powder has also been found to be useful as a general treatment for dyspepsia (indigestion). In 1984, scientists from India were able to extract "anti-ulcer compounds" found in banana powder, which ended up creating a type of powder that was "300 times more active" in preventing ulcers in the stomach. It was later discovered that the banana powder also increased cell growth, which allowed more rapid healing of the area where ulcers had previously occurred.

With this point of view, a project was undertaken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to study the effects of drying and pretreatments on quality retention of banana flour with the following objectives-

1) Standardisation of drying parameters for banana flour production
2) Shelf life studies of packed banana flour
3) Analysis of quality parameters of banana flour

CHAPTER 2
REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various research workers related to the present studies that gives the general information on banana, its physiochemical characteristics, drying and flour optimization and its storage studies.

2.1 Banana (*Musa paradisiaca*)

2.1.1 History and distribution

Historical report suggest banana as a native of the Papua, New Guinea. Bananas are a common herbaceous plant of the genus *Musa* (Arvanitoyannis, Mavromatis *et al*., 2008). Many species of bananas were traded over the last few centuries, and bananas are now cultivated in more than hundred countries around the world (Arvanitoyannis, *et al*., 2008). Among all the production countries, India, Brazil, Ecuador, Philippines, and China are the top 5 banana producers in the world (FAOSTAT, 2012). Major banana producing states in India are Tamil Nadu, Maharashtra, Karnataka, Kerala, Gujarat, Andhra Pradesh, Assam and Madhya Pradesh. Among this Tamil Nadu is the major banana producing state with 125.4 ha cultivating area and a productivity of 65.8 MT/ha (NHB, 2011).

2.1.2 Botanical aspects

Banana plants are monocotyledonous perennial and important crop in the tropical and subtropical world region (Valmayor *et al*., 2000). Banana fruits grow in clusters hanging from the top of the plant. The fruit is variable in size, color and firmness, but is usually elongated and curved, with soft flesh rich in starch covered with a rind which may be green, yellow, red, purple, or brown when ripe. Depending upon cultivar and ripeness, the flesh can vary in taste from starchy to sweet, and texture from firm to mushy. Both the skin and inner part can be eaten raw or cooked. The banana's flavour is due, amongst other chemicals, to isoamyl acetate which is one of the main constituents of banana oil (Marriot and Lancaster, 1996). The fruit is usually harvested at its mature but unripe stage ripens within two to seven days, thus making plantain a highly perishable crop, particularly in the overripe stage (Robinson, 1996). During the ripening process, bananas produce the gas ethylene, which acts as a plant hormone and indirectly affects the flavour. Among other things, ethylene stimulates the formation of amylase, an enzyme that breaks down starch into sugar, influencing the taste of bananas. The greener, less ripe bananas contain higher levels of starch and, consequently, have a "starchier" taste. On the other hand, yellow bananas taste sweeter due to higher sugar concentrations. Furthermore, ethylene signals the production of pectinase, an enzyme which breaks down the pectin between the cells of the banana, causing the banana to soften as it ripens (Ogazi, 1992).

2.1.3 Varieties of Banana

Almost all modern cultivated varieties of edible bananas and plantains are hybrids and polyploid of two wild, seeded banana species, *Musa acuminate* and *Musa balbisiana. Banana* plants were originally classified by Linnaeus into two groups which are called *Musa paradisiaca* those used as cooking bananas (plantains) *and Musa sapientum* those used as dessert bananas. In India banana is grown under diverse conditions and production systems. Selection of varieties therefore is based on a large number of varieties catering to various kinds of needs and situations (Valmayor *et al*., 1993). However, around 20 cultivars viz. *Dwarf Cavendish, Robusta, Monthan, Poovan, Nendran, Red banana, Nyali, Safed Velchi, Basarai, Ardhapuri, Rasthali, Karpurvalli, Karthali* and *Grandnaine,* etc. are cultivated.

2.1.4 Nutrient composition

Bananas are healthy fruits with high energy but low fat. Every 100 g fresh weight of ripe bananas contains 22.84 g carbohydrate and only 0.3 g total lipid. Therefore bananas are a preferred fruit in healthy diet (Aurore *et al.*, 2009; USDA, 2012).

Bananas are also a good source of several; vitamins and minerals that will help to meet the recommended daily intake. It contains vitamins A, B, C and E, as well as potassium, phosphorous, iron, calcium, etc. in 100 g of fresh banana 0.4 mg of vitamin B_6 (Theodoratou *et al*., 2008). Every 100 g of fresh weight of banana contain 358 mg potassium (Aurore *et al*., 2009). Variation in nutrient composition of fresh banana has also been reported (Table 2.1).

2.1.5 Post harvest utility

Matured green bananas can be stored for up to three weeks in ethylene free air or up to six weeks in a controlled atmosphere at 14°C and 90-95% relative humidity. The ripe banana is utilized in a multitude of ways in the human diet, from simply being peeled and eaten out of hand to being sliced and served in fruit cups and salads, sandwiches, custards and gelatins, being mashed and incorporated into ice-cream, bread, muffins and cream pies (Adeniji *et al*., 2006). Unripe banana or plantain may be thinly sliced vertically or transversely for preparing banana chips (Berg *et al*., 1971).Banana or plantain flour, or powder is made domestically by sun drying slices of unripe fruits and pulverizing (Anon, 1999). The flour can be mixed 50:50 with wheat flour for making cup cake. Banana flour can also be used as an infant food (Dimirel and Torhan, 2003).

2.2 Drying

2.2.1 Pretreatments

Pretreatment have been used commercially to accelerate the drying of fruits. Dipping fruits for several seconds in pretreatment solutions greatly reduces the drying time (Radler, 1964; Bolin *et al*., 1975). They are applied to the surface of the fruit by dipping; resulting in a coating which apparently breaks down the cuticular fruit surface, resulting in a reduced resistance to moisture loss and this increases the drying rate (Ponting and Mc Bean, 1970). Pretreatment in banana prevents discolouration by oxidation, keep a fresher colour, have a more pliable texture help retain vitamins A and C and in most cases accelerate the rate of drying.

Table 2.1 Nutritional value per 100 g raw banana

(Marriot and Lancaster, 1983; Aurore *et al*., 2009; Theodoratou *et al*., 2008)

Energy	371 kJ
Carbohydrates	22.84 g
Sugars	12.23 g
Dietary fiber	2.6 g
Fat	0.33 g
Protein	1.09 g
Thiamine (vit. B_1)	0.031 mg
Riboflavin (vit. B_2)	0.073 mg
Niacin (vit. B_3)	0.665 mg
Pantothenic acid (B_5)	0.334 mg
Vitamin B_6	0.4 mg
Folate (vit. B_9)	20 µg
Choline	9.8 mg
Vitamin C	8.7 mg
Iron	0.26 mg
Magnesium	27 mg
Manganese	0.27 mg
Phosphorus	22 mg
Potassium	358 mg
Sodium	1 mg
Zinc	0.15 mg

Doymaz *et al*. (2005) reported that citric acid or lemon juice may also be used as anti-darkening and anti-microbial pretreatments. Such pretreatment breaks the waxy cuticular fruit surface, resulting in reduced resistance to moisture and thereby increases the drying rate.

Blanching involves subjecting raw commodities to boiling or near boiling temperatures for short period (Pritty S. B; 2012). The principle function of blanching is to inactivate enzymes but the operation also partially cooks the tissue and renders the cell membrane more permeable to moisture (Lee, 1983). The process can either be carried out in water or steam.

Alzamori *et al*. (1985) studied the water soluble vitamin losses during the blanching of peas and found that blanching at higher temperatures reduces leaching loss.

Tayo (2004) analyzed the effect of blanching and ripening on functional properties of plantain (*Musa AAB*) flour and concluded that blanching considerably reduces the emulsion capacity and viscosity.

Blanching of banana at 100ºC for 10 min produces a flour of high stability against retrogradation (Fagbemi *et al.*, 2011).

2.2.2 Drying of banana

Drying is a process in which water is removed to halt or slow down the spoilage microorganism as well as the occurrence of chemical reactions. Drying of fruits and vegetables demands special attention, as this is an important unit operation which determines the retention of vitamin and minerals. Dried fruits and vegetables have become an important commercial sector in agricultural industry (Karim and Hawlader; 2005, Sudheer and Indira; 2007).

Mao *et al.* (1975) studied the drying of banana puri by drum dryer and found that a drum rotation rate greater than 2 rev/min and drum temperature less than 142°C gave the best results. Brennan *et al*., 1990 reported that air drying is one of the simplest and most economical basis of commercial processing of fruits and vegetables.

Johnson *et al*. (1998) found out that in hot air drying of plantain, enough water must be removed to lower the water activity to a level which inhibits the growth of microorganism and reduces the rate at which enzymatic and non-enzymatic reactions occur.

2.3 Banana flour

Novel way of utilizing the green banana is to process the fruit into flour form which can extend the shelf life and provide easy storage (Thompson, 1995). Banana flour is rich in starch granules and this biopolymer constitutes an excellent raw material which modifies the texture and consistency of food. Consequently banana flour appears to have some commercial potential by itself or as base material with other foods such as in baby weaning food, puddings, soups and gravies.

Thompson (1995) had found out that improved cultivars of plantain and banana may provide high quality whole flour from the entire fruit for livestock feed, which may eventually provide protein in human diet from consumption of meat and other products of livestock. Such flour may be employed in traditional dishes for human consumption based on their nutritional profiles.

Adeniji *et al.* (2006) reported that banana, plantain and cooking banana (*Musa sp)* may be processed into many products at different stages of physiological maturity; unripe, ripe, overripe or in a number of ways such as frying, grilling, boiling and drying. Morton (1987) had summarised the nutritional value of banana flour per 100 g (Table 2.2).

2.4 Storage studies

Kalpalathika *et al*. (1988) conducted storage studies on canned baby foods based on carrot and green peas. Both carrot and green pea baby foods kept well for 180 days at normal storage conditions (27°C and 65% RH), but they could be stored without much change up to 135 days under accelerated conditions (38°C and 92% RH).

Rosa *et al.* (1991) reported that vitamin A added to wheat flour was sufficiently stable during the storage under controlled conditions.

Hung *et al*. (2000) reported that chips and flour will be discoloured if anti-browning agents were not used directly or in a soaking treatment for at least 15 minutes.

Table 2.2 Nutritional value of banana flour per 100 g (Morton, 1987)

Calories (kcal)	340
Moisture (g)	11.2 - 13.5
Protein (g)	3.8 - 4.1
Fat (g)	0.9 - 1.0
Carbohydrates (g)	79.6
Fibre (g)	3.2 - 4.5
Ash (g)	3.1
Calcium (mg)	30 – 39
Phosphorous (mg)	93 – 94
Iron (mg)	2.6 - 2.7

Butt *et al*. (2004) reported that fat content of the product is a limiting factor for good shelf life of maize flour.

Abdou *et al*. (2008) found out that the colour of plantain and banana flour and chips are prone to degradation during storage, especially when they are exposed to light source, so requires appropriate packaging materials and storage medium to preserve the colour of plantain and banana during distribution and storage.

Mridula *et al*. (2009) reported that moisture content of the flour is very important for its shelf life, lower the flour moisture, the better its storage stability.

2.5 Quality characteristics

Poduval (2002) opined that quality standards are of great importance in facilitating both national and international trade. Quality of the product is determined by its chemical and nutritional composition.

2.5.1 pH and titrable acidity

pH values give a measure of the acidity or alkalinity of a product, while titrable acidity gives a measure of the amount of acid present. Assessment of pH and titrable acidity of banana, cooked banana and plantain are used primarily to estimate consumption quality and hidden attributes. They could be considered as indicators of fruit maturity or ripeness.

Dadzie and Orchard (1996) reported that acids make an important contribution to the post-harvest quality of the fruit, as taste is mainly a balance between the sugar and acid contents, hence post-harvest assessment of acidity is important in the evaluation of the taste of the fruit.

Wills *et al*. (1998) reported that acids are one of the energy reserves of the fruit, therefore theses are used in the respiration process and converted to more simple molecules such as carbon dioxide and water.

Ingham and Uljas (1999) reported that temperature and pH interact to form barriers to the survival of certain pathogens.

Marupadi *et al.* (2011) studied the enhancement of storage life in quality maintenance of papaya fruit using aloevera based anti-microbial coating. The results showed that the titrable acidity in the fruit sample decreased with the storage time in both controlled and treated fruits.

2.5.2 Total soluble solids

TSS indicates soluble solid content of banana flour, and high TSS has been associated with high sucrose content in banana pulp.

Luong *et al*. (1973) reported that the average starch content drops from 80% to 70% in the pre climacteric period to less than 1% at the end of the climacteric period, while sugars, mainly sucrose accumulate to more than 10% of the fresh weight of the fruit.

Luh and Woodrff (1975) reported that the increase in TSS during storage may be due to acid hydrolysis of poly saccharides especially gums and pectin.

Singh *et al*. (1984) determined the TSS of fruits in controlled atmosphere storage using refractometer. It was observed that TSS decreased with increase in carbon dioxide composition and storage period.

Naik *et al*. (1993) observed that TSS of tomatoes increased up to 14 days of storage in polyethylene bags and thereafter gradually decreased. The control showed very rapid decrease in TSS.

Gill *et al.* (2006) reported that fresh cut mango cubes maintained good visual quality and there were no significant change in soluble solid content.

2.5.3 Ascorbic acid

Ascorbic acid or vitamin C is the water soluble vitamin and sensitive to heat (Erdman and Klein, 1982). Vitamin C is available in a wide variety of natural products but is present in significant quantities in vegetables and fruits. Plants rapidly synthesise L-ascorbic acid from carbohydrates and the variation occur in its content due to the different species of the plants, ripeness, place of origin, storage conditions and handling (Ottaway, 1993). Ascorbic acid is a water-soluble antioxidant associated with inhibition of oxidative reactions and is a key marker compound for determining the extent of oxidation in fresh-cut vegetables and fruits (Barth *et al.*, 1993).

Dhopeshwerkar and Magar (1952) found out the per cent destruction of ascorbic acid oxidase and ascorbic acid during blanching of banana puree at different time and temperature combinations.

Shrikhande *et al*. (1976) conducted studies on thermal processing using heat sterilisation for bulk packaging of mango pulp and found that carotenoid and ascorbic acid content of fresh pulp reduced from 7.9 and 39.24 mg /100 g to 4.6 and 15.38 mg/100 g after six months of storage.

Bendich and Moser (1982) found that ascorbic acid is susceptible to heat, it is difficult to retain during the dehydration of food. The loss of ascorbic acid is depend on many factors including the presence and types of heavy metals, such as copper and iron, light, pH, water activity level in the product, dissolved oxygen and the drying temperature.

2.5.4 Colour

Colour is an important quality attribute of foods to most consumers. It is an index of the inherent good quality of foods and the association of colour with the acceptability of food in universal. Discolouration due to browning is one of the major colour related problem that is always encountered during dehydration and long term storage of dehydrated fruits and vegetables.

Visual perception of colour can be described by three variables namely, hue, value and chroma. Value (lightness) distinguishes between light colour and dark colour, hue distinguishes among red, yellow, green and blue and chroma (saturation or purity) distinguishes between vivid and dull colours. The visual perception of colour is represented by three axes value (L), hue (a) and chroma (b) of hunter calorimeter (Yeshajahu *et al*., 1996).

Wakayama *et al*. (1995) studied the effect of temperature on polyphenol oxidase activity in Japanese apple. It was found that for Fuji apple, the relative PPO activity decreased from 49 to 13% as the temperature increased from 50°C to 60°C.

Lozano and Ibarz (1997) reported that maillard condensation and oxidation of ascorbic acid are the cause of browning in fruits and their derivatives. Ascorbic acid browning is the spontaneous thermal decomposition of ascorbic acid under both aerobic and anaerobic conditions and either in the presence or absence of amino compounds.

According to Irwin (1998) colour is critically important in many dimensions of food choice and influence the perception of other sensory characteristics by the consumer. Colour is actually different wavelengths of white light and is the stimulus that result from the detection of light after it has interacted with an object. A colorimeter quantifies colour by measuring three primary colour components of light viz., red, green and blue. This is usually done by preparing a sample according to directions and comparing its colour against a reference or series of references.

Roig *et al*. (1999) reported that for enzymatic browning in fruits and vegetables enzyme polyphenol oxidase can be inactivated at temperature above 60^0C. Moreover, in citrus fruits the ascorbic acid and its isomers and derivatives act as inhibitors of enzymatic browning.

Dendy and Dobrsyk (2001) have noted that very high temperature can cause deterioration (maillard browning). Chemical and thermal treatment such as sulphating or blanching is used to control enzymatic browning by enzyme inactivation in fruit and vegetables.

2.5.5 Water activity

Water activity is defined as the ratio of vapour pressure of water in a system to the vapour pressure of pure water or the equilibrium relative humidity of the air surrounding the system at the same temperature. It is a function of moisture and temperature of food. Most fresh foods can be considered as high-moisture foods and their shelf life is largely controlled by the growth of microorganisms. High-moisture foods have an a_w of 0.90 to 0.999 and they usually contain more than 50% w/w water (Guzman *et al.*, 1974).

Eskin and Robinson (2000) reported that most bacteria, molds, and yeasts are likely to grow in high-moisture foods. However, the types of spoilage microorganisms and their species are highly dependent on both aw and pH as well as other hurdles.

Eskin and Robinson (2000) found that intermediate moisture foods (IMF) have an a_w of 0.60 to 0.90 and the water content is 10 to 50%. These foods include many traditional low-moisture foods, such as grains, nuts and dehydrated fruits and a number of processed foods. The traditional and novel IMF products consumed after dehydration included some fruit cakes/pies/puddings and pop-tarts, respectively.

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the methodology adopted for satisfying the objectives of the study on preparation of banana flour.

3.1 Banana sample collection and preparation

Matured green banana (*Musa paradisiaca*) which belongs to the AAB variety procured from the local market near K.C.A.E.T Campus, Tavanur, Malappuram district. The collected bananas were washed and peeled off and sliced into uniform size thickness (2mm) using a stainless steel banana slicer developed at KCAET Tavanur (Plate 3.1).

Plate 3.1 Banana slicer

3.2 Addition of preservatives

The banana pieces were dipped in 0.5% citric acid solution for 10 min before further investigations as per Doymaz *et al*. (2005).

3.3 Physico-chemical characteristics estimation

The methods of estimating various quality attributes of banana flour for the study are briefly described below.

3.3.1 Moisture content determination of raw banana

The moisture content of raw banana was determined by gravimetric method. The known weight of the sample ($W_{initial}$) was kept inside a hot oven at a temperature of 100°C. The samples kept in the oven were weighed at regular interval of 24 h using a digital balance of 0.001g of accuracy until the weight become constant; this weight is taken as final weight (W_{final}). The moisture content was expressed as the % change in weight (Ranganna, 1995).

$$\text{Moisture content (\%)} = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100 \qquad 3.1$$

3.3.2 pH

pH being the logarithm of the reciprocal of hydrogen ion concentration, is a measure of active acidity which influence the flavour or palatability of a product and also affects its processing requirements. The pH of the banana flour samples was determined using a digital pH meter (Plate 3.2). The pH meter was standardized with buffer solutions of different pH (4.0, 7.0, and 9.2). Each sample was replicated three times and its mean value was taken as pH of the sample.

Plate 3.2 YORCO pH meter, model: YSI – 601

3.3.4 Titrable acidity

The banana flour was mixed with water and filtered through a muslin cloth. About 10 g of fresh filtered homogenised pulp were made up to 100 ml with distilled water. About 10 ml of the prepared solution was titrated against 0.1N NaOH solution using phenolphthalein as indicator. The appearance of a light pink colour was the end-point that quantifies the NaOH required to neutralize the pulp. Then the titrable acidity was calculated and expressed as % citric acid (Ranganna, 1986). Amount of titrable acidity (N_s) present in 100 g of sample was calculated as follows

$$N_s(\%) = \frac{\text{Normality of alkali} \times \text{Titre value} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken} \times 100} \quad 3.2$$

3.3.5 Total soluble solid

Total soluble solid (TSS) was measured using a hand refractometer (Plate 3.3). Banana flour was mixed with water and allows the sample to settle. One or two drops of the prepared sample were placed on the hand refractometer for TSS measurement. It was expressed in degree Brix (Ranganna, 1995).

Plate 3.3 Hand refractometer for TSS measurement

3.3.6 Ascorbic acid

Ascorbic acid otherwise known as vitamin C was determined by dye method (Sadasivam and Manickam, 1992). The reagents used were 4% oxalic acid, standard ascorbic acid solution in 4% oxalic acid and dye solution (42 mg of sodium bicarbonate and 52 mg of 2, 6, dichloro phenol indophenols dye in 200 ml of distilled water). About 100 mg of pure dry crystalline ascorbic acid was taken and made up to 100 ml using 4% oxalic acid to get the stock solution. The working standard solution (100 ml) was prepared by diluting 10 ml stock solution using 4% oxalic acid. About 5 ml each of working standard solution and 4% oxalic acid were pipetted into a conical flask and titrated against the dye solution. End point was the appearance of pale pink colour which persisted for a few minutes. The titration was repeated for 3 times to get the concordant value. The amount of dye consumed (V_1) was determined which was equal to the amount of ascorbic acid present in the working standard solution. Then the sample flour was made into pulp and 10 ml of the homogenized pulp (V_s) was taken and made up to 100 ml with 4% oxalic acid solution. Then 5 ml of the made up solution was pipetted out into a conical flask and titrated against the dye (V_2). The quantity of ascorbic acid (mg) present in 100 g of sample was calculated as follows.

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5}{V_1} \times \frac{V_2}{5} \times \frac{100}{V_s} \times 100 \qquad 3.3$$

3.3.7 Colour

Hunter Lab colourimeter (Mini Scan XE Plus) was used for the colour measurement involved in the study (Plate 3.4). It works on the principle of collecting the light and measures energy from the sample reflected across the entire visible spectrum. The meter uses filters and mathematical models which rely on “standard observer curves” that defines the amount of green, red and blue primary lights required to match a series of colours across the visible spectrum and the mathematical model used is Hunter model. It provides reading in terms of ‘L’, ‘a’ and ‘b’, recommended by the commission international de l’ Eclairage

(CIE). The ‘L’ coordinate measures the value or luminance of a colour and ranges from black at 0 to white at 100. The ‘a’ coordinate measures red when positive and green when negative and ‘b’ measures yellow when positive and blue when negative.

The colourimeter was standardised using black and white ceramic calibration tiles. The sample colour was measured by filling the banana flour samples in the transparent cup without any void space. The deviation of colour of samples from the standard were observed and recorded in the computer interface. Each sample was replicated three times and the average value of ‘L’, ‘a’ and ‘b’ were determined.

Plate 3.4 Hunter lab colourimeter

3.3.8 Water activity

Aqua lab water activity meter (Plate 3.5) was used for the measurement of water activity of the prepared sample. It is the fastest instrument for measuring water activity, giving readings in five minutes or less. Its readings are precise, providing ±0.003 accuracy. The instrument is easy to clean and checking calibration is simple (Chirife *et al*., 1992).

For the water activity determination, banana flour is filled in the disposable cups of the water activity meter and the sample drawer knob is turned to OPEN position and the drawer is opened. The prepared sample is then placed in the drawer. Checked the top lip of the cup to make sure it is free from sample residue (an over-filled sample cup may contaminate the chamber's sensors). After placing the sample, turned the sample drawer knob to the READ position. The a_w value of the sample was noted from the LCD display of the water activity meter.

Plate 3.5 Aqua lab water activity meter

3.4 Drying of banana

For drying of banana RRLT-NC dryer (Plate 3.6) was used. In the improved natural convection driers named RRLT-NC drier, the hot air is generated separately outside the drier chamber and is conveyed upwards through a separate duct by natural convection. At the top of the duct an opening is provided for the entry of the hot air to the drying chamber. Performed trays were arranged one above the other in the drying chamber. All the sides of drier chamber, except the bottom side were covered with heat insulating materials. The hot air after entering into the drying chamber tends to occupy the topmost layer just below the top-covering sheet. As the hot air comes into contact with the wet material on the top tray, the temperature of air drops, consequently the density increase & has a tendency to flow down by percolating through the trays and the wet material placed on the trays. The cooled air by the process of heat transfer finally leaves at the bottom of the drier to the atmosphere. Thus the hot air was made to flow in a downward direction after overcoming the frictional resistance offered by the perforated trays and the wet material contained in the trays without the help of any blower or fan. Thus the wet material got dried (Thomas, 2000).

About 500 g of the sliced banana samples were taken in the tray and the samples were dried in the dryer at different temperatures *viz*. 50°C, 60°C and 70°C up to 4% moisture content (w.b) of the sample.

Plate 3.6 RRLT-NC Dryer

3.5 Standardization of drying temperature and treatment

About 500 g of the sliced plantain were taken in each tray of RRLT-NC dryer. The drying of plantain slices was carried out at different temperature-treatment combinations. For this purpose nine temperature-treatment combinations are used and are represented by T1, T2, T3, T4, T5, T6, T7, T8 and T9.

T1: Drying at 50°C, without any pretreatment

T2: Drying at 50°C with 0.5% citric acid treatment for 10 min

T3: Drying at 50°C followed by 0.5% citric acid and 10 min blanching (100°C)

T4: Drying at 60°C, without any pretreatment

T5: Drying at 60°C with 0.5% citric acid treatment for 10 min

T6: Drying at 60°C followed by 0.5% citric acid and 10 min blanching (100°C)

T7: Drying at 70°C, without any pretreatment

T8: Drying at 70°C with 0.5% citric acid treatment for 10 min

T9: Drying at 70°C followed by 0.5% citric acid and 10 min blanching (100°C)

The dried samples were cooled immediately after respective treatments and are stored after grinding. The stored samples were subjected to further analysis for selection of the most appropriate temperature-treatment combination.

3.6 Design of packet size dimension

LDPE bags of 350 ± 1 gauge were used for packaging the prepared banana flour. For the purpose, different packet dimensions were made based on the weight of flour to be packed, and are represented as P1, P2, P3, P4 and P5.

P1: Packet for 100 g flour

P2: Packet for 200 g flour

P3: Packet for 400 g flour

P4: Packet for 500 g flour

P5: Packet for 1000 g flour

3.7 Standardization of fortified banana flour and shelf life studies

For preparing fortified banana flour, the treatment T8, *i*.e., 0.5% citric acid pretreatment for 10 min and drying in RRLT-NC dryer at a temperature of 70°C for 24 h, without blanching, was selected, based on quality parameters. For the purpose, prepared banana flour was mixed with different proportions of sugar, formulating six combinations as represented by Control, 90:10, 85:15, 80:20, 75:25, and 70:30.

Control- 100% banana flour

90:10 - 90% banana flour and 10% sugar

85:15 - 85% banana flour and 15% sugar

80:20 - 80% banana flour and 20% sugar

75:25 - 75% banana flour and 25% sugar

70:30 - 70% banana flour and 30% sugar

All the combinations were subjected to shelf life studies and quality analysis was performed at regular interval of one month, for selection of the optimum combination. Fig. 3.1 shows the flowchart for banana flour preparation.

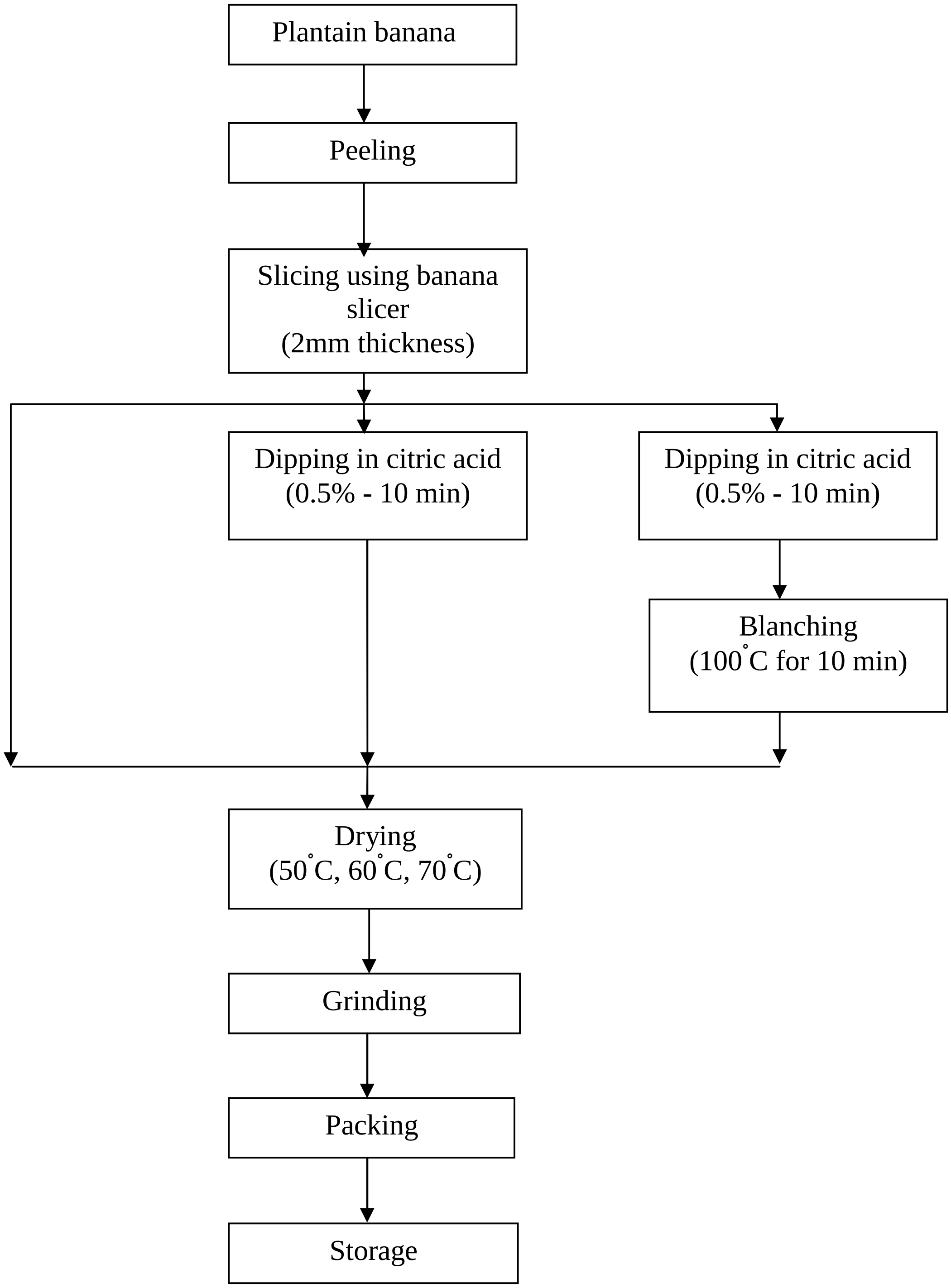

Fig: 3.1 Flow chart for banana flour preparation

CHAPTER 4

RESULTS AND DISCUSSION

The outcome of various experiments conducted to standardize temperature-treatment conditions for drying, combination of banana flour and the various quality parameters involved in the storage are enunciated and discussed in this chapter.

4.1 Physico-chemical characteristics of raw banana

The estimated composition and quality parameters before drying of the AAB variety of banana are presented in Table 4.1. The average values of chemical components *viz.*, moisture, TSS, Ascorbic acid, titrable acidity and pH were estimated to be 64% 4.79°B, 10.7 mg/100 g, 0.48%, and 4.77 respectively.

Table 4.1 Physico-chemical characteristics of raw banana

Chemical characteristics		**Mean ± *SD**
Moisture (%)		64 ± 1.29
TSS (°B)		4.79 ± 0.34
Ascorbic acid (mg/100 g)		10.7 ± 0.168
Titrable acidity (%)		0.48 ± 0.004
pH		4.77 ± 0.16
Physical characteristics		
Colour value	L	59.00 ± 0.007
	a	-4.61 ± 0.39
	b	15.47 ± 1.93

*SD: Standard deviation

The colour values of the raw banana gave 59, -4.61, and 15.47 respectively for 'L', 'a' and 'b' values in hunter colour lab measurement scheme. These values especially 'L' value gave the impression that the colour of the raw banana would tend towards white colour.

4.2 Standardization of drying temperature and treatment

The temperature-treatment combination for drying was standardized based on the result obtained from drying curves and quality parameters like colour, pH, titrable acidity, ascorbic acid and water activity. Banana slices of 2mm thickness were subjected to drying at different treatment-temperature combination (T1, T2, T3, T4, T5, T6, T7, T8 and T9, see section 3.5). Plate 4.1 shows the banana slices before drying.

4.2.1 Drying kinetics

From the following figures, it was observed that during the initial period of drying in all treatments there is a sudden decline in moisture content. This was due to the evaporation of moisture from the surface. After that there was a decrease in drying rate. This was due to the time taken for diffusion of moisture from the interior to the surface. By comparing Fig.4.1, Fig.4.2 and Fig.4.3, it was observed that drying at 50°C takes more time (48 h) than drying at 70°C (24 h).

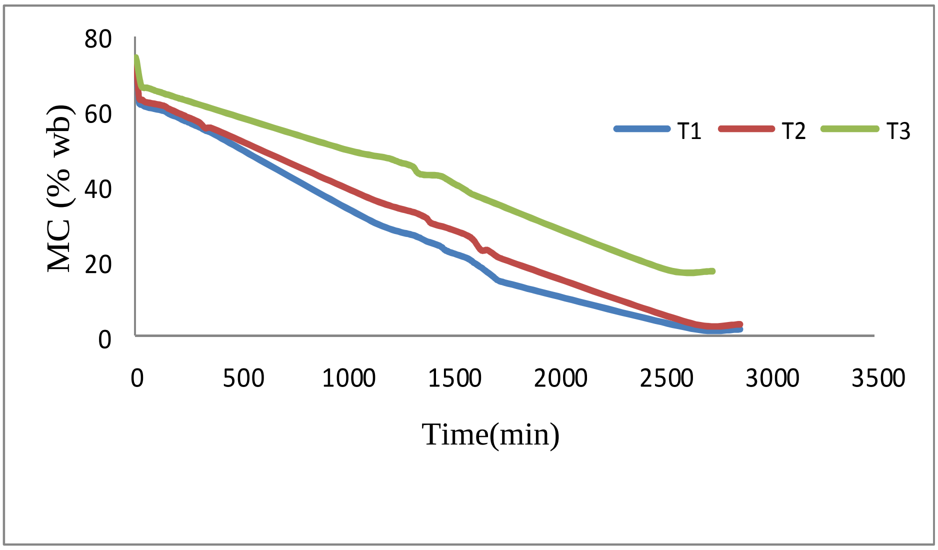

Fig.4.1 Drying kinetics at 50°C

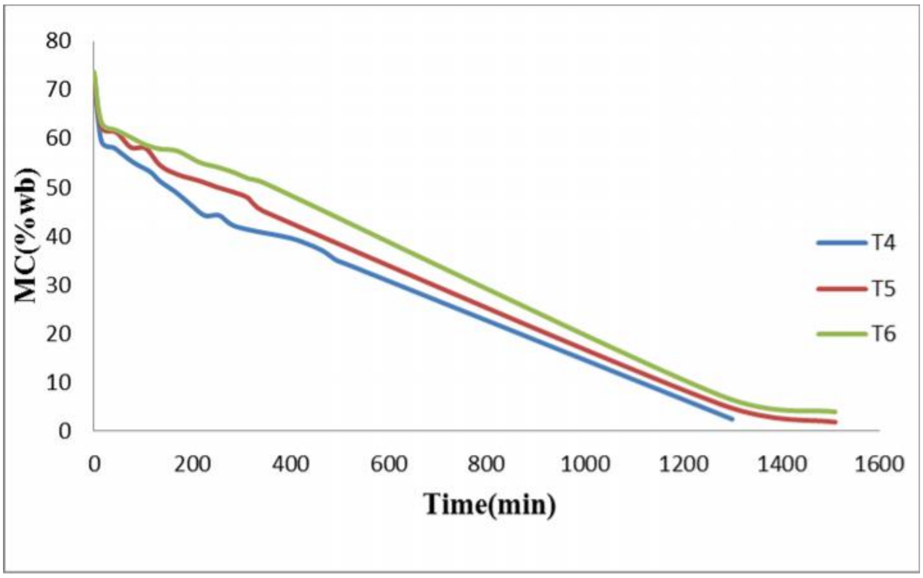

Fig.4.2 Drying kinetics at 60°C

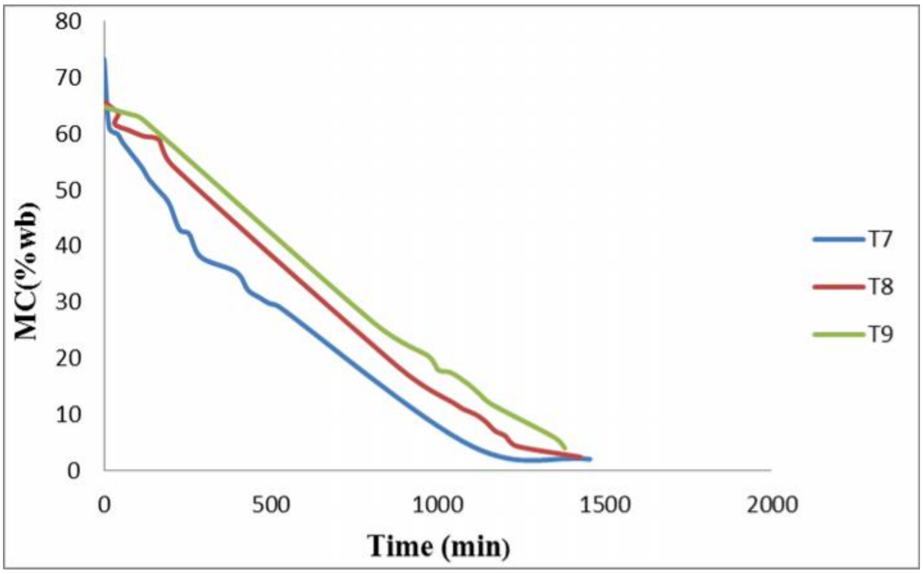

Fig.4.3 Drying kinetics at 70°C

By comparing the drying temperatures, drying at 50°C take longer time (48 h) to dry the banana but drying at 70°C take only 24 h; due to the fact that during pretreatments (soaking in citric acid, blanching) the banana slices will absorb some water and thereby increases the drying time. Marilyn *et al*., (1995) observed the similar results in drying of fruits.

Microbial contamination was found in samples dried at 50°C and 60°C but no microbial contamination was there in 70°C dried samples.

4.2.2 Water activity

The variations in water activity for different treatments are shown in Fig. 4.4. Food stability usually decreases with increase in water activity. From the figure it is evident that the water activity is maximum (0.8) for T3 treatment (drying at 50°C followed by 0.5% citric acid for 10 min and 10 min blanching at 100°C) and minimum (0.51) for T8 treatment (drying at 70°C followed by 0.5% citric acid for 10 min). The permissible water activity level for banana flour is less than 0.67 (Mossel *et al*., 1995). In general the water activity of banana flour produced at 60 and 70°C were within the permissible limit. Microorganisms respond differently to water activity depending on a number of factors. Microbial growth, and in some cases the production of microbial metabolites, may be particularly sensitive to alteration in water activity. An increase in temperature usually decreases microbial growth.

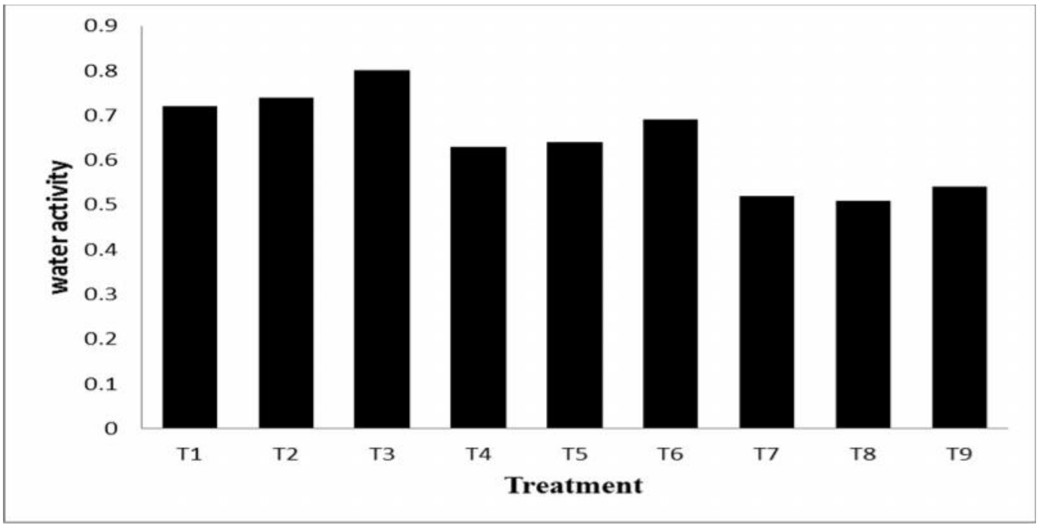

Fig.4.4 Variation in water activity for different treatments

4.2.3 Ascorbic acid

Fig. 4.5 shows the effect of various treatments on ascorbic acid content of banana flour. It was observed that the concentration of ascorbic acid decreases with increase in temperature. Ascorbic acid content is more (2.55 mg/100g) in T2 treatment (drying at 50°C followed by 0.5% citric acid for 10 min). Addition of citric acid decreased the enzyme activity thereby reducing the ascorbic acid degradation (Ryley *et al.*, 1994). Vitamin C degradation was high (1.22 mg/100g) in T9 treatment (drying at 70°C followed by 0.5% citric acid for 10 min and 10 min blanching at 100°C). The destruction of ascorbic acid oxidase and ascorbic acid during blanching of banana increases with increase in temperature (Dhopeshwerkar and Magar, 1952).

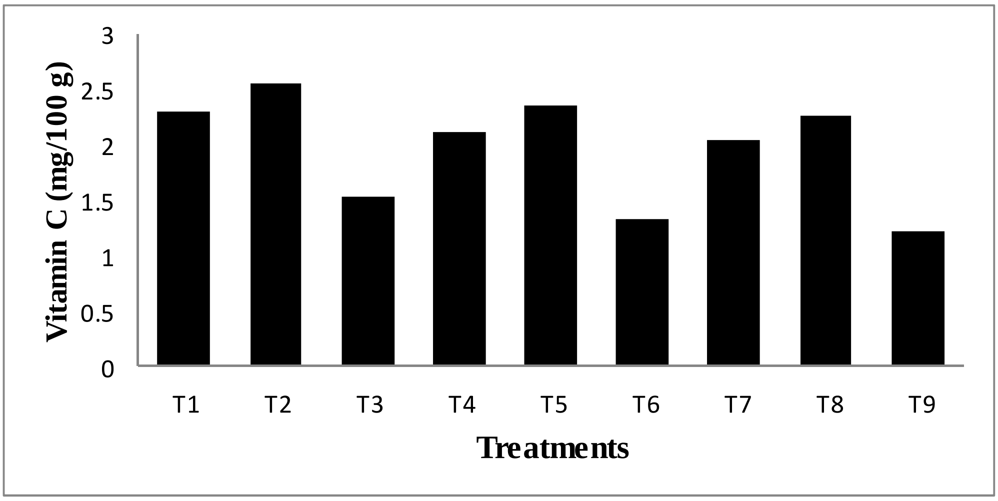

Fig. 4.5 Variation in ascorbic acid content for different treatments

4.2.4 Colour

The hunter colorimeter colour values (Fig. 4.6) showed that T1 and T8 treatments retained the colour than other treatments. The average CIE colour values *viz.*, 'L', 'a', and 'b' of the raw sample were 59.00, -4.61, 15.47 respectively. From the figure 4.6 it is clear that the 'a' value for T8 treatment (drying at 70°C followed by 0.5% citric acid for 10 min) is less than that of T7 (drying at 70°C). Decrease in 'a' value meant a gain in greenness. The gain in green colour was because of the citric acid pretreatment, which lowered the pH of the sample and prevented the change of fresh green colour of chlorophyll into pheophytin which is unattractive brownish green (NIIR Board, 2003).

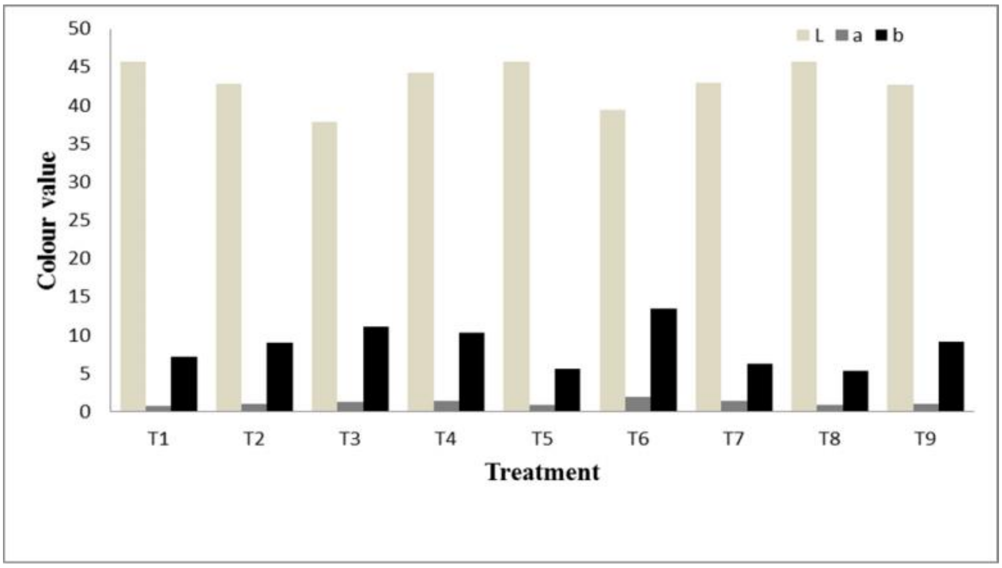

Fig. 4.6 Variation in colour for different treatments

4.2.5 Total soluble solids

The TSS for different treatments is shown in Fig. 4.7. The results showed that there was no significant change in the amount of TSS among various treatments. There was a slight increase in TSS for T1 (3.53^{o}B), T4 (3.3 ^{o}B) and T7 (3.6^{o}B) treatments. TSS content of unblanched samples was more than that of blanched ones, due to leaching loss of soluble solids during blanching (Guerrant *et al*., 1946).

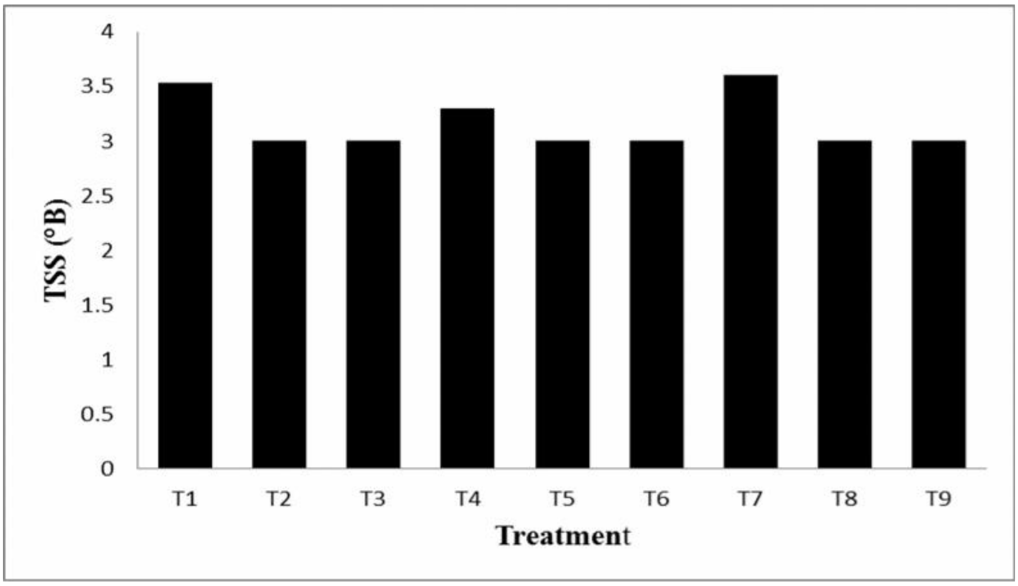

Fig. 4.7 Variation in TSS for different treatments

4.2.6 Titrable acidity

The variation of titrable acidity for different treatments is shown in Fig. 4.8. Results showed no significant changes in the value of titrable acidity among various treatments.

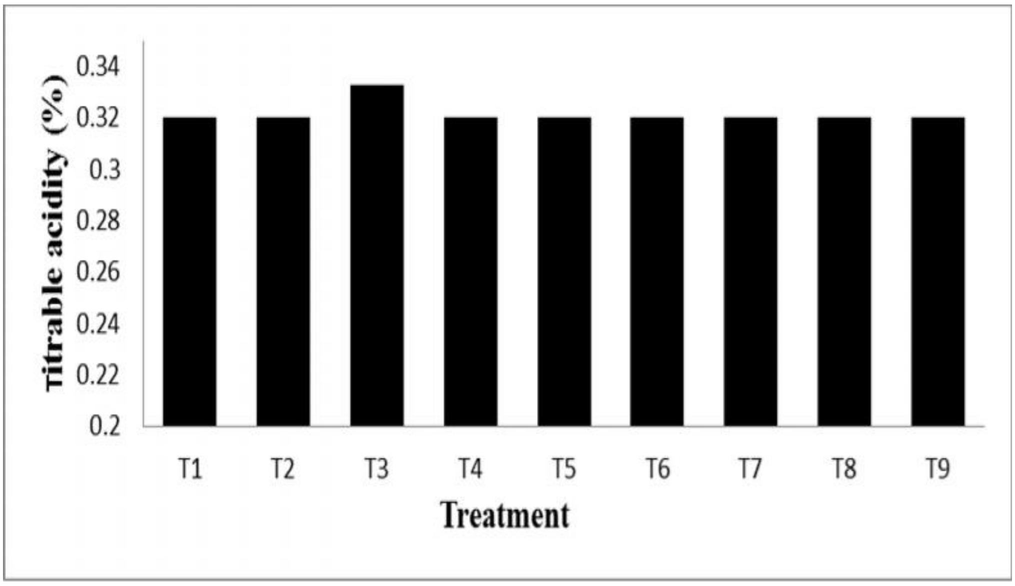

Fig. 4.8 Variation of titrable acidity for different treatments

4.3. Standardization of drying process

Drying of banana was carried out at different temperature-treatment combinations. Drying at 70°C followed by 0.5% citric acid treatment for 10 min (T8), in 24h, was standardized based on the results of the quality parameters like water activity, colour, titrable acidity, TSS and ascorbic acid. Microbial contamination was found in samples dried at 50°C and 60°C but no microbial contamination was observed in samples dried at 70°C. Water activity was less (0.51) and ‘L’ value (Lightness) was greater for T8 treatments. Vitamin C retention of these samples were more compared with other samples and observed that addition of citric acid decreased the enzyme activity and thereby reducing the degradation of ascorbic acid. During blanching the destruction of ascorbic acid was high due to thermal degradation/oxidation process. Considering the above results, drying temperature of 70°C followed by 0.5% citric acid pretreatment for

24h, in RRLT-NC dryer was selected for further storage studies. Plate 4.2 shows the banana flour at different drying temperature treatment combinations.

4.3 Design of packet size dimension for banana flour

Different packet dimensions were made based on the weight of flour to be packed; Table 4.2 represents the dimension of packet size based on weight of flour to be packed.

Table 4.2 Different packet size dimensions

Weight (g)	Packet size (cm x cm)
100	17 x 12
200	17 x 15
400	17 x 20
500	21 x 19
1000	21 x 25

4.4 Shelf life study of fortified banana flour

Matured green banana slices of 2mm thickness were dried at optimized drying conditions. A drying temperature of 70°C followed by 0.5% citric acid pretreatment for 10 min, in 24h, in RRLT-NC dryer was selected based on the quality parameters. Dried samples were cooled and grinded. The flour obtained was mixed with sugar at different proportions and they are represented as control, 90:10, 85:15, 80:20, 75:25, 70:30 (as per section 3.7).

The variation in quality characteristics of flour with storage period were as follows.

4.4.1 Change of TSS on storage

The variation in TSS concentration is illustrated in Fig. 4.9. It is clear from the figure that there is an increase in TSS concentration during storage. The increase in TSS during storage may be due to acid hydrolysis of poly saccharides especially gums and pectin (Luh and Woodruff, 1975). At the end of storage period, the TSS in 70:30 (70% of banana flour and 30% sugar) was the highest

(7.8°Brix). This may be due to the increase in sugar content in this sample. The lowest of 5.3°Brix was observed for control sample (100% banana flour). The increasing trend in TSS for different combinations of banana flour is depicted by the linear equation

TSS = 0.023x + 5.24 (R^2=0.928) ……………………………….………….. (4.1)

Where, x is storage period (days)

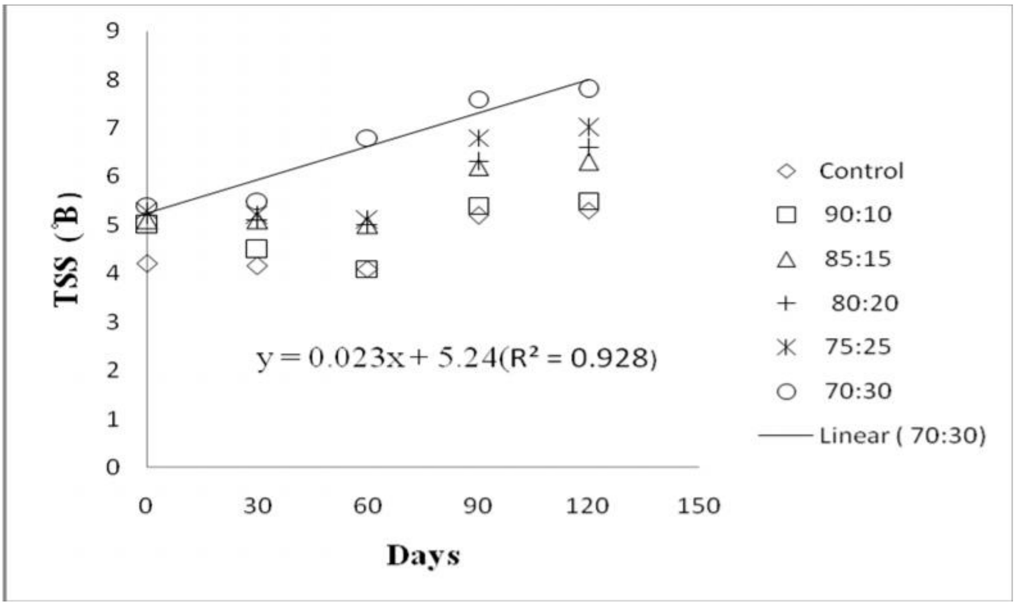

Fig. 4.9 Variation of TSS on storage

4.4.2 Variation of titrable acidity on storage

The change in titrable acidity with storage is shown in Figure 4.10. The titrable acidity of banana flour decreased with storage which could be expressed using the linear equation given below.

Titrable acidity = −0.0004x + 0.324 (R^2=0.964)…………………..…............ (4.2)

Where, x is the storage period in days.

Titrable acidity of different combination of banana flour significantly decreased compared to initial values. This decrease may be due to the acid hydrolysis of poly saccharides especially gums and pectin (Luh and Woodrff, 1975). However a slight hike (0.247%) in the titrable acidity was observed in 75:25 combinations (75% of banana flour and 25% flour).

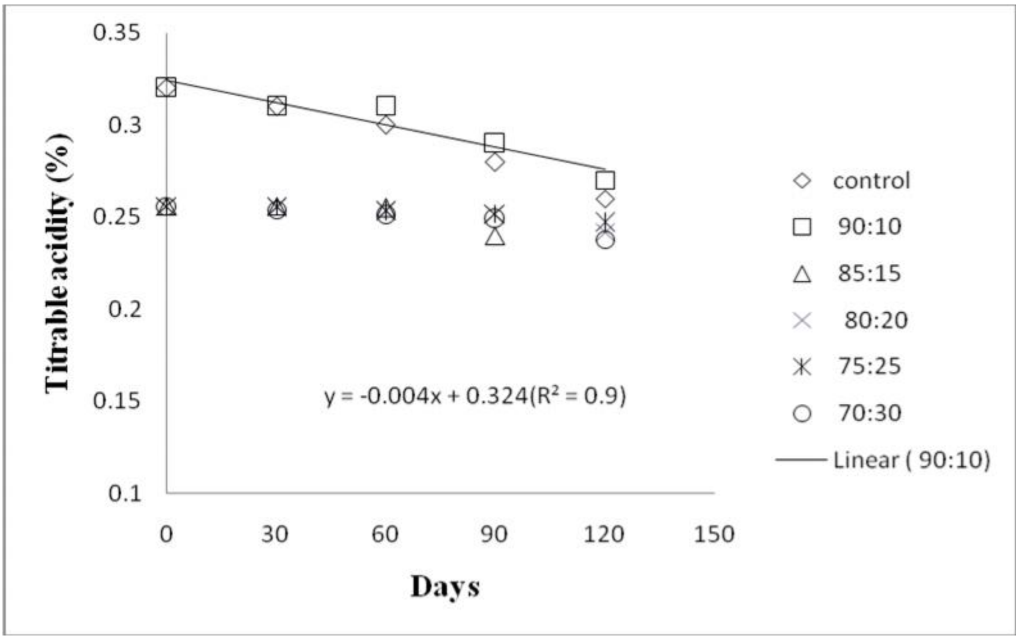

Fig.4.10 Variation of titrable acidity on storage

4.4.3 Variation of Ascorbic acid on storage

Fig.4.11 shows the effect of various combinations on ascorbic acid content of stored banana flour. It was observed that the concentration of ascorbic acid had a decreasing trend with storage irrespective of treatment of banana flour. Izumi *et al*., (1984) had also reported similar findings. At the end of 120^{th} day of storage, the maximum value of ascorbic acid (4.45mg/100 g) was found in 75:25 combinations. The addition of sugar and starch seems to have a protecting action of vitamin C (Banu *et al.*, 2003). The decreasing trend was explained by the linear equation.

Vitamin C = -0.004x + 5.01 (R^2= 0.989)………………………………….. ... (4.3)

Where, x is storage period in days.

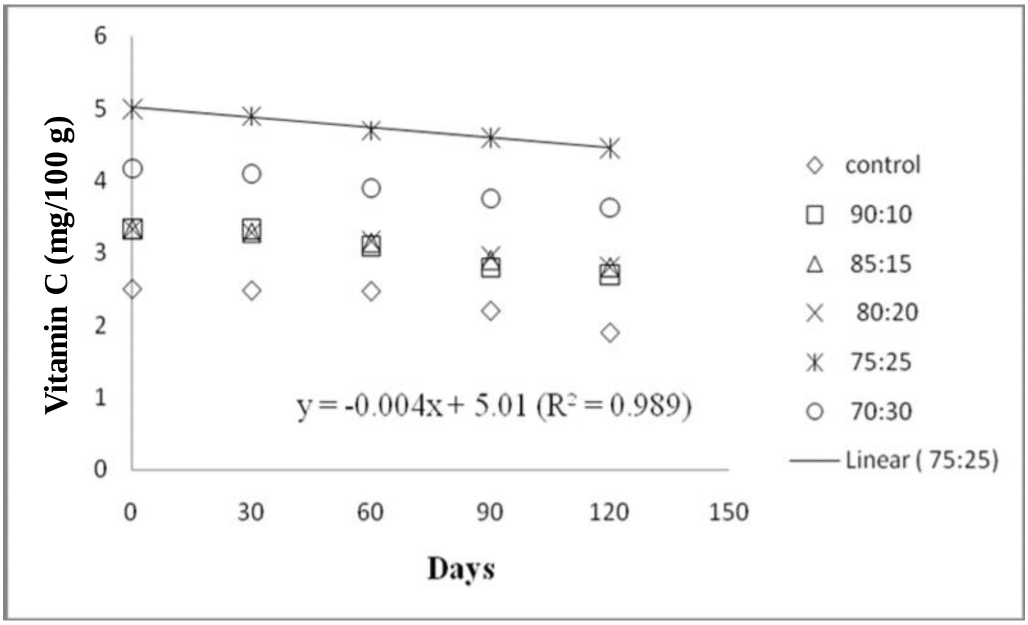

Fig. 4.11 Variation of ascorbic acid on storage

4.4.4 Variation of pH on storage

Fig. 4.12 shows the variation of pH on storage. The pH of banana flour increased with storage which could be expressed using the linear equation given below.

pH = 0.011x + 4.322 (R^2=0.936)………………………………………… (4.4)

where, x is the storage period in days.

On 120th day of storage, the maximum value of pH was found to be 5.75 in combination 70:30 and the minimum value was found to be 5.34 in control. The increase in pH with increase in sugar content in the flour is may be due to the acid hydrolysis of polysaccharides (Luh and Woodrff, 1975).

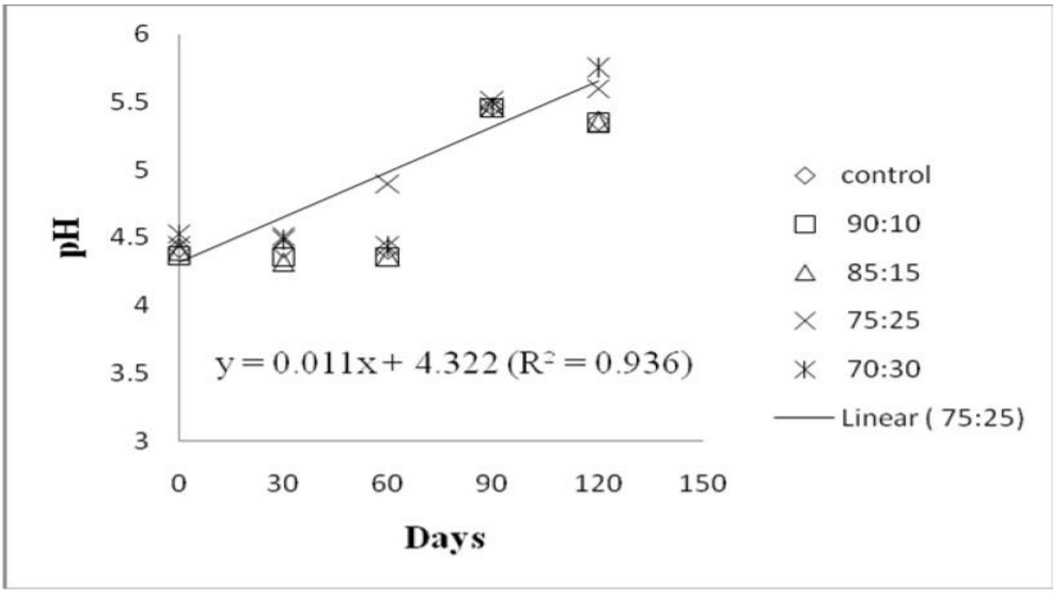

Fig. 4.12 Variation of pH on storage

4.4.5 Variation of water activity on storage

Most bacteria, moulds, and yeasts are likely to grow in high-moisture foods. An increase in water activity level indicates that the food is more susceptible for spoilage (Eskin and Robinson, 2000).

Fig.4.13 shows the variation of water activity of different combination of banana flour on storage. There was an increase in water activity level with increase in storage period. At the end of 120^{th} day of storage the minimum water activity level (0.513) was found in 70:30 combinations. This may be due to the presence of sugar in the sample which acted as preservative as well as a protectant against microbial activity (Banu *et al.,* 2003). The increase in trend of water activity is given by the following linear equation.

Water activity = = 0.006x + 0.431 (R^2 = 0.972)………………………… (4.5)

Where, x is storage period in days.

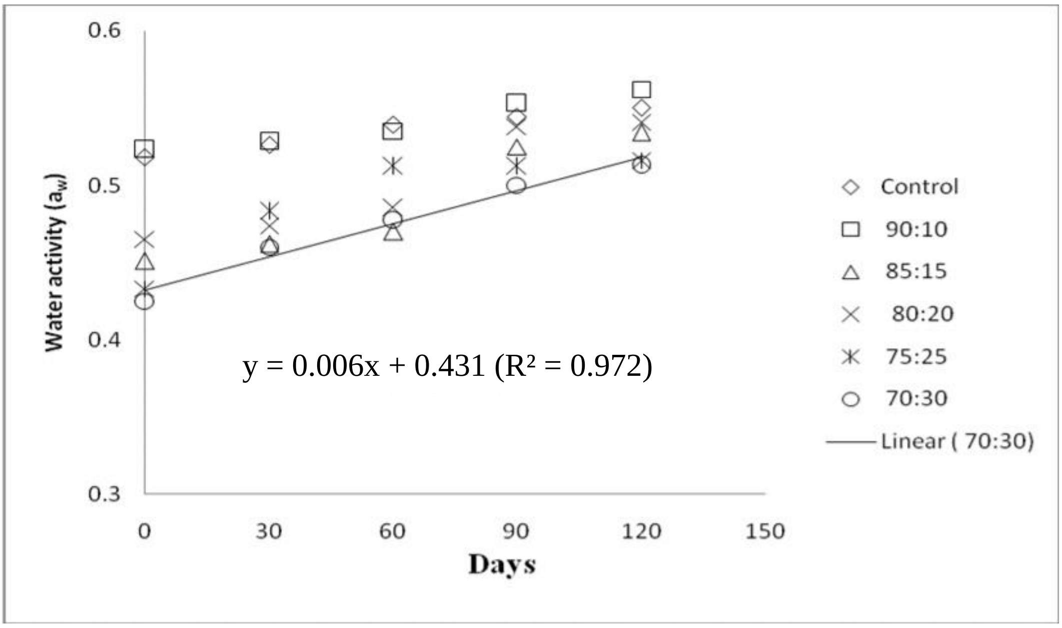

Fig.4.13 Variation of water activity on storage

Banana slices without treatment

Banana slices with 0.5% citric acid

Banana slices with 0.5% citric acid and blanching at 100°C

Plate 4.1 Banana slices before drying

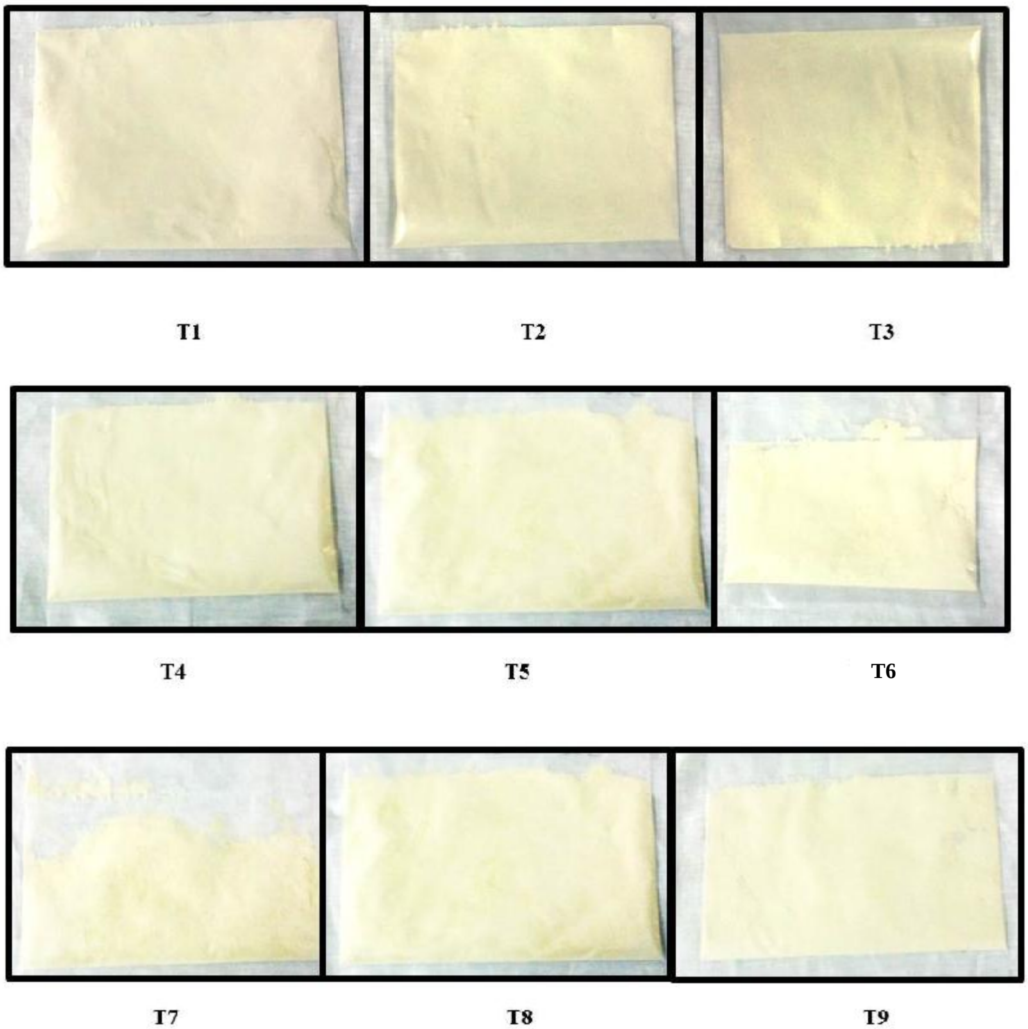

Plate 4.2 Banana flour at different temperature-treatment combination

CHAPTER 5

SUMMARY AND CONCLUSION

In the recent years, demand for both fresh and processed fruits and vegetables have been substantial and this trend is likely to continue in future. The increasing demand can be regulated by either increasing their production or by adapting suitable processing techniques for its preservation. Banana a common herbaceous plant of the genus *Musa,* is the cheap source of carbohydrate and rich source of potassium, calcium, antioxidants and other micro nutrients. But this fruit is highly perishable owing to its higher water content and it is susceptible to many diseases, especially fungal infection. Post production losses of banana can be reduced by adopting various post-harvest management practices like cleaning, sorting, pre-storage treatments etc. The objective of the present study was to optimize the drying condition for preparing the banana flour, standardize the banana flour and its shelf life studies.

The effects of different temperature-treatment combination on drying of banana were studied. Drying of banana was carried out at different temperature-treatment combinations. Drying at 70°C followed by 0.5% citric acid treatment for 10 min (T8), in 24h, was standardized based on the results of the quality parameters like water activity, colour, titrable acidity, TSS and ascorbic acid. Water activity value (0.51) was less for T8 treatment. Food stability usually decreases with increase in water activity and increase in temperature decreases the microbial growth. Vitamin C retention of samples which are treated with citric acid are compared with other samples and observed that addition of citric acid diminishes the enzyme activity and thereby reducing the degradation of ascorbic acid. During blanching the destruction of ascorbic acid is high.

The hunter colorimeter colour values showed that T8 treatment (Drying at 70°C followed by 0.5% citric acid for 10 min) retained the colour more than other samples. It has an ‘L’ value of 45.64 which is close to that of fresh sample. The decreased ‘a’ value inT8 sample is because of the addition of citric acid i.e. citric acid lowers the pH of the sample and prevent the change of fresh green colour of chlorophyll. There is no significant variation in TSS with temperature variation. But TSS content of unblanched samples was more than that of blanched ones, due to leaching of soluble solids due to blanching. Also there is no significant variation in titrable acidity among various samples.

By comparing the drying temperatures, drying at 50°C take longer time (48 h) to dry the banana but drying at 70°C take only 24 h. Microbial contamination was found in samples dried at 50°C and 60°C but no microbial contamination was there in 70°C dried samples. In the energy point of view also this was found to be viable as the blanching process could be bypassed.

After optimizing drying conditions, the prepared flour was mixed with different proportions of sugar (control, 90:10, 85:15, 80:20, 75:25 and 70:30) and packed in polyethylene bags of 350 ± 1 gauge. The packet dimension is 17cm x 12 cm and contains a weight of 100 g. The packed samples were stored at room temperature and were subjected to shelf life studies. They were evaluated at an interval of 30 days. The results obtained for different parameters are summarized below.

The results revealed that in general the TSS and pH has an increasing trend with storage. While the titrable acidity and ascorbic acid content of different sample decreases with storage.This is due to acid hydrolysis of poly saccharides especially gums and pectin. Increased sugar content in the sample increases the TSS concentration.

It was found that the water activity level of different combination of banana flour increases with storage. An increase in water activity level indicates that the food is more susceptible to spoilage.

This study shows that the drying of banana at 70°C followed by 0.5% citric acid for 10 min, in 24 h, in RRLT-NC dryer is a better method of drying of banana without microbial contamination. The mixing of banana flour with sugar in the ratio 75:25 (75% of banana flour and 25% of sugar) gives maximum vitamin C retention and less microbial spoilage.

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APPENDIX I

Variation of moisture content of banana (RRLT-NC dryer at 50°C)

Drying at 50°C (T1)		Drying at 50°C (with 0.5% citric acid) (T2)		Drying at 50°C (with 0.5% citric acid and blanching at 100°C) (T3)	
Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)
0	72.96228955	0	73.56108192	0	74.54528625
15	62.31072712	15	63.5004203	25	66.8960536
30	61.84909196	30	63.15730713	50	66.43407857
45	61.33058954	45	62.58164006	70	66.13161459
130	60.2344077	130	61.62076665	90	65.65147698
155	59.45176895	155	60.79363194	115	65.25291666
180	58.87940363	180	60.18435849	135	64.8112604
200	58.4366341	200	59.62413742	170	64.23074421
220	57.82151843	220	59.21293321	200	63.65238463
245	57.25854829	245	58.49056604	230	63.14331666
265	56.73514826	265	58.07074609	984	50.111659
300	55.85957666	300	57.14174394	1190	47.59575684
330	54.95139493	330	55.58307311	1245	46.49978924
360	54.26340002	360	55.58307311	1310	45.34795138
1114	30.69908815	1114	36.63837794	1345	43.293123
1320	26.77600308	1320	32.96225572	1435	42.87494807
1375	25.32424997	1375	31.54095096	1470	41.99739867
1440	23.97972793	1400	30.10547719	1505	40.77317922
1475	22.61392949	1475	28.81794651	1535	39.92353905
1565	20.82600241	1565	26.94589569	1565	38.88662543
1600	19.58239278	1600	25.54487613	1600	37.72409889
1635	18.23658793	1635	22.90079903	2501	17.85732066
1695	15.7137224	1665	22.90079903	2733	17.21854305
1730	14.43155	1695	21.78612059		
2631	1.838236	1730	20.63873792		
2863	1.644857	2631	3.259849906		

APPENDIX II

Variation of moisture content at banana (RRLT-NC dryer at 60°C)

Drying at 60°C (T4)		Drying at 60°C (with 0.5% citric acid) (T5)		Drying at 60°C (with 0.5% citric acid and blanching at 100°C) (T6)	
Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)
0	72.39665	0	72.67759563	0	73.655432
15	59.46907	15	62.40601504	15	63.35
40	58.16616	45	61.33408705	45	61.76
55	57.04597	75	58.23	75	60.276
75	55.502	105	58.02238806	105	58.733
90	54.56	135	54.5	135	57.883
115	53.172495	170	52.67	170	57.475
135	51.21533721	215	51.345	215	55.1393
165	49.15858952	250	50.087	250	54.20829
195	46.6425362	285	49.021	285	53.08642
225	44.26209203	315	47.789	315	51.79296
255	44.26209203	345	45.135	345	51
290	41.96110376	1275	5.6	1275	7.4
395	39.75266885	1510	1.893287435	1510	4
430	38.61727331				
465	37.06062056				
495	35.00323083				
525	33.84912959				
1300	2.5				

APPENDIX III

Variation of moisture content at banana (RRLT-NC dryer at 70°C)

Drying at 70°C (T7)		Drying at 70°C (with 0.5% citric acid) (T8)		Drying at 70°C (with 0.5% citric acid and blanching at 100°C) (T9)	
Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)	Time int (min)	m/c (%wb)
0	73.29526369	0	65.71497313	0	64.80902206
15	61.12944628	25	64.5265014	30	64.25361122
40	59.97684195	43	63.60230732	60	63.74737645
55	58.4747976	32	61.70555829	80	63.42871808
75	56.95023556	75	60.60270943	115	62.5894244
90	55.80264072	116	59.58975328	810	26.254
115	53.88497346	166	58.81998796	970	20.5
135	51.83131873	206	54.2671	1000	18.02
165	49.81060606	886	18.256	1035	17.59
195	47.56109627	1046	12.123	1065	16.5678
225	43.021	1076	11.012	1095	15.256
255	42.14	1111	10.123	1125	13.6789
290	38.0426	1141	8.89	1160	11.896
395	35.41552	1171	7.145	1350	5.93295
430	32.21928553	1201	6.26	1380	4.056
465	30.88158581	1236	4.436		
495	29.80442365	1426	2.5		
525	29.18540952				
1100	4.469				
1455	2.1				

APPENDIX IV

Variation of water activity level of different treatments

Treatments	Average water activity (a_w)	Average Vitamin C (mg/100 g)	Average TSS (o Brix)	Average Titrable acidity (%)
T1	0.72	2.3	3.53	0.32
T2	0.74	2.55	3	0.32
T3	0.8	1.53	3	0.3328
T4	0.63	2.12	3.3	0.32
T5	0.64	2.36	3	0.32
T6	0.69	1.33	3	0.32
T7	0.52	2.04	3.6	0.32
T8	0.51	2.26	3	0.32
T9	0.54	1.22	3	0.32

APPENDIX V

Variation of colour in different treatments

Treatments	‘L’	‘a’	‘b’
T1	45.72	0.796667	7.136667
T2	42.83333	1.05	8.96
T3	37.87	1.33	11.06
T4	44.29	1.39	10.34
T5	45.73	0.886667	5.586667
T6	39.38333	1.98	13.44333
T7	42.98	1.36	6.296667
T8	45.64667	0.866667	5.376667
T9	42.7	1.05	9.126667

APPENDIX VI

Variation of TSS (□ B) during storage of banana flour

Combination	0th day	30th day	60th day	90th day	120th day
Control	4.2	4.15	4.1	5.2	5.1
90:10	5	4.5	4.1	5.6	5.4
85:15	5.1	5.1	5	6.2	6.1
80:20	5.2	5.1	5	6.4	6.2
75:25	5.3	5.2	5.1	7	6.8
70:30	5.5	5.4	5.3	7.5	7.2

APPENDIX VII

Variation of titrable acidity (%) during storage of banana flour

Combination	0th day	30th day	60th day	90th day	120th day
Control	0.32	0.31	0.3	0.28	0.26
90:10	0.32	0.31	0.31	0.29	0.27
85:15	0.256	0.256	0.255	0.24	0.216
80:20	0.256	0.255	0.254	0.251	0.242
75:25	0.256	0.256	0.253	0.252	0.247
70:30	0.256	0.254	0.251	0.249	0.238

APPENDIX VIII

Variation of ascorbic acid (mg/100 g) during storage of banana flour

Combination	0th day	30th day	60th day	90th day	120th day
Control	2.5	2.48	2.47	2.2	1.9
90:10	3.33	3.33	3.1	2.8	2.7
85:15	3.33	3.28	3.14	2.9	2.8
80:20	3.33	3.28	3.16	2.95	2.8
75:25	5	4.9	4.7	4.6	4.45
70:30	4.17	4.1	3.9	3.75	3.63

APPENDIX IX

Variation of pH during storage of banana flour

Combination	0th day	30th day	60th day	90th day	120th day
Control	4.42	4.42	4.41	5.47	5.36
90:10	4.37	4.36	4.36	5.46	5.34
85:15	4.4	4.32	4.36	5.46	5.35
80:20	4.43	4.47	4.53	5.44	5.43
75:25	4.43	4.51	4.9	5.55	5.6
70:30	4.53	4.48	4.43	5.47	5.75

APPENDIX X

Variation of water activity (a_w) during storage of banana flour

Combination	0^{th} day	30^{th} day	60^{th} day	90^{th} day	120^{th} day
Control	0.518	0.526	0.539	0.544	0.55
90:10	0.523	0.528	0.535	0.553	0.562
85:15	0.451	0.462	0.47	0.525	0.534
80:20	0.465	0.474	0.485	0.538	0.541
75:25	0.433	0.483	0.512	0.512	0.516
70:30	0.425	0.46	0.477	0.5	0.513

Abstract

DEVELOPMENT OF PROCESS PROTOCOL FOR BANANA FLOUR

By

DHANASREE B

SNEHA SUKUMARAN

VITHU PRABHA

ABSTRACT

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In

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Faculty of Agricultural Engineering and Technology
Kerala Agricultural University

Department of Post-Harvest Technology and Agricultural Processing

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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KERALA, INDIA

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ABSTRACT

Banana a common herbaceous plant of the genus *Musa*, is the cheap source of carbohydrate and rich source of potassium, calcium, antioxidants and other micro nutrients. But this fruit is highly perishable owing to its higher water content and it is susceptible to many diseases, especially fungal infection. Post production losses of banana can be reduced by adopting various post-harvest management practices like cleaning, sorting, pre-storage treatments etc.

Banana flour is a powder made from processed bananas. The plantain flour has a good potential for use as a functional agent in bakery products on account of its high water absorption capacity. It is used as a component for production of milk shakes and baby foods, cakes, biscuits etc. Banana flour contains high per cent of starch hence it is used for the formulation of nutritious weaning mixes and supplementary foods. Hence a study has been undertaken to standardize the protocol for banana flour preparation. Plantain slices were dried at various temperature-treatment combinations. The prepared flour was mixed with different proportions of sugar and is stored. The various quality parameters were tested periodically at an interval of 30 days. Prediction equations were also developed for various quality parameters of prepared flour.

This study showed that a banana dried at 70°C followed by 0.5% citric acid treatment in 24 h in RRLT-NC dryer is a better method of drying of banana without microbial contamination. The mixing of banana flour with sugar in the ratio 75:25 (75% of banana flour and 25% of sugar) gives maximum vitamin C retention and less microbial spoilage. By considering the economy this combination is also a suitable one. The observations of various quality parameters during the storage study also support this result.