Product diversification of jackfruit

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2009

CERTIFICATE

Certified that this project report entitled **"Product diversification of jackfruit"** is a record of project work done jointly by Akhila,B.G and Shareena,K.P under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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Assistant Professor
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Place : Tavanur
Date :

DECLARATION

We hereby declare that this project report entitled ***"Product diversification of jackfruit"*** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Akhila,B.G
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Akhila,B.G **Shareena,K.P**

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SYMBOLS AND ABBREVIATIONS

%	percentage
/	per
@	at the rate of
^{0}C	degree Celsius
^{0}F	degree farenheit
AICRP	All India Co-ordinated Research Project
APEDA	Agricultural and Processed food products Export Development Authority.
Ca	calcium
cacl2	calcium chloride
cal	calorie
cm	centimeter
CO_2	Carbon dioxide
Cu	copper
et al.	and other people
etc.	etcetera
EVA	Ethylene Vinyl Acetate
FAO	Food and Agricultural Organization
FBD	fluidized bed drier
g	gram
HDPE	High Density Polyethylene
HIV	Human Immune Virus
hrs	hours
IBA	Indole-3-butyric acid
i.e	that is
IU	Int. Units
K	Potassium
KAU	Kerala Agricultural University
kg	kilogram

kg/m^3	kilogram per cubic meter
L	Lam
LDPE	Low Density Polyethylene
MAP	Modified Atmospheric Packaging
mg	milligram
min.	minutes
mm	millimeter
NAA	1-Naphthaleneacetic acid
OPP	Oriented Polypropylene
PE	Polyethylene
PHT & AP	Post Harvest Technology and Agricultural Processing
PP	Polypropylene
Ppm	parts per million
PS	Polystyrene
PVC	Poly Vinyl Chloride
RH	relative humidity
s	second
viz	namely
wb	wet basis
µl	micro litre
µm	micro metre

Chapter I

INTRODUCTION

India is endowed with a wide spectrum of agro-climatic conditions, ranging from tropical to dry temperate zone and holds a unique position for growing a wide variety of fruits and vegetables. Fruits and vegetables is considered as important group of protective and nutritious foods as most of them are rich in carbohydrates, proteins, vitamins, minerals, dietary fibre and trace elements. India has become the second largest producer of fruits and vegetables production after China. The total production of fruits and vegetables in India during 2007 was 52 million tons and 85 million tons respectively. Fruit production in India increased from 28.6 to 52 million tons between 2000 and 2007 (National Horticulture Board, 2007) for India. Fruit production contributes 10 % on average to the gross value of total agricultural output in India, and 13 % of the export earnings attributable to major agricultural products. India's exports of fresh fruit and vegetable have increased from Rs.1658.72 crores in 2005-06 to Rs.2411.66 crores in 2007-08 (APEDA, 2008).

Fruits and vegetables are highly perishable commodities. Due to high water content on fresh horticultural crops, they are subjected to desiccation, mechanical injury and also susceptible to attack by bacteria and fungi, resulting as pathological breakdown. This results in changes in texture, colour, flavour and nutritional value of the food. These changes can render food unpalatable and potentially unsafe for human consumption. Though India is the largest producer of fruits and vegetables after China, it processes only less than 2.5% of the huge production as compared to 70-83% in advanced countries. According to the Ministry of Food Processing Industries (2009), the lack of processing and storage of fruits and vegetables results in huge wastes estimated about 35%, which is approximately 3000 crores annually. Because of these losses, the per capita consumption per day is hardly of the order of 70g for fruits and 140g for vegetables which is far below the national dietary requirements of 120g and 280g respectively(National Institute of Nutrition, 2004).

Jackfruit (*Artocarpus heterophyllus* L.*)* is a very large and evergreen tree belonging to the Moraceae family. It is a multi-purpose species providing food, fodder, timber, fuel, medicinal and industrial products and is widely grown in south and south east Asia, parts of central and

eastern Africa, Brazil, Suriname and islands of West Indies. In India, it is grown in southern and eastern states viz., Kerala, Karnataka, Tamilnadu, West Bengal, Bihar etc. It is the largest edible fruit in the world and is the national fruit of Bangladesh. Jackfruit, which was considered as heavenly fruit in ancient people in Kerala, has lost its status and it is one of the under exploited fruits of the state today. Being grown without any management practices, the fruit has the potential to be identified as the organic fruit of Kerala. People consumed it mostly as a fruit when ripe but also as vegetable in the unripe stage. It is a rich source of vitamins A, B and C, potassium, calcium, iron, proteins, and carbohydrates and offers numerous health benefits. The fruit's isoflavones, antioxidants and phytonutrients mean that it has cancer-fighting properties. It is also known to help cure ulcers and indigestion. The exterior of the compound fruit is pale green or yellow when ripe. The interior consists of large edible bulbs of yellow, banana-flavoured flesh that encloses a smooth, oval, light-brown seed. There are two main varieties- *Koozha* chakka and *Koozha pazham (Varika)*. In *Koozha* chakka, the fruits are small, fibrous, soft and mushy, but very sweet carpals. *Koozha pazham* is crisp and almost crunchy though not quite as sweet. This form is the more important commercially and is more palatable to western tastes.

Jackfruits mature 3 to 8 months from flowering. When mature, there is usually a change of fruit colour from light green to yellow-brown. Spines, closely spaced, yield to moderate pressure, and there is a dull, hollow sound when the fruit is tapped. Yield varies from a few fruits during first year of bearing and it may be as high as 250 fruits after 15years of age **(**Sharma et al., 1997**).** Unripe jackfruits are cooked as vegetables and ripe jackfruit is eaten raw. Jackfruit chips are prepared from the mature jackfruits.

In every year, a considerable amount of jackfruit, specially obtained in the glut season (June-July) goes waste both in quality and quantity due to lack of proper postharvest technology during harvesting, transporting and storing. Proper postharvest technology for prolonging shelf life is, therefore, necessary. The two main goals of post harvest technology are loss prevention and value addition to the raw food commodities through preservation and processing. A substantial amount of post harvest losses can be prevented through proper value addition.

Preservation of fruits by processing has been the research pursuits of many developed and

developing countries and has yielded quite a number of technologies. However, there has been a little research in the preservation techniques of jackfruit. The market potential of jackfruit can be better exploited if the fruits are made available to the consumers in a ready to eat or cook form throughout the year. Development of processing facilities that can undertake primary processing at producers level can greatly increase the consumer acceptance and demand of jackfruit. Technologies like dehydration for preservation of jack flakes need to be standardized and popularized for ensuring availability throughout the year and for avoiding market glut during season. A proper storage technique can definitely contribute towards quality product and fetch better price and thus improve the financial status of the jackfruit growers in the state which perhaps create a positive influence in state and national economy.

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

1. To study the effect of pretreatments on quality of products.
2. To study the effect of drying on quality of products.
3. Quality evaluation of the dried products in terms of vitamin content, protein content, rehydration ratio, tannin, beta carotene etc.
4. Storage studies of the dried jackfruit.

Chapter II

REVIEW OF LITERATURE

This chapter gives general information on jackfruit, its chemical composition, blanching characteristics, drying, packaging methods and its storage studies. Research done on these aspects are also reviewed and discussed in detail.

2.1 Jackfruit (*Artocarpus heterophyllus* L.)

Jackfruit is native to the rain forests of Western Ghats of India. It is popularly grown in Southern and Eastern parts of India. The plant is a homestead crop or a shade tree in coffee gardens. In India, major states growing jackfruit are Kerala, Assam, Bihar and Tamilnadu. Kerala has the largest area of jackfruit cultivation of about 93000 ha and production around 21lakh tons (FIB 2007). This attractive large tree has glossy, dark green leaves and produces a very large, oval shaped rather unusual looking segmented (spiked) fruit. Jackfruit must be planted in flood free well drained soils **(**Upadhyaya, 2008**).** Jackfruits mature 3 to 8 months from flowering. When mature, there is usually a change of fruit colour from light green to yellow-brown. Spines, closely spaced, yield to moderate pressure, and there is a dull, hollow sound when the fruit is tapped. After ripening, they turn brown and deteriorate rather quickly. Yield varies from a few fruits during first year of bearing and it may be as high as 250 fruits after 15 years of age **(**Sharma et al., 1997).

2.1.1 Propagation

Most common method of propagation followed in jackfruit is through seeds. Seeds loose viability within a short time and hence they should be sown immediately after extraction from ripe fruits. Soaking seeds in NAA (25ppm) for 24hrs enhances percentage of germination and seedling growth. Since seeds will not be true to type and have a juvenile period, vegetative propagation is preferred. Cutting gave 90% success when shoots are etiolated and ringed for thirty days and then treated with IBA (3000ppm)+ferulic acid(2000ppm) (Dhua et al.,1983). Air layering is reported as a better method which gave 100% rooting with IBA treatment. Epicotyls grafting with 3 to 4 months old scion and 5 to 10 days old stocks results in 80 to 90% success under mist in Kerala (Jose and Valsalakumari, 1991).

2.1.2Varieties

In South India, jackfruits are classified as of two general types: 1) *Koozha* chakka, the fruits of which have small, fibrous, soft, mushy, but very sweet carpel; 2) *Koozha pazham*, more important commercially, with crisp carpel of high quality known as *Varika*. These types are apparently known in different areas by other names such as *Barka*, or *Berka* (soft, sweet and broken open with the hands), and *Kapa* or *Kapiya* (crisp and cut open with a knife). The equivalent types are known as *Kha-nun nang* (firm; best) and *Kha-nun lamoud* (soft) in Thailand; and as *Vela* (soft) and *Varaka*, or *Waraka* (firm) in Ceylon. The *Peniwaraka*, or honey jack, has sweet pulp, and some have claimed it the best of all. The *Kuruwaraka* has small, rounded fruits. The *Vela* type predominates in the West Indies (Tankard and Glenn, 1987).

2.1.3 Nutritional values

Jackfruit is good source of vitamins and minerals. Ripe fruit flakes contain carbohydrate, carotene, thiamine, minerals etc. Seeds are rich source of starch. Tree has certain medicinal properties also. It is used for curing inflammation, constipation, and wound healing and skin diseases. Lectine, a natural protein from fruit is used in cancer treatment. An extract of jackfruit called 'Jacaline' inhibited the growth of HIV infection '*in vitro'*. Hot water extracts of leaves improve glucose tolerance level of diabetic persons. A volatile flavour constituent from *varika* type was analyzed by capillary GC. Of the 61 compounds tentatively identified, 23 were esters and 15 were alcohols. Esters and alcohols together are important contributors to the jackfruit aroma (Roy *et al.,* 2002).

Chemical composition of bulbs from 24 different firm-type jackfruit clones was analyzed to study the variability. A wide variation in the Total soluble solid (TSS), acidity, TSS: acid ratio, sugars, starch and carotenoid contents was observed in the bulbs of jackfruit types considered in the present investigation. The results of the study are helpful for attempting crop improvement and selection of superior desirable jackfruit genotypes for bringing to cultivation. (Jagadeesh *et al.*, 2004**)**. The carotenoid composition of jackfruit was successfully determined, where 14 of the 18 identified carotenoids were reported for first time. Differences among batches may be due to genetic and/or agricultural factors. (De Faria *et al.,* 2006**).** The incorporation of jack fruit seed into savory products can be recommended because of its low fat absorption capacity. Since jack

fruit seeds are comparatively cheap, the cost of the product can also be brought down by addition of this protein rich byproduct. (Rajarajeshwari and Jamunaprakash, 1999).

Table 2.1:Nutritional composition of jackfruit

Moisture content (%)	84
Protein(g)	2.6
Fat(g)	0.3
Mineral(g)	0.9
Fibre(g)	2.8
Carbohydrate(g)	9.4
Energy(cal)	51
Calcium(mg)	30
Phosphorus(mg)	40
Iron(mg)	1.7

Source: Gopalan *et al*., 2000

2.1.4 Harvesting

Tender jackfruit comes to the market in spring and continues until summer and is used as a popular vegetable. Common vegetable are scarce and costly at that time of the year, jackfruit enjoys a high demand and premium price (Samaddar, 1985). Cold storage trials indicate that ripe fruits can be kept for 3 to 6 weeks at 52 to 55^0F and relative humidity of 85 to 95%. Immature fruit is boiled, fried, or roasted. The ripe fruit is not liked by many people due to its characteristic flavour, however its seed is cooked and used in many culinary preparations (Siddappa and Bhatia,1955) Little work is done on the biochemical composition of jackfruit seed (Roy and Mithra,1970) The only handicap is copious gummy latex which accumulates on utensils and hands unless they are first rubbed with cooking oil. In south-east Asia dried slices of unripe

jackfruit are sold in the markets. The ripe bulbs, fermented and then distilled, produce potent liquor.

2.2 Pre-treatment studies

Pretreatments such as blanching and quick freezing were given to reduce the rate of biochemical and microbiological changes, brighten the colour and increase shelf life of the product.

2.2.1. Blanching

It is defined as heat treatment given to plant material for inactivating enzymes and killing plant tissues to prevent enzymatic and microbial deterioration. Blanching is required prior to dehydration and freezing of many commodities since temperature associated with dehydration and freezing are insufficient to inactivate enzymes within the product. It prevents discolouration, softening and off-flavour development during subsequent storage. Blanching also has an additional cleaning effect and reduces microbiological load of vegetative cells on the vegetable. Factors influencing blanching are size of product particle, shape of particle, heating medium and duration of process. Various blanching methods include water blanching, steam blanching, vacuum steam blanching, in-can blanching, microwave blanching and hot gas blanching.

Thomas and Gopalakrishnan (1993) reported that green pepper blanched in boiling water for 2minutes gave black colour. The colour could be improved by 15minutes boiling in water.

Doyle *et al*. (1994) reported that boiling and steaming of yam reduced the oxalate levels by 37 and 15% respectively

Eano *et al*. (1995) studied effect of three different blanching methods (progressive immersion in hot water steaming at 90^0C for 150 and 180 sec and microwaving for 75 or 105 sec) on texture of white asparagus. It is suggested that asparagus subjected to microwave blanching before frozen storage should also be treated by immersion in boiling water in order to reduce toughness.

Schyvns and Lin *(*1995) did blanching on 15 selected vegetables and fruits which were processed by conventional procedures with modified blanching conditions. Low temperature long time (LTLT) blanching considerably increases the final firmness of sterilized carrot and

green beans.

Yoo Yang Ja (1995) studied the effect of blanching on retention of minerals on spinach and broccoli. Result showed that in spinach, Na was greatly reduced after two minute blanching were as K, Fe, Ca, Mg, P and Cu decreased gradually as blanching time increased. In broccoli also all minerals decreased as blanching time increased.

Aranguiz *et al*. (1998) studied the effects of blanching on PPO activity and texture of apples. HTST blanching of apple piece caused PPO inactivation and sample softening .PPO inactivation was nominal during immersion in water at 40^0C, but it increased with temperature after 15 minute exposure at 65°C. Samples blanched at 40^0C were softer than those heated at 55^0C in $cacl_2$ solution, thus suggesting PME activation after 15 minutes at 55^0C.

Bognar *et al*.(2002) studied the blanching effect on vegetables. Three vegetables spinach, carrot and bell pepper were blanched conventionally in water and using pulsed microwave at 95 ± 2^0C. The study highlights the potential application of microwave blanching in reducing the loss of valuable nutrients. The study revealed that the temperature and absorbed power levels during microwave blanching was influenced by the vegetable itself, its quality, shape, location in the oven and the microwave power applied.

Kumar and Khurdiya (2002) compared microwave blanching with conventional water bath blanching method. Fully ripened, peeled bananas were blanched in domestic micro wave oven for 3 minute and water bath at 100^0C for 8 minute separately. Enzymatic browning was completely retarded by both blanching treatment.

Dikshith *et al*. (2003) found the effect of blanching was less severe than that of lye peeling on some of the nutritional parameters of aonla fruit.

Karthika *et al*. (2004) osmoses potato slice with different pre treatments. This study conducted that the better colour, flavor and taste was obtained for potato slices with blanching followed by cooking in KMS.

Dahal and Swamylingappa (2004) studied the effect of blanching on the oxalate level in colacasia tuber. They found that blanching the whole colacasia tuber in boiling water and

1%NaCl salt solution for 30 minutes resulted in reducing oxalate content by 15.7% and 13.6% respectively. The reduction in oxalate during blanching may be due to leaching of soluble oxalate.

Singh and Kulshrestha (2006) studied the effect of pretreatments on the preservation of carrot powder. In blanching treatment, the peeled and grated carrots were steam blanched for 1 minute and then immersed in 0.125%KMS solution for 4 minutes. In boiling treatment pieces of carrot were pressure cooked at 10lb psi for 10 minutes. Analysis revealed significantly high levels of β-carotene content and total dietary fibre content in carrot powder prepared by boiling methods.

2.2.2. Studies on quick freezing

It is a method of preservation of food by rapid freezing. If the rate of freezing is low the ice crystal size is large and clusters are also formed leading to physical rupture of cells. Rate of freezing is of importance because rapid or instantaneous freezing produces ice crystals of small size and also minimizes concentration effects of solute by decreasing the time of contact between solutes and food tissues and other constituents. During deep freezing ice crystals are formed within and intercellular spaces. These voids will be maintained even after drying. So there will be better rehydration even after long time storage. Rapid freezing avoid structural change that would affect flavour or appearance of food.

Kuprianoff (1962) recognized that the rate of freezing as critical factor in tissue damage and the conventional slow freezing of fruit and other multicelullar structures as often harmful.

Khan *et al*. (1967) observed that freezing rate considerably alter the rehydration and organoleptic properties of tomato slices and mushroom and suggested that rapid freezing preserves the integrity of muscle tissues to a greater extent than slow freezing.

Brown (1967) showed that rapid freezing in liquid nitrogen resulted in less tissue damage and consequently better texture than conventionally frozen beans.

Sterling (1968),observed that freezing rates has considerable influence on textural characteristics of tissues of apple.

Ramamurthy (1979) conducted studies on the effect of freezing methods on the quality of

freeze dried alphonso mangoes. Result indicated that freezing temperature is the most critical factor affecting the cell structure of mango. Freezing at -20^{0}C or at -40^{0}C results in considerable disruption of cellular structure whereas it was minimal at -10^{0}C.

Alexander *et al.* (1988) conducted an experiment on preservation of volatile components of mango by deep freezing. They stored mango slices for 14 months in a deepfreeze at -15^{0}C and then analyzed for their volatile aroma components. Results were remarkably similar to those obtained for the fresh fruit although the amount of important constituent, car-3-ene was slightly reduced

Butter *et al.* (2002) studied the effect of freezing condition on the quality of freeze-chilled reconstituted mushed potato. The objective was to examine the effect of different freezing conditions (-30,-60and-90^{0}C) on selected quality parameter of potato flakes. Lowering of freezing temperature reduced the time required for freezing, gave a softer product and led to reduction in drip loss.

2.3. Effect of drying on quality

The preservation of fruits by drying involves the reduction of their water content to a point at which the concentration of the soluble solids (sugar, acids, salt etc) has become so high that the material is relatively stable chemically and no longer constitutes a suitable substratum for the growth of moulds, yeast, bacteria etc.The drawback with dried fruits is their tendency to deteriorate in storage, especially if not dried sufficiently, if over-dried, on the other hand, considerable losses of sugar may occur. Various types of driers available are

2.3.1. Tray dryer

The food is spread out, generally quite thinly, on trays in which the drying takes place. Heating may be by an air current sweeping across the trays, by conduction from heated trays or heated shelves on which the trays lying, or by radiation from heated surface.

2.3.2. Fluidized bed dryer

The food material is maintained suspended against gravity in an upward flowing air stream. Heat is transferred from air to the food material, mostly by convection.

2.3.3. Freeze dryer

Material is held on shelves or belts in a chamber which is under high vacuum. Heat is

transferred to the food by conduction or radiation and the vapour is removed by vacuum pump and then condensed.

2.3.4. Rotary dryer

Food stuff is contained in a horizontal inclined cylinder through which it travels, being heated either by air flow through the cylinder, or by conduction of heat from the cylinder walls.

Talburt and Smith (1975) found that the slow dehydration at low temperature gives a hard dense product while use of higher temperature results in a more porous material which rehydrates more rapidly.

Flink (1979) conducted a study about the influence of osmotic dehydration on drying behaviour and product quality of carrot slices. This study indicates that osmotic dehydration can yield good quality product with better texture and colour stability.

Islam and Flink (1982) noted that the moisture removal resistance from osmosed potato significantly increased during air drying.

Rahman and Lamb (1991) reported that effective diffusivity of moisture transport during air drying decreased with the increase of solid gain during osmotic concentration.

Phirke *et al*. (1992) reported that the removal of moisture of chilli from the trays at the lowest position was faster than the upper successive tiers while drying chilli in waste fired drier.

Mclaughlin (1996) found that drying rate increased with increasing temperature.

Vergara *et al*. (1997) analyzed the drying process of apples using the characteristic curve mode. According to this study an increase in temperature reduces the time needed to reach desired moisture content and also moisture transfer rate depends on drying temperature as well as on initial solid content.

Shablana *et al.* (2003) conducted a study on the effect of convective drying on apparent density, porosity and moisture diffusivity of potato and apple. During air drying apparent density of apple and potato varied from 676.2 to 839.6 kg/m^3 and 1214 to 1050 kg/m^3 respectively. In both cases porosity increased with decrease in moisture content. Drying temperature in the range of 60 to 80^{0}C did not have any effect on the degree of pore formation. Within the same

temperature the range of effective moisture diffusivity for potato and apple increased drastically.

Abraham *et al*. (2004) obtained jackfruit drying curves using a convective tray drier at three different drying temperatures. The drying curve enables to predict the moment at which the process should be stopped when the required moisture content has been reached and thus obtaining a good quality product.

Amala *et al*. (2004) conducted the effect of blanching and drying on quality of mace. Blanching of mace followed by drying in an agricultural waste-fired dryer yielded good quality product. Blanching in 75^0C hot water for 2 minutes reduce the drying time by 12.5% and enhanced the colour by 22.06%. Blanched mace acquired a uniform red colour with a glossy appearance.

Behera *et al*. (2006) conducted study on the effect of drying conditions on the quality of dehydrated selected leafy vegetables. Amaranth, curry leaves, drumsticks and spinach were dried in cabinet dryer, solar dryer and low temperature dryer to evaluate the best drying condition for maximum retention of nutrients. Cabinet dryer was good for dehydration of leafy vegetables in respect of higher β-carotene, ascorbic acid, chlorophyll content, better rehydration ratio and less time required for drying with low non-enzymatic browning and less moisture in the product dried in bulk at a time compared to other dryers.

Saxena *et al.*, (2009).had dealt with optimization of osmotic dewatering process. Jackfruit bulbs in pitted and pre-cut form were subjected to a multitarget preservation technique involving water activity (a_w) regulation, acidification, and in-pack pasteurization. The overall shelf-life of multitarget preserved high moisture jackfruit bulbs was found to be 8, 6 and 4 months under the respective storage temperatures of 6^0C, ambient, and 37^0C.

2.4 Quality evaluation of the dried product

Quality evaluation includes texture, colour, nutritional quality etc.

2.4.1 Texture

Texture is a quality attribute that is important for most of the food materials. It is highly critical for those food materials where textural attributes decide their acceptance such as snack

food. It includes those qualities that can feel with the fingers, tongue, the palate or the teeth. Textural characteristics of food have both positive and negative connotations for the consumer. Those textures that are universally liked are crisp, crunchy, tender, juicy and firm. .The subjective method of analyzing the texture of the food materials is by using a texture analyzer.

Segini *et al.* (1999) developed an Instron punch test with a three point support of a potato chip and the factors affecting the results were evaluated. The moisture content and their texture of fried potato chips were determined at oil temperatures of 140^0C and 180^0C. He found out that the maximum force of break was in the 2-4% moisture region.

Wellington and Badri (2003) conducted a study on the quality characteristics of osmo-dehydrated Christophene in syrups. Christophene cubes immersed in 50% sucrose/50% blend of glucose and 100% fructose syrup were more preferred to those in 100% sucrose. Variations in blends of sucrose with glucose/fructose produced changes in colour ('L'), texture, total soluble solids and overall acceptability.

Pedreschi *et al. (*2004) evaluated the texture of fried potatoes. The texture of potatoes with different shapes was evaluated after frying and in some cases after baking. He also conducted a study on blanched and unblanched potato slices at the four oil temperatures: 160,170,180 and 190^0C until reaching a moisture content of 1.7%.The texture was evaluated using a bending test with two support points. The maximum force of deformation and maximum deformation were extracted from the force versus distance curves. It was found that the unblanched potato slices are crisper than blanched chips for moisture content lower than 4%.

Falade and Aworh (2005) reported the study of sensory evaluation and consumer acceptance of osmosed and oven dried African star apple and African mango. It was found that there are no significant differences in all the sensory attributes of oven dried African star apple slices preosmosed in the sucrose solutions. However unosmosed and dried samples received consistent poor scores for all the sensory attributes. There was no significant differences in the quality attributes of preosmosed oven dried African mango except the taste. Consumer's acceptance showed no significant differences in all the sensory attributes of preosmosed African star apples and African mango slices.

2.4.2. Colour

Colour is actually different wavelengths of white light. 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.

Segini *et al*. (1999) compared the relationship between instrumental and sensory analysis of texture and colour of potato chips. The instrumental measurement of puncture test with an Intron Universal testing machine and the parameters fracture force, deformation and stiffness were considered. The instrumental colour quantification was done by computerized video image analysis technique and the colour was expressed as L*a*b* values. Sensory evaluation of texture and colour was performed by a sensory panel especially trained in evaluating potato chips. Discriminated analysis showed that tenderness and crunchiness could predict correctly 90% of the data while fracture force correlated well with all sensory attributes.

Pua *et al.* (2008) had conducted an experiment on storage stability of jackfruit powder packaged in aluminium laminated polyethylene and metalized co-extruded biaxially oriented poly propylene. The total colour difference (ΔE), rates of adsorbed moisture and sensory attributes of drum-dried jackfruit powder packaged in aluminium laminated polyethylene (ALP) and metalized co-extruded biaxially oriented polypropylene (BOPP/MCPP) pouches stored at accelerated storage (38^0C, with 50%, 75% and 90% relative humidity (RH)) were determined over 12 weeks period. The changes in total colour followed zero order reaction kinetics. The powder packaged in ALP significantly ($p < 0.05$) reduced total colour change, rates of adsorbed moisture, lumpiness intensity of jackfruit powder and was rated higher in terms of overall acceptability over BOPP/MCPP.

2.5 Storage studies

2.5.1Packaging materials

When selecting packaging films for fruits and vegetable chips, the main characteristics to consider are gas permeability, water vapour transmission rate, mechanical properties, transparency, type of package and sealing reliability. Traditionally used packaging films like low

density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), ethylene-vinyl acetate (EVA) and oriented polypropylene (OPP) are not permeable enough for highly respiring products like fresh-cut produces, mushrooms and broccoli. But this can be effectively used for packing snacks. Films designed with these properties are called permeable films.

2.5.1.1 Polyethylene

LDPE is heat sealable, inert, odour free and shrinks when heated. It is a good moisture barrier but is relatively permeable to oxygen and is a poor odour barrier. It is less expensive than most films and is therefore widely used for bags, for coating papers or boards and as a component in laminates. LDPE is also used for shrink or stretch wrapping. High-density polyethylene (HDPE) is stronger, thicker, less flexible and more brittle than LDPE and a better barrier to gases and moisture. Sacks made from HDPE have high tear and puncture resistance and have good seal strength. They are waterproof and chemically resistant and are increasingly used instead of paper or sisal sacks.

2.5.1.2 Polypropylene

Polypropylene is a clear glossy film with a high strength and puncture resistance. It has a moderate barrier to moisture, gases and odours, which is not affected by changes in humidity. It stretches, although less than polyethylene. It is used in similar applications to LDPE. Oriented polypropylene is a clear glossy film with good optical properties and a high tensile strength and puncture resistance. It has moderate permeability to gases and odours and a higher barrier to water vapour, which is not affected by changes in humidity. It is widely used to pack biscuits, snack foods and dried foods.

2.5.1.3 Aluminium films

Films are coated with other polymers or aluminium to improve their barrier properties or to impart heat sealability. For example a nitrocellulose coating on both sides of cellulose film improves the barrier to oxygen, moisture and odours, and enables the film to be heat sealed when broad seals are used. A thin coating of aluminum (termed ‘metallization’) produces a very good barrier to oils, gases, moisture, odours and light. This metalized film is less expensive and more flexible than plastic/aluminum foil laminates.

2.5.2 Packaging techniques

2.5.2.1 Vacuum packaging

It is the earliest form of modified atmospheric packaging developed commercially used for products such as meat cuts, cheeses and ground coffee. It is not suitable for bakery products since it causes deformation of the product. The process involves packaging the product in film of low oxygen permeability and sealing after evacuating the air. Under good vacuum conditions the oxygen level is reduced to less than 1%. Due to barrier properties of films used, entry of oxygen from outside is restricted

2.5.2.2 Modified Atmospheric Packaging (MAP)

Modified Atmospheric Packaging is defined as "the packaging of a perishable product in an atmosphere which has been modified so that its composition is other than that of air". MAP is a technique used for prolonging the shelf-life period of fresh or minimally processed foods. In this preservation technique the air surrounding the food in the package is changed to another composition. This way the initial fresh state of the product may be prolonged. The initial flushed gas- mixture will be maintained inside the MA package. If the permeability (for O_2 and CO_2) of the packaging film is adapted to the product's respiration, an equilibrium modified atmosphere will establish in the package and the shelf-life of the product will increase. The principle of MAP involves the removal of air from the pack and its replacement with a single gas or mixture of gases by either passive or active methods, depending upon the type of product.

2.5.2.3 Active modified atmospheric packaging

Active packaging is a group of technologies in which the package is actively involved with food products or interacts with internal atmosphere to extend shelf-life while maintaining quality and safety (Floros *et al.*,1997). The advantages of active modification of micro atmosphere are the rapid establishment of desired gas mixtures. Adsorbents and absorbents may be included in the package system to reduce O_2, CO_2, ethylene and vapour. This kind of packaging is generally used in case of highly perishable goods like minimally processed vegetables and fruits (Labuza *et al.*, 1996).

2.5.2.4 Passive modified atmospheric packaging

The passive atmospheric packaging is also called commodity generated modified atmosphere. In this there is matching of the commodity respiratory characteristics with gas permeability of the packaging system so that a suitable equilibrium micro atmosphere can be evolved (Kader *et al.*, 1988). This is through the consumption of O_2 and evolution of CO_2 in respiration process. This system of packaging can be adopted for some keepable commodities. Passive MAP mainly relies on the selective permeability of the packaging materials to different gases and on product respiration. Normally it is a slow process. The gas flush MAP involved the establishment of the specific gas composition within the package in single stage during the packaging operation, by flushing with the selected gas mixture before sealing.

2.5.3 Gases used in Modified Atmosphere Packaging

The atmosphere in an MA package consists of N_2, O_2, and CO_2. It is the altered ratio of these gases that makes a difference in the prolongation of shelf life. Oxygen is essential when packaging fresh fruits and vegetables as they continue to respire after harvesting. The absence of O_2 can lead to anaerobic respiration in the package which accelerates senescence and spoilage. Too high levels of O_2 do not retard respiration significantly and it is around 12% of O_2, where the respiration rate starts to decrease. So oxygen is used in low levels (3-5%) for positive effect. In the case of vegetables and fruits, CO_2 is not a major factor since CO_2 levels above 10% are needed to suppress fungal growth significantly. Nitrogen is used as filler gas since it neither encourages nor discourages bacterial growth.

Baisya and Bose (1973) conducted studies on the dehydration of dahi (milk curd) by various methods and quality evaluated. They concluded that spray drying and infra-red drying gave products better than from tray drying process. Of all drying process employed freeze drying and air diffusion drying gave better results.

Krishnankutty (1981) conducted an experiment on packaging and storage studies of deep-fat fried *nendran* banana chips. Suitability of flexible packages and inert gas packing in sealed tins for storing fried *nendran* banana chips were investigated. It was found that for banana chips fried in fresh coconut oil, 300 gauge high density polyethylene and 400 gauges low density polyethylene bag packing are satisfactory up to 2 months while packing in tins under CO_2 is satisfactory up to 6 months at room temperature (28-32^{0}C). But banana chips fried in marvo oil

and packed in sealed tins under CO_2 were quite good up to 6 months whereas the chips fried in groundnut oil and packed under similar conditions were inferior in quality.

Tawfik and Huyghebaert (1999) described the interaction of packaging materials and vegetable oils and the stability of oil. The effects of different plastic films polyethylene terephthalate (PET), PVC, PP and polystyrene(PS) on the stability of olive, sunflower and palm oils were studied at 24^0C and 37^0C during 60 days of storage. Their study indicated the major role of plastic permeability in oil stability. The rate of oxidation was not reduced by antioxidant migration from plastic films to oils. Natural antioxidant (vitamin E) retarded the oxidation rate, and this was dependent on its concentration in oils examined. The results showed that the ranking of stability of oil samples is PVC≥PET>PP≥PS. Further, the stability was dependent on the type of oil. Palm oil exhibited high stability properties while the highest oxidation rate was observed in sunflower oil. In addition, increasing storage temperature accelerated the oxidation and limited the stability of vegetable oils.

Sagar *et al.* (2000) studied the storage of dehydrated bitter gourd rings. Storage study of dehydrated bitter gourd rings packed in LDPE 200 gauge, PP 150 gauge and HDPE 200 gauge pouches were carried out for six months at room temperature and low temperature. The study revealed that the moisture and non-enzymatic browning increase with increase in storage period and increase was higher in the samples packed in 150 gauge PP followed by 200 gauge LDPE pouches. They found that the values for chlorophyll, ascorbic acid, rehydration and sensory score were better in the samples packed in 200 gauge HDPE pouch.

Susana *et al.* (2002) reviewed a modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages. Respiration rate and gas exchange through the package material are the processes involved in creating a modified atmosphere inside a package that will extend shelf life of fresh fruits and vegetables. Thus, modelling respiration rate of the selected produce is crucial to the design of a successful Modified Atmosphere Packaging (MAP) system. Factors affecting the respiration rate and respiratory quotient are outlined, stressing the importance of temperature, O_2 and CO_2 concentrations, and storage time. Respiration rate models in the literature are also reviewed.

Sandhya and Singh (2003) carried out studies on modified atmosphere packaging of peas.

The peas were packed in LDPE bags of 25 µm thickness. The shelf life of shelled peas packed in LDPE bags was 45 days, 17 days, 7 days and 4 days when stored at the temperatures of 11,5,15^{0}C and room temperature, respectively, considering the quality indices like total soluble solids, total water soluble sugars, protein, physiological weight loss and decay. The shelf life of peas was 20 days when packed in LDPE bags with 5% CO_2 and stored at the temperature of 5^{0}C. Statistical analysis showed that there is significant effect of temperature and storage period on total water soluble sugar, weight loss and decay of peas.

Dirim *et al.* (2004) studied the modification of water vapour transfer rate of LDPE films for food packaging. To improve the water vapour transfer of the film, zeolite–polymer composite films and perforated films were produced. The overall evaluation indicates that the water vapour transfer rates can be modified by the composite and the perforated films which provide packaging material variety for foods of different moisture content. The available polyethylene area is reduced by the presence of solid particles and these solid particles have an important sorption property. This leads to the increasing water vapour transfer rates by the perforated films. The solid– polyethylene composite films showed less permeability to water vapour than the polyethylene film.

Roopa *et al.* (2006) evaluated the effect of various packaging materials on the shelf stability of banana chips. Stability of banana chips packed in PE, PP, paper aluminium foil polyethylene laminate, PP/nylon/PP and metalized polyester and stored at 5^{0}C, ambient (19 to33^{0}C) and 37^{0}C were determined. Slices (2.4mm thick) of banana were fried in coconut oil for 5 minutes at 150^{0}C, cooled and packed. Sensory evaluation showed that banana chips stored after packing in PE and PP were acceptable up to 3 months while those in PFP, PP/nylon/PP and MP were acceptable up to 4 months stored under ambient temperature at 37^{0}C.

Kaliyan *et al*. (2007) conducted a study on applications of carbon dioxide in food and processing industries. Carbon dioxide as high pressure gas and supercritical fluid would find a niche in food and processing industries in the future especially in applications involving non-thermal sterilization and supercritical extraction due to its inertness, non-explosiveness, non-corrosiveness, high volatility, cooling ability, and low cost characters.

Mohammed and Wickham (2007) conducted an experiment on shelf life of bitter gourd

through the use of reduced temperature and polyethylene wraps. They were stored individually wrapped in LDPE film or unwrapped for up to 21 days at 5–7^{0}C, 20–22^{0}C and 28–30^{0}C respectively. Assessment was done on several quality parameters including marketable quality. Storage of film-wrapped fruit at 5–7^{0}C resulted in extension of shelf-life in excess of two weeks and delayed appearance of chilling injury symptoms. Additionally, film-wrapped fruits stored at 5–7^{0}C were still marketable after 21 days, had lowest fresh weight losses, less softening, reduced incidence of post harvest rots and minimal changes in vitamin C content and pH. Storage of individually wrapped fruits at reduced temperatures therefore offers an effective method of prolonging the shelf-life of bitter gourd.

Wang *et al*. (2007) conducted a study on keeping quality of fresh-cut bitter gourd at low temperature of storage. Bitter gourd is chilling sensitive and usually cannot be stored at a low temperature for a long period. Whole and cut bitter gourds were placed in polyethylene pouches and stored at 2 or 100C. The results showed that the cutting enhanced the microbial growth, loss of chlorophyll starch and ascorbic acid and increased reducing sugar content, ethylene production and respiration rate of bitter gourd. The decrease of chlorophyll starch, soluble protein and ascorbic acid in the cut bitter gourd was significantly reduced. No significant indication of chilling injury in the cut or intact bitter gourd was observed during the storage for 7 days at 20C. These results suggested that fresh-cut bitter gourd can be stored at 20C to maintain its quality with high levels of ascorbic acid, chlorophyll soluble protein and microbiological safety.

Molla *et al.* (2008) found out a suitable preparation technique of quality jackfruit chips and their good packaging. Fruit's slices were treated with preservative and firming agents, pricked, blanched and then processed. Fried chips were packed in three packaging materials namely; metalex foil pouch, high density polyethylene and polypropylene pouch. A taste-testing panel for different sensory attributes using a 9- point hedonic scale tasted the fresh and stored chips. The result of sensory analysis during the two months storage showed that the chips packed in metalex foil pouch secured the highest sensory score followed by HDPE pouch and polypropylene pouch.

Chapter III

MATERIALS AND METHODS

This chapter mainly deals with the materials used and methods followed for the preservation of jackfruit. The various pretreatments and dehydration methods involved during the processing are listed below:

3.1 Test Sample

Tender, mature and ripe jackfruit procured from the Instructional Farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur were the samples selected for study.

The outer skins of the fresh jackfruit were peeled off and cut into pieces. Seeds were removed before slicing, in case of mature and ripe jackfruits. The compositions of the fresh sample were found out as per standard procedure.

Three samples of the jackfruit approximately weighing 10g each were taken. These were sliced shortly and put in petridishes labelled accordingly. Initial weights of the petridishes were noted. These were placed in the oven for drying at 70 $\pm 1^0$C. Drying process was continued till constant weight achieved. The dry weights of the samples were taken and moisture content was calculated using the equation (Chakravarthy, 2000)

$$\text{Moisture (\%wb)} = \frac{Ww}{W} \times 100$$

Where,

Ww = Weight of water, g

W = Initial weight of the sample, g

3.2 Pre treatments

Pretreatments such as blanching and quick freezing were conducted prior to drying to enhance rehydration, prevents discolouration and off flavor development during storage.

3.2.1 Blanching

Blanching is the heat treatment given to plant materials prior to further processing for inactivating enzymes and killing plant tissues to prevent enzymatic and microbial deterioration.

Generally, it is given prior to dehydration and freezing. Conventional method of blanching was conducted in this study. Turmeric powder was mixed with water at the rate of 5 gm per litre to enhance the appearance. The samples were blanched by dipping in turmeric water at 100^0C for 1 minute, 2 minutes and 4 minutes. After blanching, the hot water was drained and the samples were placed on a Whatman No.4 filter paper to drain the excess water.

Plate.3.1: Blanching of matured jackfruit

The different treatments conducted during blanching are:

- W1 -test samples blanched in turmeric water at 100^0C for 1min.
- W2 -test samples blanched in turmeric water at 100^0C for 2min.
- W3 - test samples blanched in turmeric water at 100^0C for 4min.

The sliced jackfruit without blanching kept as the control.

3.2.2 Quick Freezing

Quick freezing is a method of increasing the shelf life of perishable foods by subjecting them to conditions of temperature low enough to inhibit the oxidative, enzymatic and microbial changes, which are responsible for the changes in flavour and colour of foods. At low temperature, there is a physical change within the food by conversion of the moisture in it, into ice crystals. This helps to capture the biological condition of fresh food at a point at which it is frozen, and thereby presents the same flavour, colour and taste of food on its defreezing or thawing. The blanched samples were frozen by placing in a deep freezer at temperatures of -10^0C and -20^0C for 1 hr, 3 hr. The frozen samples were then allowed to thaw at room temperature.

Plate.3.2: Deep freezer

The different treatments conducted during quick freezing are:

- F1 - the blanched samples kept in a deep freezer at -20^{0}C for one hour.
- F2 - the blanched samples kept in a deep freezer at -10^{0}C for three hour.
- F3- the blanched samples kept in a deep freezer at -20^{0}C for three hour.
- F4- the blanched samples kept in a deep freezer at -10^{0}C for one hour.

The jackfruit slices neither blanching nor deep freezing kept as the control.

3.3 Drying

To study the drying characteristics of jackfruit a series of preliminary experiments were conducted in a RRLT-NC dryer, solar dryer and traditional sun drying. But the qualities of the sun and solar dried products were very poor due to the variability in solar radiation. Hence mechanical drying alone was selected for this study. The jackfruit samples after thawing were dried in a RRLT-NC drier (Regional Research Laboratory Trivandrum-Natural Convection dryer) as shown in Plate3.3. Drying was accomplished by vaporizing the water that is contained in the food. 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. Perforated trays are arranged one above the other in the drying chamber. All the sides

of drier chamber, except the bottom side are 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 and 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 is 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 gets dried. The driers are simple in design, easy to operate, energy utilization is maximum.

The treated jackfruit samples were kept in RRLT-NC drier at different temperatures viz., 50, 60 and 70^0C till the moisture content of the dried sample was in the range of about 12% ± 0.5 (w.b.). The time taken for each sample to reach this range of moisture content was noted. After the dryer reached steady-state conditions for the set points (at least 30 min), the samples were distributed uniformly in thin-layer. Each sample utilised in the experiment weighed 100 ± 2 g. The weight loss was recorded at every 15 min. Drying process was stopped when the moisture content of the samples was about 12% ± 0.5 (w.b.). The dried products were cooled and packed in poly propylene (PP 200 gauges), low-density polyethylene (LDPE 400 gauges) and laminated film (100 gauge). The experiments were replicated three times.

The different treatments conducted during drying are:

- D1- treated samples dried at 50^0C.
- D2- treated samples dried at 60^0C.
- D3- treated samples dried at 70^0C.

The jackfruit slices without blanching and freezing were directly taken for drying in a RRLT-NC dryer kept as the control sample

Plate 3.3: RRLT-NC drier

3.3.1 Standardization of the drying temperature

The drying characteristics of jackfruit were evaluated from the data of moisture removed with respect to time. A graph was plotted with time as abscissa and moisture content (wb) as ordinate and drying curves for control sample and samples dried at 50, 60 and 70^{0}C were drawn. From the graph, time required for the samples to reduce the moisture content to predetermined level could be found out. The drying temperatures were standardized based on the following factors.

3.3.1.1. Appearance

The colour, odour, crispness, brightness etc of dried samples (control, tender, mature and ripe jackfruit) were carefully examined by physical observation.

3.3.1.2. Rehydration ratio

The dried samples (control, tender, mature and ripe jackfruits) were subjected to water absorption studies. Rehydration characteristics of dehydrated product are of great importance and are expressed in terms of rehydration ratio. About 5gm of dried product were immersed in boiling water for 5 minutes after which contents were filtered through Whatman No.4 filter paper. The weight of the sample retained on the filter paper was recorded as rehydrated weight. The rehydration ratio (RR) was then computed as the ratio of weight of rehydrated sample to that of dehydrated sample. Instead of water, sugar syrup was used for rehydration of ripened sample (Lin *et al*,2005).

$$\text{Rehydration ratio} = \frac{W\,2}{W\,1}$$

Where,

W_2= Weight of rehydrated sample, g

W_1=Weight of dehydrated sample, g

3.4 Quality evaluation of the dried jackfruit sample

Quality assessment of the dried jackfruit samples were evaluated in terms of rehydration ratio, protein content, vitamin C, tannin, texture, colour and organoleptic evaluation.

3.4.1 Rehydration ratio

Rehydration ratio was calculated as discussed in 3.3.1.2

3.4.2 Estimation of protein

Plate 3.4: Protein estimator

100 mg of sample were weighed and transferred to a 30ml digestion flask. 2g potassium sulphate, 90mg mercuric oxide and 2ml conc.H_2SO_4 were added to the digestion flask. Boiling chips/glass beads were added and the sample was digested till the solution became colourless. After cooling the digest, it was diluted with a small quantity of distilled ammonia-free water and transferred to the distillation apparatus. The kjeldahl flasks were rinsed with successive small quantities of water. 100ml conical flask containing 5ml boric acid solution with a few drops of

mixed indicator were placed with the tip of the condenser dipping below the surface of the solution.10ml of sodium hydroxide-sodium thiosulphate solution to the test solution in the apparatus. Distill and collect the ammonia on boric acid. Rinse the tip of the condenser and titrate the solution against the standard acid until the first appearance of violet colour the end point. Run a reagent blank with an equal volume of distilled water and subtract the titration volume from the sample titre volume.

$$\text{Protein content in g\%} = \frac{\text{Titre value} \times 1.4007 \times 0.1 \times 6.25}{\text{Sample weight in g}}$$

3.4.3. Estimation of vitamin C.

Vitamin c was found out by 2, 6-dichloro phenol indophenol method. Ascorbic acid reduces the 2, 6-dichloro phenol indophenols dye to a colourless leucobase. The ascorbic acid gets oxidized to dehydro ascorbic acid. Though the dye is a blue coloured compound, the end point is the appearance of pink colour. The dye is pink coloured in acid medium. Oxalic is used as the titrating medium.5ml of standard sample was pipette out into 50 ml standard flask and made up to mark with oxalic acid. 5ml of this was pipette out and titrated against the dye and end point was the appearance of pale pink colour. The titration was repeated for concordant values.

$$\text{Amount of ascorbic acid in mg/100gm of sample:} \quad \frac{0.5\text{mg} \times V_2 \times 100\text{ml} \times 100}{V_1 \times 5 \times 100\text{mg.}}$$

3.4.4Estimation of tannin

0.5gm of the powdered material were weighed and transferred to a 250ml conical flask. 75ml of water was added. The flask was gently heated and boiled for 30 minutes and centrifuged at 2000rpm for 20 minutes. The supernatant was collected in 100ml volumetric flask and made up the volume.

1ml of the sample extract was transferred to a 100ml volumetric flask containing 75ml water and shaken well. The absorbance was read at 700nm after 30min. A blank was prepared with the water instead of sample.

3.4.5 Objective analysis

3.4.5.1 Texture profile analysis

Textural properties of the product was carried out on dried jackfruit samples using a food texture analyzer (Stable Micro Systems, UK) (Plate3.5). The dried samples were compressed using a cylindrical probe under measure force in compression mode with a test speed of 0.5 mm/sec. From the force deformation curves, the peak force is designated as hardness and area under the curve as toughness.

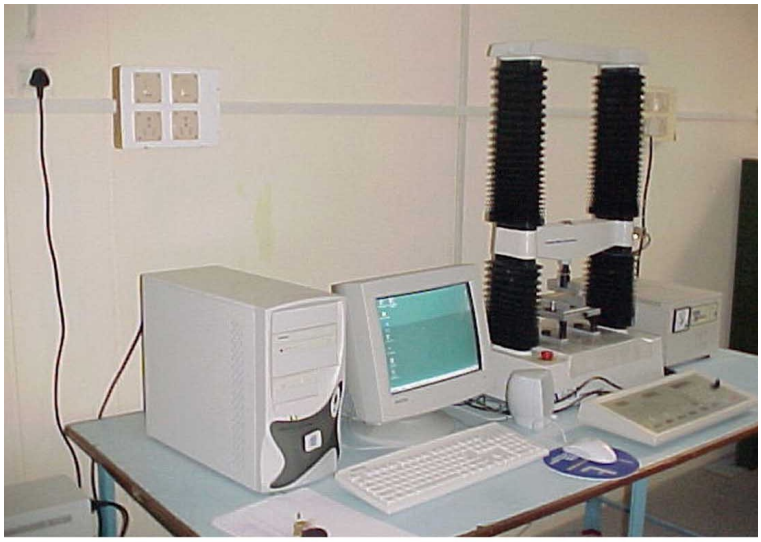
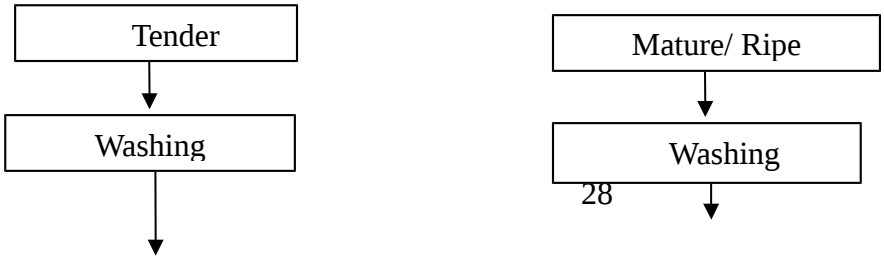


Plate 3.5: Texture analyzer

3.4.5.2 Colour

The colour was measured using a Hunter colorimeter. It was set up to operate in reflectance mode, with an observer angle of 10^0 to record L*, a* and b* values. The L* value represents relative colour brightness ranging from total black (L*=0) to total white(L*=100). The a* value represents the colour hue ranging from red(+) to green(-). The b* value represents the colour hue ranging from blue (-) to yellow (+).The instrument was standardized each time with a white and black ceramic plate. The final dried jackfruit samples were broken into small pieces and was inserted in a 10 cm^3 transparent cell and the L*, a* and b* values were measured.



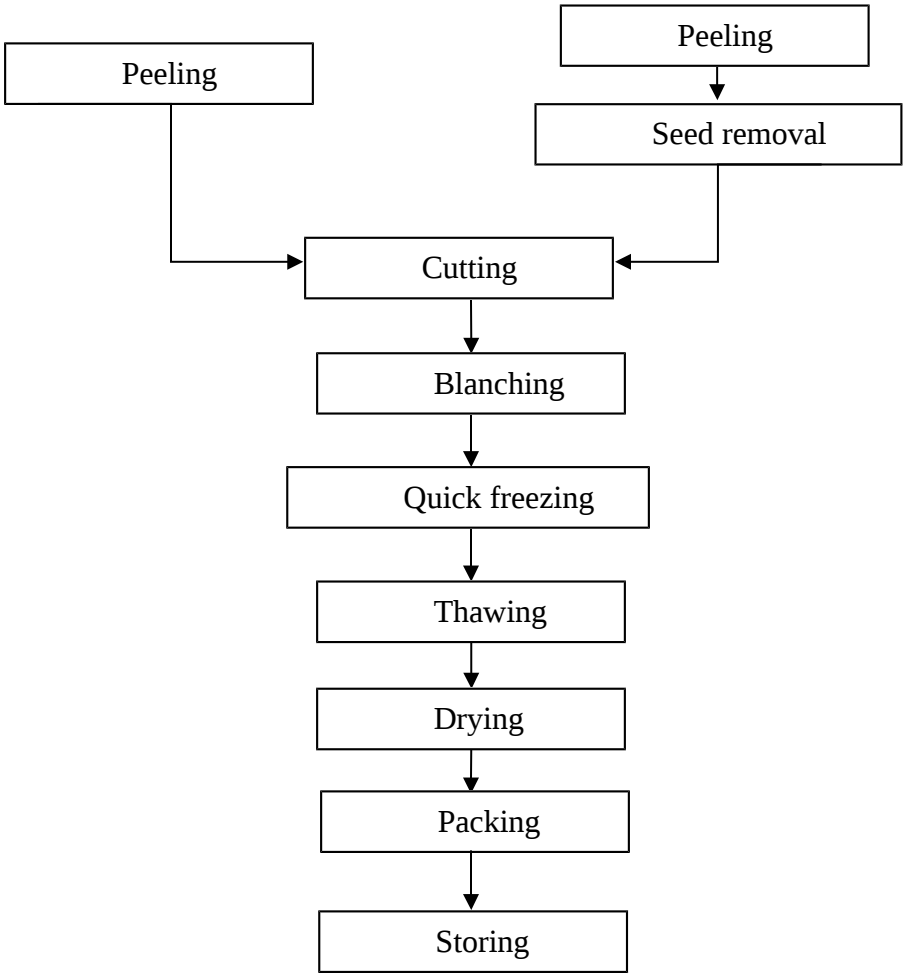


Fig3.1:Flow diagram of jackfruit preservation

3.5 Storage studies of dried jackfruit

In order to standardize the suitable packaging material to enhance the shelf life of dried jackfruit, the samples were put in bags made of Low-density polyethylene (LDPE 400 gauges) Polypropylene (PP 250gauges) and aluminium foil(100 gauge). The dried samples (tender, mature and ripe jackfruit) were packed in the three different plastic materials. The packets were sealed using the hand sealing machine. The storage study was conducted for six months.

The dried jackfruit were packed in

- P1 - Low-density polyethylene (LDPE 400 gauges)
- P2 - Polypropylene (PP 200gauges)
- P3 - Aluminum foil.

Plate 3.6 Vacuum packaging machine

A sample of 10g each was packed in the above said packages. The various packaging techniques conducted were 1) Massive MAP 2) Active MAP and 3) Vacuum packaging. Vacuum packaging machine was employed for active MAP and vacuum packaging whereas ordinary sealing machine was used for passive MAP. The packed samples were kept inside a wooden box. For every 15 days interval, the packets were examined for the microbial attack. Also the quality of the stored product was assessed in terms of rehydration, protein, tannin, texture, vitamin C.

3.5.1. Subjective method

The rehydrated jackfruit after cooking was taken for sensory evaluation by a panel of 10 expert judges. Different attributes that is appearance, colour, texture, flavour and taste were observed by a 5-point hedonic rating scale.

The following 5- point hedonic scale was used for the purpose.

5- Excellent

4-Very Good

3-Good

2-Poor

1-Very Poor

The samples were arranged in tables with specific codes. The scale was easily understood by each of the panelist and their response was converted to numerical values for computation purposes. Final results were obtained by calculating the average of all the marks given by panelist. Analysis for the product appearance, texture, taste, flavour, colour were performed individually using one way ANOVA and Tukey's post- ANOVA test.

3.5.2 Microbial analysis

A portion of the infected samples were scraped with a blade and placed in a test tube containing distilled water and shaken well. It becomes turbid if the sample were infected with bacteria. An expert could easily observe through microscope the bacterial attack if the infected samples are placed on a slide with a few drops of water. The scraped samples were also put in a polythene bag with few drops of water. After blowing air the bag were tied and kept undisturbed. The bag would be completely filled with mould growth if the samples were infected with fungus. If the preliminary tests were positive further tests for identifying the species were carried out as follows.

3.5.2.1. Serial dilutions test:

This method is used for quantitative estimation of microbial cells in a known volume of original sample. In this method the organism that is present in large numbers in the mixture was isolated.

10g of the sample was taken and dissolved in 90ml of sterile water in a 250 ml conical flask and mixed thoroughly with a shaker to give 1: 10 (10^{-1}) dilution of original sample i.e., the original sample has been diluted to 1/10th. From these solutions, was taken and it was added to 9 ml of sterile water which gave 1: 100 or 10^{-2} dilution of original sample. Similarly we prepared 1: 1000(10^{-3}),1: 10,000 (10^{-4}), 1: 10, 0000 (10^{-5}) and so on dilutions of the original sample up to 10^{-6}. Media were prepared for the determination of different microorganisms like bacteria and fungus. Nutrient agar and potato dextrose media were used for bacteria and fungus respectively. For bacteria it was diluted up to 10^{-6} and for fungus up to 10^{-3} .Finally one ml of required dilution (depending on the type of micro organism) was added to a sterile petridish to which prepared

9ml of sterile, cool, molten medium was added. For each organism 3 replications were prepared for getting more accuracy. The dishes were incubated at suitable temperature. Within few days colonies of each kind of microbes grew in the dish. The number of colonies of each kind was counted. This number was then multiplied by the dilution factor to find the total number of cells per ml of the original sample.

The number of bacteria on the surface was estimated by the following formula

B = N/D

Where, B = number of bacteria N = number of colonies counted on a plate D = dilution factor (either 1, 10 or 100)

In a dilution, the dilution factor is equal to the ratio of final volume of solution to the

initial volume of the solution. But for serial dilution it is a product of the individual dilution factor

3.5.2.2. Colony Forming Unit (CFU)

In microbiology, colony-forming unit (CFU) is a measure of viable bacterial numbers. Unlike in direct microscopic counts where all cells, dead and living, are counted, CFU measures viable cells. By convenience the results are given as, colony-forming units per millilitre. The theory behind the technique of CFU establishes that a single micro organism can grow and become a colony, via binary fission. These colonies are clearly different between each other. However, some microorganisms do not separate completely during the sample preparation process and the results of the count will be below the number of individual cells using direct methods.

The equipments used for the aforesaid purpose are glass wares, hot air oven, autoclave, rotary shaker, microwave oven and laminar air flow.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter enunciates the various experiments conducted to standardize the drying process and the various parameters involved. The chapter also discusses in detail the storage of the dried jackfruit along with the quality aspects of the stored jackfruit.

4.1 Test samples

Tender, mature and ripe jackfruit procured from the Instructional Farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur were the samples used for study**.** Peeling and slicing of the test samples were done uniformly. The initial moisture content and jackfruits composition per 100 gram edible portion were found out and described in Table 4.1.

Table 4.1: Composition of the jackfruit of different maturity levels

	Tender	Mature	Ripe
Moisture content (%)	80.23	77.25	72.39
Protein (g)	7.6	4.3	3.2
Vitamin C(mg)	12.14	12.83	11.62
Tannin (mg)	0.14	0.11	0.17

The composition of tender, mature and ripe jackfruit was found out as per chapter III. The moisture content of tender, mature and ripe jackfruit was estimated as 80.23, 77.25 and 72.39% respectively. The protein content decreased with maturity level. Maximum value of 7.6g found in tender jackfruit and a minimum value of 3.2g in ripe samples. Mature jackfruit had the maximum value of vitamin C as compared to other maturity levels. In tannin content, ripe jackfruit had the maximum value of 0.17mg and mature sample had the least value of 0.11mg.

4.2. Effect of Pre Treatment on Quality of Jackfruit

Jackfruit samples were subjected to various pretreatments viz., blanching and quick freezing. An investigation on the effect of various pretreatment methods on the quality of the dried jackfruit was done. The details are discussed below.

4.2.1. Studies on Blanching

Jackfruit slices of uniform thickness were subjected to blanching as per chapter III. The samples blanched for four min appeared to be cooked. No colour variations were observed among the samples blanched for 1, 2 and 4 min. Hence, by visual observation the best one among these treatments could not be found out.

4.2.2. Studies on Quick Freezing

The blanched samples were quick freezed at -10 and -20^{0}C for 1 and 3 hours. The best freezing temperature could not be found out visually because all the samples after this treatment were similar in appearance.

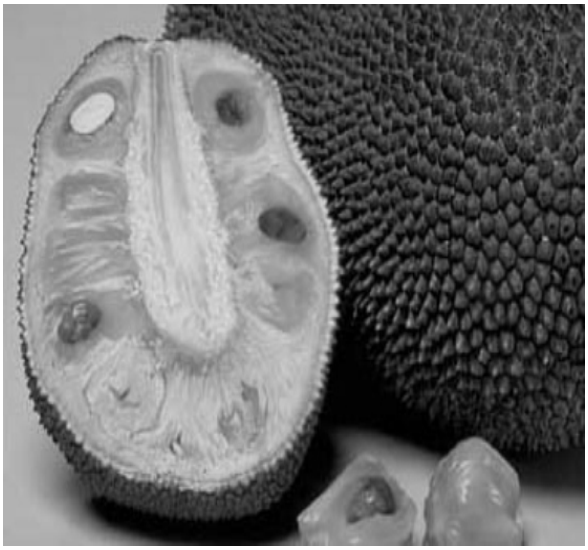


Plate 4.1: Fresh jackfruit

Plate 4.2:sliced samples

4.3 Effect of Drying on Quality of Jackfruit

Drying is the major food processing operation in the food industry for the removal of water from a product. It leads to an improvement in the quality of output and extent the shelf life of foods by a reduction in water activity.

4.3.1 Standardization of the drying temperature

The drying was carried out using RRLT-NC dryer using three different temperatures- 50, 60 & 70^{0}C for control samples, pretreated tender, mature and ripe jackfruits. The data on moisture content present versus drying time were plotted for all samples at 50, 60 and 70^{0}C and for control sample at 60^{0}C. During the first hours of drying there is a sudden decline in moisture content. This is due to evaporation of moisture from the surface. After that there is a decrease in drying rate. This is due to time taken for diffusion of moisture from the interior to the surface. From the Fig4.1, it was observed that in tender jackfruit, at 60^{0}C the time taken for reducing the moisture content to 11.35% (wb) was 4 hours 15 min. for treated sample but for control sample moisture reached only 20.83% after this time. The increased drying rate of pretreated samples may be due

to better rigidity of the structural components and porosity of the products during blanching (Rahman and Lamb,1991) Similar trends were observed in mature and ripe jackfruit samples also.

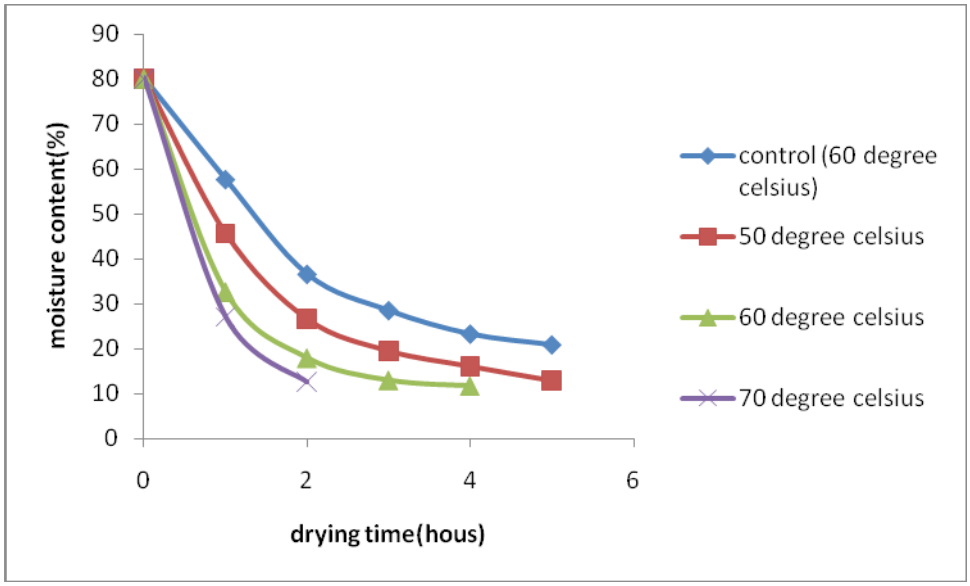


Fig.4.1:. Drying curve of tender sample

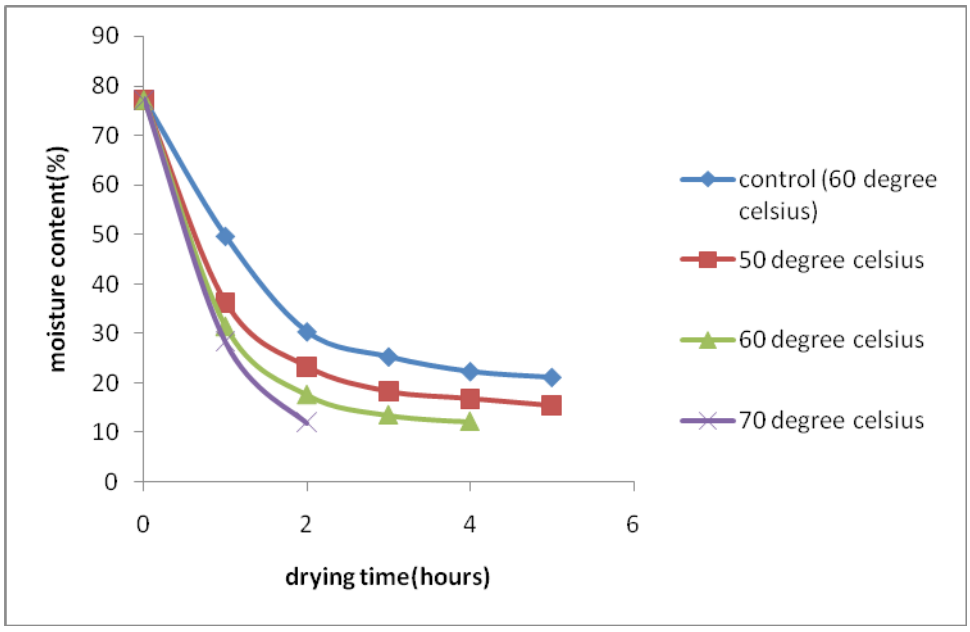


Fig.4.2: Drying curve of mature sample

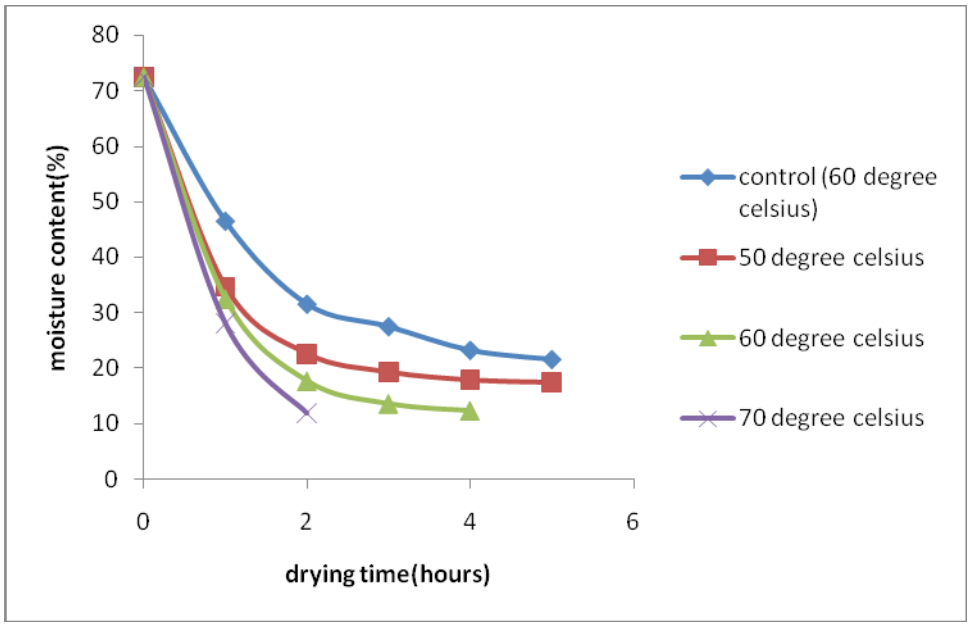


Fig.4.3: Drying curve of ripe sample

The drying at 60^{0}C was standardized for mature, tender and ripened jackfruit based on the following results

4.3.1.1. Appearance of the dried product

Visual observation was carried out in terms of colour, brightness, hardness etc. The colour and brightness of all the control samples were found poor. Also, the dried products were too hard and brittle and hence they were discarded. In treated samples, it was found that the dried samples at 50^{0}C maintained good color and brightness but were found too hard and brittle. Similar study was conducted in carrots by Talburt and Smith (1975) and found that, the colour of the sliced carrot dried at 50^{0}C got good appearance, but it consumes more time and slow dehydration at low temperature gives a hard dense product. The pretreated samples dried at 70^{0}C became darker. Blackened scorches were also observed in ripened sample at 70^{0}C. This may be due to the formation of non enzymatic browning compounds and extractable colour at higher drying temperature (70^{0}C). The colour and brightness of the treated samples dried at 60^{0}C were found to be good with an average hardness. The best blanching time and freezing time got at 2 min and 3 hour. Blanching in hot water for 2 minutes enhanced the colour (Amala Dhas *et al.*, 2004). So blanching at 100^{0}C for 2 min, quick freezing at -10^{0}C for 3 hours and drying at 60^{0}C was

selected to be the best treatment for all the samples (tender, mature and ripe jackfruits). Confirmations of this result were done by performing sensory evaluation.

4.3.1.2 Rehydration ratio

One of the problems in hot air drying of fruits and vegetables is the irreversible damage to the structure that can occur leading to shrinkage as well as slow and incomplete rehydration. The rehydration ratio was affected significantly by the pretreatments and drying temperatures. In control samples, the value of rehydration ratio was found low. The rehydration ratio increased slightly with increase in blanching and freezing time, but decreased with increase in drying temperature. It may be due to detrimental effect of temperature that caused the caramelization of sugar, and thus resulted into the clogging of pores on the surface. This leads to lower diffusion of water through the surface during rehydration. Maximum value of rehydration ratio was obtained at a blanching time of 2 minutes at 100^0C, freezing time of 3hours at -10^0C drying temperature of 50^0C. The rehydration ratio values at 50^0C were slightly greater than the values obtained at 60^0C (table 4.2), but the drying time taken was longer than drying at 60^0C. So blanching at 100^0C for 2 min, quick freezing at -10^0C for 3 hours and drying at 60^0C could be considered optimum for obtaining a high quality product for all the samples (tender, mature and ripe jackfruits).

Table 4.2: Rehydration ratio of dried jackfruit samples at different temperatures

Sample	Tender			Matured			Ripened		
	50^0C	60^0C	70^0C	50^0C	60^0C	70^0C	50^0C	60^0C	70^0C
Control	2.79	2.7	2.57	2.26	2.2	2.14	1.27	1.23	1.12
Treated sample (Blanching time 2 min Quick freezing-10^0C for 3hours)	3.31	3.22	2.89	2.64	2.59	2.32	1.69	1.6	1.47

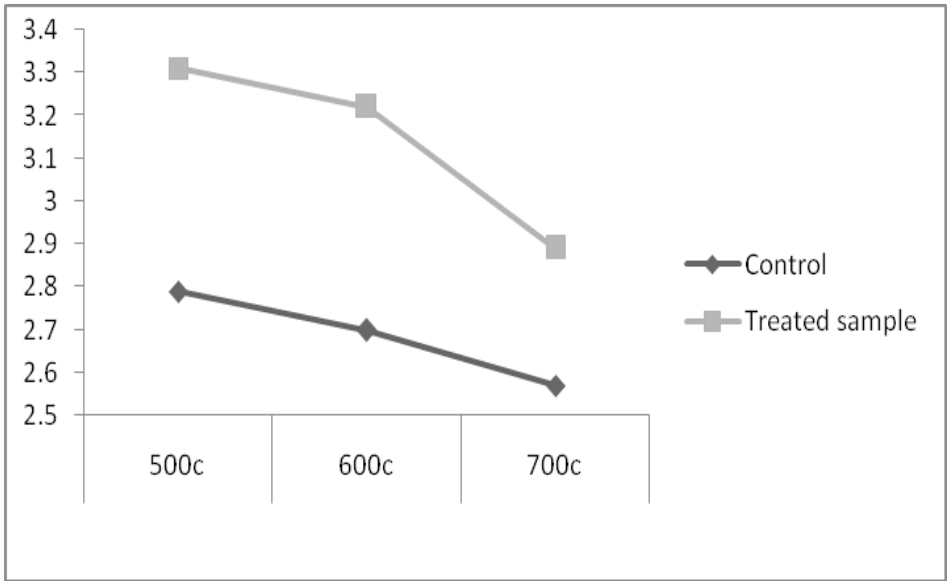


Fig4.4: Rehydration ratios of tender samples as affected by drying temperatures

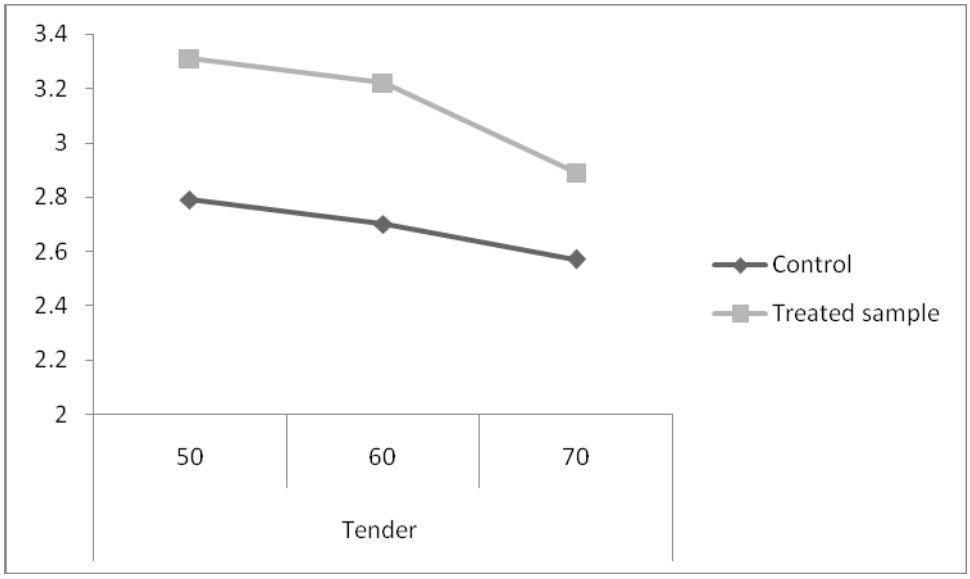


Fig4.5: Rehydration ratios of matured samples as affected by drying temperatures

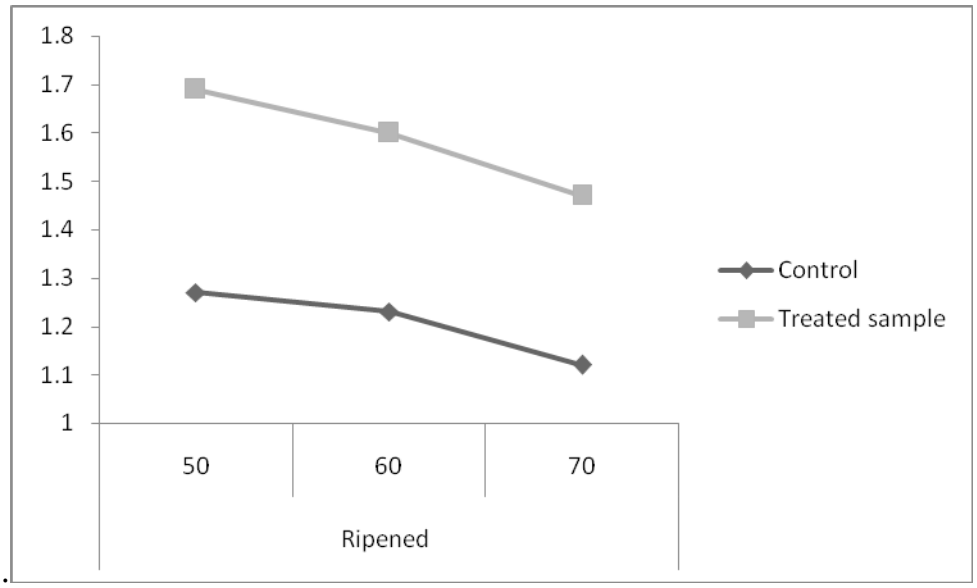


Fig4.6: Rehydration ratios of ripened samples as affected by drying temperatures

4.4 Quality evaluation of the dried jackfruit samples

The quality of the dried jackfruit was assessed in terms of moisture content, rehydration ratio, protein, vitamin C, tannin, texture, colour and sensory evaluation.

4.4.1 Moisture content

The moisture content of tender, mature and ripe jackfruits were 80.23%, 77.25% and 72.39%. After drying at a temperature of 60^0C, the moisture content values of samples reduced to 11.35%, 12.24% and 12.3%. The corresponding time required for the removal of moisture content were 4 hrs 15 min, 4hrs 10 min and 4hrs 05 min respectively.

4.4.2 Rehydration ratio

Rehydration ratios of dried tender, mature and ripe samples are shown in Fig 4.1, 4.2, 4.3. The rehydration ratio values of control samples were very poor as compared with the treated samples. The treated sample showed better rehydration due to pretreatments provided prior to drying. Khan et al.(1967) also observed that freezing rate considerably alter the rehydration of mushroom and suggested that rapid freezing preserves the integrity of muscle tissues to a greater extent than slow freezing. The rehydration ratio values of control samples (tender, mature and ripe jackfruit) dried at 60^0C were 2.7, 2.2 and 1.23. The corresponding values of treated sample were 3.22, 2.59 and 1.6 respectively.

Plate 4.3: Sample before and after rehydration

4.4.3 Protein

The protein content of the tender, mature and ripe samples are shown in table4.3

The protein content of the fresh tender, mature and ripe samples were 7.6, 4.3 and 3.2%. After drying at 60^0C the protein content has been observed as 7.52, 4.26 and 3.14 respectively. There is not much change in the protein content after drying. Mota *et al.* (2009) also observed that some chemical components such as protein are not affected during convective drying of the onions.

Table 4.3 Protein content (g%)before and after drying

Samples	Fresh sample	After drying at 60^0c
Tender	7.6	7.52
Mature	4.3	4.26
Ripe	3.2	3.14

4.4.4 Vitamin C

The vitamin C content of the tender, mature and ripe samples before and after drying are tabulated in Table 4.4.

Vitamin C content has been decreased from 12.14 to 8.5 mg in tender, 12.83 to 9.20 mg in mature and 11.62 to 8.85 mg in ripe samples during drying. The decrease in vitamin C content may be mainly due to pretreatments. Seung *et al*. (2000) observed that blanching reduces the

vitamin C content during processing of horticultural crops.

Table 4.4 Vitamin C(mg) before and after drying

Samples	Fresh sample	After drying at 60^0C
Tender	12.14	8.50
Mature	12.83	9.20
Ripe	11.62	8.85

4.4.5 Tannin

The tannin content of the tender, mature and ripe samples before and after drying are represented in Table 4.5.

Table 4.5 Tannin content (mg%) before and after drying

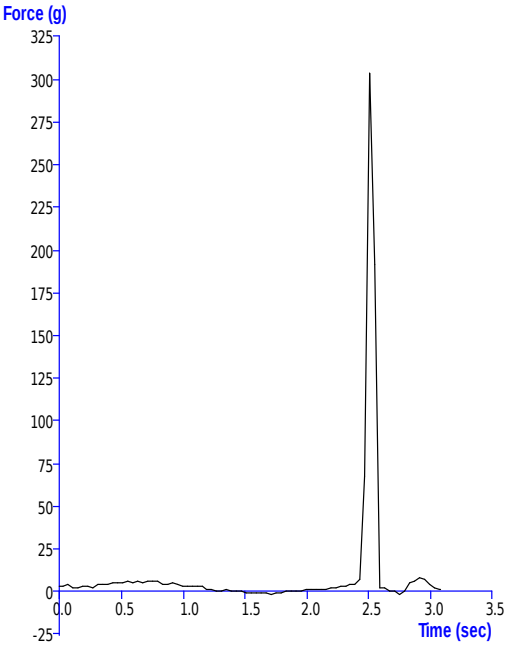
samples	Fresh sample	After drying at 60 ^{0}C
Tender	0.14	0.009
Mature	0.11	0.009
Ripe	0.17	0.019

The tannin content of the fresh tender sample are found to be 0.14 mg. This has been decreased to 0.009 mg during drying. Similar trend were also observed during drying of mature and ripe jackfruit.

4.4.6 Objective analysis

4.4.6.1. Texture

The texture characteristics of dried jackfruit in terms of hardness were measured using a Stable Micro System TA-XT2 texture analyzer fitted with a 5mm cylindrical probe. Compression tests have been more widely reported for fruits and vegetables than tensile tests. The presence of air cells within many fruits and vegetables has a significant effect upon the results of such tests. Hardness value was considered as mean peak compression force and expressed in Newton. The studies were conducted at a pre test speed of 1.0 mm/s, test speed of 0.5 mm/s, distance of 10 mm and load cell of 5 kg.



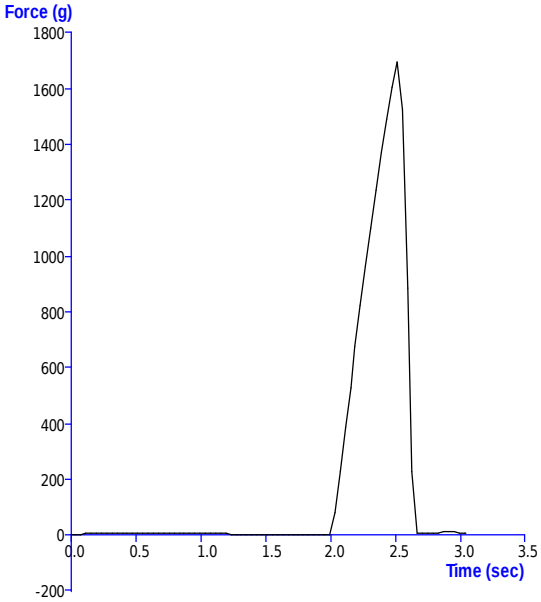
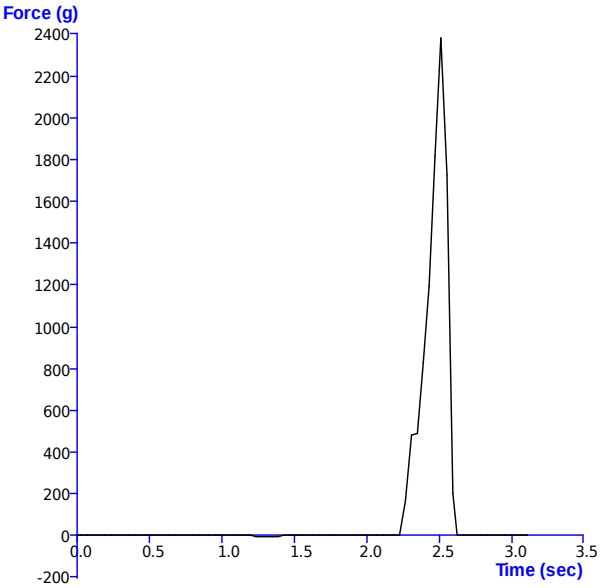


Fig4.7Force-Deformation curve-control sample ***Fig 4.8Force-Deformation curve-treated sample***

Typical Force-Deformation curves for the texture analysis of tender jackfruit samples



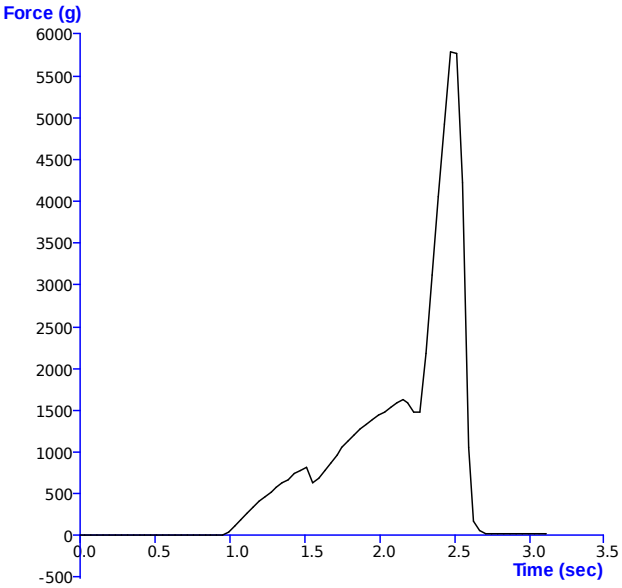


Fig 4.9Force-Deformation curve-control sample ***Fig 4.10Force-Deformation curve-treated sample***

Typical Force-Deformation curves for the texture analysis of mature jackfruit samples

The texture of the control and treated samples were analyzed and the parameters like toughness and hardness of the samples were recorded (AppendixIII). The toughness and hardness found to be lower in control samples as compared to that of treated samples.The toughness (N sec) values for the control samples dried at 60^0C were 0.298 for tender and 3.612 for mature

sample and that of treated samples were 5.965 for tender and 24.262 for mature. The hardness values (kg) for the control samples dried at 60^0C were 0.303 for tender and 2.380 for mature and, and that of treated samples were 1.697 for tender and 5.789 for mature sample.

4.4.6.2. Colour

The first judgment of a food's quality is dependent on its various appearances, characteristics such as its colour, surface structure and shape. Colour, in particular, is an important sensory attribute (Brimelow and Groesbeck, 1993). The L*, a*, b* uniform colour space is based on the CIE system reference. L* defines lightness, a* denotes the red/green value and b* the yellow/blue value. A dark product is usually unappealing to the consumer as it indicates over processing. The CIE system of colour measurement transforms the reflection or transmission spectrum of the object into three dimensional space using the spectral power distribution of the illuminant and colour matching functions of the standard observer (MacDougall, 1993).

Table 4.6: L*,a* and b* colour values of control and treated samples

Sample	Lightness(L*)		Red/green value(a*)		Yellow/blue value(b*)	
	Control	Treated	Control	Treated	Control	Treated
Tender	9.61	9.79	-0.17	-0.54	14.69	17.45
Mature	9.3	10.06	-0.12	-0.43	15.00	18.07
Ripe	9.79	10.21	-0.65	-0.87	14.33	17.67

a. Lightness (L*)

The L* value is a measure of brightness and so this should be as high as possible. The pretreatments viz., blanching and freezing had an effect on the L* value of the dried samples. The L* values of dried treated and control samples (tender, mature and ripe jackfruit) were 9.79, 10.06, 10.21 and 9.61, 9.3, 9.79 respectively. Since L* is a measure of the colour in the light-dark axis, this falling value indicate that the samples were turning darker. This may be due to the inactivation of enzymes which cause the development of undesirable colours during processing and storage.

b. Red/green value (a*)

The a* is regarded as an indication of the red/green colouration. The a* value should be as low as possible in good quality samples. The treated samples led to a decrease in the a* values after drying. The a* value of treated and control samples were -0.54, -0.43, -0.87 and -0.17, -0.12,-0.65 respectively. The higher a* value of control samples showed that it became more red when dried.

c. Yellow/blue value (b*)

The b* is regarded as an indication of yellow/blue colouration. This value should be high in good quality samples. From the Table 4.6, it is observed that the b* value of treated samples is higher than the control samples.

An increase in a* value and decrease in L* and b* value of control samples showed that they lost their greenness and yellowness and become more dark. Increase in a* value and decrease in b* value may be due to decomposition of chlorophyll and carotenoid pigments and the formation of brown pigments.

4.5 Storage studies of the dried product

The materials after drying were packed in different packaging materials such as PP, LDPE and Aluminum laminate. The different packaging techniques used for storage were active MAP, passive MAP and vacuum packaging. In active MAP, nitrogen flushing were done and stored in ambient atmospheric condition. For every 15 days intervals, the packages were examined for the quality in terms of protein, tannin, texture, vitamin C, beta-carotene, rehydration ratio and microbial attack.

4.5.1Rehydration ratio

The rehydration ratio of the samples are tabulated in the Table 4.6. In tender jackfruit the rehydration ratio was 3.22 at the time of packing, has decreased to 3.15 after 15 days and was further decreased to 3.10 after 30 days. The same decreasing trend was also observed in ripe and mature sample during the storage period.

Table 4.7: Rehydration ratio of the jackfruit samples after storage

Test samples	Rehydration ratio		
	Initial	15th day	30th day
Tender	3.22	3.15	3.10
Mature	2.60	2.59	2.40
Ripe	1.61	1.59	1.43

4.5.2. Protein

The protein content of the stored samples was analyzed at every 15 days interval and results are given in Table 4.7. It was found that the protein content in tender sample was 7.52 before packing. After 15 days the protein content was 7.45 and at the end of 30th day protein content were 7.43. Similar trend were also observed in mature and ripe samples. During storage of dehydrated fruits and vegetables a continuous decline in nutrients are observed (Negi et al., 2001).

Table 4 .8: Protein content of the jackfruit samples after storage

Test sample	Protein content , g %		
	Initial	15th day	30th day
Tender	7.52	7.45	7.43
Mature	4.26	4.18	4.17
Ripe	3.14	3.09	2.95

4.5.3. Vitamin C

The amount of vitamin C in different test samples was found out and tabulated in the table 4.8.

Table 4.9 Vitamin C content of the jackfruit samples after storage

Test sample	Vitamin C mg/100g sample		
	Initial	15th day	30th day
Tender	8.50	8.46	8.41

Mature	9.20	9.10	9.03
Ripe	8.85	8.83	8.78

In tender samples, the vitamin C content was 8.50 at the time of packing which reduced to 8.46 on the 15th day of storage and 8.41 on the 30th day. Similar effects were also observed in mature and ripe samples. In general, degradation of vitamin C is a function of time. Zee *et al.*1991, also observed that these compounds are sensitive to light and oxygen and may decompose under normal storage conditions, resulting in reduction of the nutritional value of the foodstuffs.

4.5.4Tannin

The tannin content of the stored samples was analyzed at every 15 days interval. It was found that the tannin content in tender sample was 0.009 before packing. After 15 days the tannin content was 0.0038. At the end of 30th day tannin content was 0.0034. Similar trend were also observed in mature and ripe samples.

Table4.10: Tannin content of the jackfruit samples after storage

Test sample	Tannin, mg		
	Initial	15th day	30th day
Tender	0.009	0.0038	0.0034
Mature	0.009	0.0016	0.0015
Ripe	0.019	0.0028	0.0025

4.5.5. Subjective method

Sensory quality greatly influences the consumer acceptability and market performance of the product. Sensory analysis (preference test) was carried out in sensory analysis lab.10 expert panelists were assigned to assess the difference in the products using a 5-point hedonic scale. Panelists evaluated parameters such as appearance, texture, taste, flavour and colour of jackfruit samples.

From the sensory analysis it was observed that the samples which were blanched for two min. and freezed at -10^{0}C for three hour followed by drying at 60^{0}C were better than the others. Based on the above results the treatments B2F2D2 were standardized for tender, mature and ripe. (Appendix I). Statistical analysis was also conducted and the best treatment among the different parameters were confirmed (Appendix II).

4.5.6. Microbial Analysis

The dried jackfruit samples were kept for storage. The samples packed in 200 gauge polypropylene with passive MAP were found to be infested by various micro-flora and micro organisms after three weeks of storage. The same infection was also found in LDPE after five weeks of storage. Preliminary studies conducted at the Product Analysis Lab of Dept of Post Harvest Technology of this college showed that the samples were infected with both bacteria and fungi. In order to confirm the result and for further investigations, the infected samples were taken to College of Horticulture for identification. Samples were subjected to microbial analysis by the standard method explained in chapter III. It was observed that the samples packed with poly propylene having 200 gauge were infected with both fungus and bacteria. The attack was faster in PP and LDPE. This may be due to the impermeable nature of the packed material. No microbial infestation was found in aluminum laminate. Vacuum packaging and active MAP were found superior than passive MAP (Appendix IV).

Plate4.4 Bacterial colony

Plate 4.5 Fungi colony

Population of different fungal species observed were

Rhizopus : 0.40 %

Aspergillus niger (Black) : 0.80 %

Aspergillus (Yellow) : 51.2 %

Aspergillus (Green) : 47.5 %

Operating cost per kg for drying of tender, mature and ripe jackfruit was calculated. It was observed that the cost is maximum for tender and minimum for ripe samples. Tender sample requires more labour hours for peeling and cutting. The cost of operation for tender mature and ripe samples per kg is Rs.20.87/-, Rs.12.43/- and Rs.10.09/- respectively.

Plate 4.6:Vacuum packed LDPE

Plate 4.7: nitrogen flushed polypropylene

Plate4.8:aluminium laminate

Chapter v

SUMMARY AND CONCLUSION

Jackfruit was considered as heavenly fruit by ancient people of Kerala. It is a rich source of vitamins, minerals and calories and offers numerous health benefits. The fruit is highly perishable due to its inherent compositional and textural characteristics. Proper postharvest technology for prolonging shelf life is necessary to makes its availability throughout the year.

Preservation of fruits by processing has been the research pursuits of many developed and developing countries and has yielded quite a number of technologies. However, there has been a little research in the preservation techniques of jackfruit. 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 jackfruit.

Tender, mature and ripe jackfruit were peeled off with the help of a knife and then cut into pieces of uniform size. Seeds were removed from mature and ripe samples. The effect of pretreatments such as blanching and quick freezing on drying rate and the quality of dried jackfruit were investigated. The samples without pretreatments were taken as control.

The drying was carried out using RRLT-NC dryer at three different temperatures 50, 60 and 70^0C. The lowest moisture content of the samples after a drying period of 4 hours 15 minutes were obtained for treated samples at 70^0C (9.64%), followed by 60^0C (12.3%) and at 50^0C (17.84 %). However the control samples registered a higher moisture content for the same period; ie., 16.46%at 70^0C followed by 20.4%at 60^0C and 25.34% at 50^0C. Rehydration studies were conducted on dried jackfruit samples to standardise the drying temperature. The rehydration ratio was influenced significantly by the pretreatments and drying temperatures. The rehydration ratios of control samples were significantly low. Also, the dried products were too hard and brittle and hence they were discarded. Similarly, drying of treated samples at 70^0C resulted in darker colour. Black scorches were observed in dried ripe jackfruit. The colour and brightness of the treated samples dried at 60^0C were found good with an average hardness. Also samples blanched for 2 min in boiled water and quick freezing at -10^0C for 3 hrs followed by drying at 60^0C got better rehydration and appearance. The quality of the dried samples was assessed in

terms of protein, tannin, vitamin C, texture and colour. The toughness and hardness values were low in control samples as compared with treated samples. The toughness (N sec) values for the control samples dried at 60^0C were 0.298 for tender and 3.612 for mature sample and that of treated samples were 5.965 for tender and 24.262 for mature. The hardness values (kg) for the control samples dried at 60^0C were 0.303 for tender and 2.380 for mature and, and that of treated samples were 1.697 for tender and 5.789 for mature sample. The hunter parameters (L*, a*, b*) of dried jackfruit were investigated. The control samples changed all the three colour parameters (L*, a*, b*) resulting a colour shift towards the darker region. In tender jackfruit, L, a*, b* values of control and treated sample were 9.61, -0.17, 14.69 and 9.79, -0.54, 17.45 respectively. An increase in a* value and decrease in L* and b* values of control sample showed that they lost their greenness and yellowness and become more dark. Similar trends were observed in mature and ripe jackfruit also. But pretreatments such as blanching and quick freezing had a good effect on retaining colour in all stages of jackfruit.

Storage studies were conducted using various packaging materials and packaging techniques. In order to standardize a suitable packaging material for the stored products, three packaging materials viz., LDPE, PP and aluminum laminates of different gauges were studied. The packaging techniques used were active MAP, passive MAP and vacuum packaging. The microbial attack was faster in PP and LDPE packets. No microbial infestation was found in aliminium laminate. Vacuum packaging and active MAP were found superior than passive MAP. Apart from the quality evaluation, microbial and sensory analysis was done in every 15 days interval. From the sensory analysis it was confirmed that the samples which were blanched for two minutes and frozen at -10^0C for three hours followed by drying at 60^0C were the best.

Operating cost/kg for drying of tender, mature and ripe samples were calculated. The cost of operation/kg for tender, mature and ripe samples is Rs.20.87/-, Rs.12.43/- and Rs.10.09/- respectively.

Suggestions for future work

- Suitable mechanism may be developed for peeling and slicing of jackfruit which is a time consuming and laborious process.
- Steam blanching studies may be done as an alternative to hot water blanching to study the effect of dried product quality .
- Freeze drying on ripe jackfruit may be done to study the effect of rehydration quality.

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APPENDIX I

The identification of sample codes is as follows

- B1 - water blanched for one min.
- B2 - water blanched for two min.
- F1 - freezing at -10^{0}C for one min.
- F2 - freezing at -10^{0}C for three min.
- D1 -dried at 50^{0}C
- D2 - dried at 60^{0}C
- P1 -packed in PP
- P2 - packed in LDPE
- P3 -packed in aluminium laminate

samples	appearance	flavour	Taste	texture	colour
B1F1D1P1	2.4	2.6	2.7	2.0	2.2
B1F1D1P2	2.0	2.4	2.5	2.3	2.3
B1F1D1P3	2.5	2.6	2.4	2.1	2.4
B1F1D2P1	2.6	3.3	3.5	2.3	2.6
B1F1D2P2	2.9	3.5	3.5	2.4	3.0
B1F1D2P3	3.0	3.6	3.4	2.3	2.9
B1F2D1P1	2.4	3.4	3.6	2.2	2.5
B1F2D1P2	2.5	3.7	3.6	2.4	2.8
B1F2D1P3	3.1	3.6	3.4	2.3	3.0
B1F1D2P1	3.0	3.2	3.3	2.3	3.1
B1F1D2P2	2.9	3.5	3.1	2.4	2.9
B1F1D2P3	3.1	3.9	3.8	2.6	3.1

B2F1D1P1	2.5	3.4	3.7	2.4	2.6
B2F1D1P2	3.0	3.6	3.7	2.9	2.8
B2F1D1P3	3.0	3.5	3.4	2.7	2.9
B2F1D2P1	2.9	3.7	3.6	3.9	2.8
B2F1D2P2	2.9	3.7	3.9	4.0	3.0
B2F1D2P3	3.2	3.9	3.5	3.8	2.9
B2F2D1P1	2.9	3.7	3.7	3.8	2.6
B2F2D1P2	3.0	3.8	3.9	4.0	3.0
B2F2D1P3	3.5	3.9	3.7	3.9	3.1
B2F2D2P1	4.0	4.0	4.1	4.0	4.0
B2F2D2P2	4.1	4.2	4.3	4.1	4.1
B2F2D2P3	4.1	4.2	4.4	4.2	3.9

APPENDIX II

Analysis for the character Appearance

Oneway Anova
Summary of Fit

Rsquare	0.811017
Adj Rsquare	0.736907
Root Mean Square Error	0.308274
Mean of Response	2.986111
Observations (or Sum Wgts)	72

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Tr	20	20.799444	1.03997	10.9433	<.0001*
Error	51	4.846667	0.09503		
C. Total	71	25.646111			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B1F1D1P1	3	2.40000	0.17798	2.0427	2.7573
B1F1D1P2	3	2.00000	0.17798	1.6427	2.3573
B1F1D1P3	3	2.50000	0.17798	2.1427	2.8573
B1F1D2P1	6	2.63333	0.12585	2.3807	2.8860
B1F1D2P2	6	2.90000	0.12585	2.6473	3.1527
B1F1D2P3	6	3.06667	0.12585	2.8140	3.3193
B1F2D1P1	3	2.43333	0.17798	2.0760	2.7906
B1F2D1P2	3	2.50000	0.17798	2.1427	2.8573
B1F2D1P3	3	3.16667	0.17798	2.8094	3.5240
B2F1D1P1	3	2.50000	0.17798	2.1427	2.8573
B2F1D1P2	3	3.00000	0.17798	2.6427	3.3573
B2F1D1P3	3	3.00000	0.17798	2.6427	3.3573
B2F1D2P1	3	2.90000	0.17798	2.5427	3.2573
B2F1D2P2	3	2.93333	0.17798	2.5760	3.2906
B2F1D2P3	3	3.23333	0.17798	2.8760	3.5906
B2F2D1P1	3	2.96667	0.17798	2.6094	3.3240
B2F2D1P2	3	3.03333	0.17798	2.6760	3.3906
B2F2D1P3	3	3.50000	0.17798	3.1427	3.8573
B2F2D2P1	3	4.06667	0.17798	3.7094	4.4240
B2F2D2P2	3	4.16667	0.17798	3.8094	4.5240
B2F2D2P3	3	4.16667	0.17798	3.8094	4.5240

Std Error uses a pooled estimate of error variance

Tukey’s post-ANOVA test

B2F2D2P3	A					4.16666667
B2F2D2P2	A					4.16666667
B2F2D2P1	A	B				4.06666667
B2F2D1P3	A	B	C			3.5
B2F1D2P3	A	B	C	D		3.23333333
B1F2D1P3		B	C	D		3.16666667
B1F1D2P3			C	D		3.06666667
B2F2D1P2			C	D		3.03333333
B2F1D1P3			C	D		3
B2F1D1P2			C	D		3
B2F2D1P1			C	D		2.96666667
B2F1D2P2			C	D	E	2.93333333
B1F1D2P2			C	D		2.9

B2F1D2P1	C	D	E	2.9
B1F1D2P1		D	E	2.63333333
B1F2D1P2		D	E	2.5
B1F1D1P3		D	E	2.5
B2F1D1P1		D	E	2.5
B1F2D1P1		D	E	2.43333333
B1F1D1P1		D	E	2.4
B1F1D1P2			E	2

Levels not connected by same letter are significantly different.

Analysis for the character Texture

Oneway Anova
Summary of Fit

Rsquare	0.964164
Adj Rsquare	0.95011
Root Mean Square Error	0.183467
Mean of Response	2.990278
Observations (or Sum Wgts)	72

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Tr	20	46.186528	2.30933	68.6072	<.0001
Error	51	1.716667	0.03366		
C. Total	71	47.903194			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B1F1D1P1	3	2.00000	0.10592	1.7873	2.2127
B1F1D1P2	3	2.30000	0.10592	2.0873	2.5127
B1F1D1P3	3	2.10000	0.10592	1.8873	2.3127
B1F1D2P1	6	2.35000	0.07490	2.1996	2.5004
B1F1D2P2	6	2.46667	0.07490	2.3163	2.6170
B1F1D2P3	6	2.35000	0.07490	2.1996	2.5004
B1F2D1P1	3	2.23333	0.10592	2.0207	2.4460
B1F2D1P2	3	2.53333	0.10592	2.3207	2.7460
B1F2D1P3	3	2.30000	0.10592	2.0873	2.5127
B2F1D1P1	3	2.40000	0.10592	2.1873	2.6127
B2F1D1P2	3	2.90000	0.10592	2.6873	3.1127
B2F1D1P3	3	2.70000	0.10592	2.4873	2.9127
B2F1D2P1	3	3.93333	0.10592	3.7207	4.1460
B2F1D2P2	3	4.00000	0.10592	3.7873	4.2127
B2F1D2P3	3	3.80000	0.10592	3.5873	4.0127
B2F2D1P1	3	3.83333	0.10592	3.6207	4.0460
B2F2D1P2	3	4.03333	0.10592	3.8207	4.2460
B2F2D1P3	3	3.93333	0.10592	3.7207	4.1460

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B2F2D2P1	3	4.06667	0.10592	3.8540	4.2793
B2F2D2P2	3	4.16667	0.10592	3.9540	4.3793
B2F2D2P3	3	4.20000	0.10592	3.9873	4.4127

Std Error uses a pooled estimate of error variance

Tukey's post-ANOVA test

B2F2D2P3	A			4.2
B2F2D2P2	A			4.16666667
B2F2D2P1	A			4.06666667
B2F2D1P2	A			4.03333333
B2F1D2P2	A			4
B2F2D1P3	A			3.93333333
B2F1D2P1	A			3.93333333
B2F2D1P1	A			3.83333333
B2F1D2P3	A			3.8
B2F1D1P2		B		2.9
B2F1D1P3		B	C	2.7
B1F2D1P2		B	C	D 2.53333333
B1F1D2P2		B	C	D 2.46666667
B2F1D1P1		B	C	D 2.4
B1F1D2P3			C	D 2.35
B1F1D2P1			C	D 2.35
B1F2D1P3			C	D 2.3
B1F1D1P2			C	D 2.3
B1F2D1P1			C	D 2.23333333
B1F1D1P3				D 2.1
B1F1D1P1				D 2

Levels not connected by same letter are significantly different.

Analysis for the character Taste

Oneway Anova
Summary of Fit

Rsquare	0.902472
Adj Rsquare	0.864226
Root Mean Square Error	0.180595
Mean of Response	3.575
Observations (or Sum Wgts)	72

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Tr	20	15.391667	0.769583	23.5964	<.0001

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Error	51	1.663333	0.032614		
C. Total	71	17.055000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B1F1D1P1	3	2.70000	0.10427	2.4907	2.9093
B1F1D1P2	3	2.56667	0.10427	2.3573	2.7760
B1F1D1P3	3	2.40000	0.10427	2.1907	2.6093
B1F1D2P1	6	3.55000	0.07373	3.4020	3.6980
B1F1D2P2	6	3.55000	0.07373	3.4020	3.6980
B1F1D2P3	6	3.46667	0.07373	3.3187	3.6147
B1F2D1P1	3	3.63333	0.10427	3.4240	3.8427
B1F2D1P2	3	3.63333	0.10427	3.4240	3.8427
B1F2D1P3	3	3.46667	0.10427	3.2573	3.6760
B2F1D1P1	3	3.73333	0.10427	3.5240	3.9427
B2F1D1P2	3	3.70000	0.10427	3.4907	3.9093
B2F1D1P3	3	3.46667	0.10427	3.2573	3.6760
B2F1D2P1	3	3.63333	0.10427	3.4240	3.8427
B2F1D2P2	3	3.90000	0.10427	3.6907	4.1093
B2F1D2P3	3	3.56667	0.10427	3.3573	3.7760
B2F2D1P1	3	3.73333	0.10427	3.5240	3.9427
B2F2D1P2	3	3.93333	0.10427	3.7240	4.1427
B2F2D1P3	3	3.73333	0.10427	3.5240	3.9427
B2F2D2P1	3	4.10000	0.10427	3.8907	4.3093
B2F2D2P2	3	4.36667	0.10427	4.1573	4.5760
B2F2D2P3	3	4.40000	0.10427	4.1907	4.6093

Std Error uses a pooled estimate of error variance

Tukey's post-ANOVA test

B2F2D2P3	A			4.4
B2F2D2P2	A			4.36666667
B2F2D2P1	A	B		4.1
B2F2D1P2	A	B	C	3.93333333
B2F1D2P2	A	B	C	3.9
B2F2D1P1		B	C	3.73333333
B2F2D1P3		B	C	3.73333333
B2F1D1P1		B	C	3.73333333
B2F1D1P2		B	C	3.7
B2F1D2P1		B	C	3.63333333
B1F2D1P1		B	C	3.63333333
B1F2D1P2		B	C	3.63333333
B2F1D2P3		B	C	3.56666667

B1F1D2P1	C		3.55
B1F1D2P2	C		3.55
B2F1D1P3	C		3.46666667
B1F2D1P3	C		3.46666667
B1F1D2P3	C		3.46666667
B1F1D1P1		D	2.7
B1F1D1P2		D	2.56666667
B1F1D1P3		D	2.4

Levels not connected by same letter are significantly different.

Analysis for the character Flavour

Oneway Anova
Summary of Fit

Rsquare	0.892577
Adj Rsquare	0.85045
Root Mean Square Error	0.185592
Mean of Response	3.569444
Observations (or Sum Wgts)	72

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Tr	20	14.596111	0.729806	21.1879	<.0001
Error	51	1.756667	0.034444		
C. Total	71	16.352778			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B1F1D1P1	3	2.63333	0.10715	2.4182	2.8484
B1F1D1P2	3	2.40000	0.10715	2.1849	2.6151
B1F1D1P3	3	2.60000	0.10715	2.3849	2.8151
B1F1D2P1	6	3.36667	0.07577	3.2146	3.5188
B1F1D2P2	6	3.58333	0.07577	3.4312	3.7354
B1F1D2P3	6	3.61667	0.07577	3.4646	3.7688
B1F2D1P1	3	3.46667	0.10715	3.2516	3.6818
B1F2D1P2	3	3.73333	0.10715	3.5182	3.9484
B1F2D1P3	3	3.66667	0.10715	3.4516	3.8818
B2F1D1P1	3	3.46667	0.10715	3.2516	3.6818
B2F1D1P2	3	3.60000	0.10715	3.3849	3.8151
B2F1D1P3	3	3.56667	0.10715	3.3516	3.7818
B2F1D2P1	3	3.70000	0.10715	3.4849	3.9151
B2F1D2P2	3	3.73333	0.10715	3.5182	3.9484
B2F1D2P3	3	3.93333	0.10715	3.7182	4.1484
B2F2D1P1	3	3.73333	0.10715	3.5182	3.9484

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B2F2D1P2	3	3.86667	0.10715	3.6516	4.0818
B2F2D1P3	3	3.93333	0.10715	3.7182	4.1484
B2F2D2P1	3	4.00000	0.10715	3.7849	4.2151
B2F2D2P2	3	4.23333	0.10715	4.0182	4.4484
B2F2D2P3	3	4.26667	0.10715	4.0516	4.4818

Std Error uses a pooled estimate of error variance

Tukey's post-ANOVA test

B2F2D2P3	A					4.26666667
B2F2D2P2	A	B				4.23333333
B2F2D2P1	A	B	C			4
B2F1D2P3	A	B	C			3.93333333
B2F2D1P3	A	B	C			3.93333333
B2F2D1P2	A	B	C			3.86666667
B2F1D2P2	A	B	C	D		3.73333333
B2F2D1P1	A	B	C	D		3.73333333
B1F2D1P2	A	B	C	D		3.73333333
B2F1D2P1	A	B	C	D		3.7
B1F2D1P3		B	C	D		3.66666667
B1F1D2P3			C	D		3.61666667
B2F1D1P2			C	D		3.6
B1F1D2P2			C	D		3.58333333
B2F1D1P3			C	D		3.56666667
B1F2D1P1			C	D		3.46666667
B2F1D1P1			C	D		3.46666667
B1F1D2P1				D		3.36666667
B1F1D1P1					E	2.63333333
B1F1D1P3					E	2.6
B1F1D1P2					E	2.4

Levels not connected by same letter are significantly different.

Analysis for the character Colour

Oneway Anova
Summary of Fit

Rsquare	0.787697
Adj Rsquare	0.704441
Root Mean Square Error	0.287938
Mean of Response	2.943056
Observations (or Sum Wgts)	72

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Tr	20	15.688194	0.784410	9.4611	<.0001
Error	51	4.228333	0.082908		
C. Total	71	19.916528			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
B1F1D1P1	3	2.26667	0.16624	1.9329	2.6004
B1F1D1P2	3	2.30000	0.16624	1.9663	2.6337
B1F1D1P3	3	2.46667	0.16624	2.1329	2.8004
B1F1D2P1	6	2.63333	0.11755	2.3973	2.8693
B1F1D2P2	6	3.01667	0.11755	2.7807	3.2527
B1F1D2P3	6	2.93333	0.11755	2.6973	3.1693
B1F2D1P1	3	2.56667	0.16624	2.2329	2.9004
B1F2D1P2	3	2.83333	0.16624	2.4996	3.1671
B1F2D1P3	3	3.03333	0.16624	2.6996	3.3671
B2F1D1P1	3	2.63333	0.16624	2.2996	2.9671
B2F1D1P2	3	2.80000	0.16624	2.4663	3.1337
B2F1D1P3	3	2.90000	0.16624	2.5663	3.2337
B2F1D2P1	3	2.80000	0.16624	2.4663	3.1337
B2F1D2P2	3	3.03333	0.16624	2.6996	3.3671
B2F1D2P3	3	2.93333	0.16624	2.5996	3.2671
B2F2D1P1	3	2.66667	0.16624	2.3329	3.0004
B2F2D1P2	3	3.06667	0.16624	2.7329	3.4004
B2F2D1P3	3	3.10000	0.16624	2.7663	3.4337
B2F2D2P1	3	4.00000	0.16624	3.6663	4.3337
B2F2D2P2	3	4.10000	0.16624	3.7663	4.4337
B2F2D2P3	3	3.96667	0.16624	3.6329	4.3004

Std Error uses a pooled estimate of error variance

Tukey's post-ANOVA test

B2F2D2P2	A			4.1
B2F2D2P1	A			4
B2F2D2P3	A	B		3.96666667
B2F2D1P3		B	C	3.1
B2F2D1P2			C	3.06666667
B1F2D1P3			C	3.03333333
B2F1D2P2			C	3.03333333
B1F1D2P2			C	3.01666667
B2F1D2P3			C	2.93333333
B1F1D2P3			C	2.93333333
B2F1D1P3			C	2.9

B1F2D1P2	C	2.83333333
B2F1D1P2	C	2.8
B2F1D2P1	C	2.8
B2F2D1P1	C	2.66666667
B2F1D1P1	C	2.63333333
B1F1D2P1	C	2.63333333
B1F2D1P1	C	2.56666667
B1F1D1P3	C	2.46666667
B1F1D1P2	C	2.3
B1F1D1P1	C	2.26666667

Levels not connected by same letter are significantly different

APPENDIX III

Texture Analyzer Setting : -

Sequence Title : Return to Start (Set Dist)

Test Mode : Compression

Pre-Test Speed : 1.0 mm/sec

Test Speed : 0.5 mm/sec

Post-Test Speed : 10.0 mm/sec

Target Mode : Strain /distance

Strain : 40.0 %/ 3mm

Tare Mode : Auto

Points per second: 500

Mature jackfruit

Sample	Initial		After 30 days	
	Toughness (N sec)	Hardness (Kg)	Toughness (N sec)	Hardness (Kg)
Control	3.612	2.380	3.523	2.295
Treated	24.262	5.789	24.875	5.635

Sample	Initial		After 30 days	
	Toughness (N sec)	Hardness (Kg)	Toughness (N sec)	Hardness (Kg)
Control	0.298	0.303	0.309	0.323
Treated	5.965	1.697	5.975	1.797

Tender jackfruit

APPENDIX IV

Media compositions

Nutrient agar media

- Beef extract =0.3 g
- Peptone =5 g
- Sodium chloride =5 g
- Agar =18 g
- Distilled water =1000 ml

Potato dextrose

- Peeled potato =250 g
- Dextrose =20 g

- Agar =18 g
- Distilled water =1000 ml

Incubation temperature

Bacteria : 28±2^{0}C for 3 days

Fungus : 28±2^{0}C for 3 days

1 Microbial analysis of different packaging of samples

PP

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	124	253	132	268
Mature	nil	nil	116	248	125	260
Ripened	nil	nil	215	263	223	291

LDPE

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	nil	nil	133	258
Mature	nil	nil	nil	nil	130	250
Ripened	nil	nil	nil	nil	220	300

Aluminium laminate

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	nil	nil	nil	nil
Mature	nil	nil	nil	nil	nil	nil
Ripened	nil	nil	nil	nil	nil	nil

2 .Microbial analysis of different packaging atmosphere of samples

Ordinary packaging

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	124	253	132	268
Mature	nil	nil	116	248	125	260
Ripened	nil	nil	215	263	223	291

vaccum packaging

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	nil	nil	nil	nil
Mature	nil	nil	nil	nil	nil	nil
Ripened	nil	nil	nil	nil	nil	nil

Nitrogen flushing

sample	1st week		3rd week		5th week	
	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})	Bacteria (10^6 g^{-1})	Fungi (10^3 g^{-1})
Tender	nil	nil	nil	nil	nil	nil
Mature	nil	nil	nil	nil	nil	nil
Ripened	nil	nil	Nil	nil	nil	nil

APPENDIX V

Cost analysis

1. Cost of operation of convective dryer(RRL)/hr

Assumptions

Initial cost of drier = 31,740/-

Useful life period = 12 years

Annual working hours = 1000hours

Salvage value = 10% of initial cost

Interest on initial cost = 10% annually

Repairs and maintenance = 5% of initial cost

Electricity charge = Rs 2/unit

Labor wages = Rs 150 per day for 8 working hours

a. Fixed cost

Depreciation $= \frac{(C-S)}{L}$

$= \frac{(31,740-3174)}{}$

12

=2380.50/-

Interest = $\frac{(C+S)}{2}$ x10 %

= $\frac{(31,740+3174)}{2}$ x 0.1

=1745 /-

b. Variable cost

Repair and Maintenance = 31,740 x 5/100

=1587/-

Electricity cost = (1000 x 3000 x 2)/1000

= 6000/-

Labor cost = (150 x 1000)/ 8 =18750 /-

Total cost = fixed cost + variable cost

=2380.5+1745+1587+6000+18750

=30462.5/-

Total working hours = 1000 hours

Cost of operation of convective drier (RRL)/hr = Total cost/ total working hour

=30.4/-

Number of batches required for drying

100 kg of jackfruit = 5

Total cost of drying operation = cost of operation/hr x no of batch x time required for drying in one batch

= 30.4 x 5 x 4

= 608 /-

Cost of operation of deep freezer/hr

Assumptions

Initial cost of deep freezer = 96,000/-

Useful life period = 12 years

Annual working hours = 1000hours

Salvage value = 10% of initial cost

Interest on initial cost = 10% annually

Repairs and maintenance = 5% of initial cost

Electricity charge = Rs 2/unit

Labor wages = Rs 150 per day for 8 working hours

a. Fixed cost

Depreciation = (C-S)/L

= (96000-9600)/12

=7200/-

Interest = (C+S)/2 x I

= (96000+9600)/2 x 10 %

= 5280/-

b. Variable cost

Repair and Maintenance = 96000 x 5%

= 4800/-

Elecrticity cost = $\frac{(1000x3000x2)}{1000}$

= 6000/-

Labor cost = 18750/-

Total cost = fixed cost + variable cost

= 36630

Total working hours = 1000 hours

Cost of operation of deep freezer = Total cost/ total working hour

=36.6/-

Number of batches required for freezing

100 kg of jackfruit = 2

Total cost of freezing operation = cost of operation/hr x no of batch x

time required for drying in one batch

= 36.6 x 2x1

= 73.2 /-

2. Labor cost

i) For tender jackfruit:

Quantity of jack fruit bulbs = 100 kg

Total number of jackfruit required	=50
Working hours required for peeling cutting and blanching,	=1.50 x 50 =75hours
Total wages	=75 x150/8 =1406.25
Total expenditure for drying 100 kg of jackfruit	= labour cost + total drying cost + total freezing cost =1406.25+608+73.2 =2087.45/-
Total expenditure for drying 1 kg of jackfruit	=20.87/-

ii) For mature jack fruit:

Quantity of jack fruit bulbs	= 100 kg
Total number of jackfruit required	=25
Working hours required for peeling, removing bulbs	=1 x 25 =25hours
Working hours required for cutting and blanching	=5 hours
Total labor hours	=30 hours
Total wages	=30 x150/8 =562.50/-
Total expenditure for drying 100 kg of jackfruit	= labour cost + total drying cost + total freezing cost = 562.50 +608+73.2 =1243.70/-
Total expenditure for drying 1 kg of jackfruit	=12.43/-

iii) For ripe jackfruit:

Quantity of jack fruit bulbs	= 100 kg
Total number of jackfruit required	= 25
Working hours required for peeling, removing bulbs	= 0. 5 x 25 =12.5hours

Working hours required for cutting and blanching = 5 hours

Total labor hours = 17.5 hours

Total wages =17.5 x150/8

=328.12/-

Total expenditure for drying 100 kg of jackfruit = labour cost + total drying cost+ total freezing cost

= 328.12 +608+73.2

=1009.32/-

Total expenditure for drying 1 kg of jackfruit =10.09/-

Product diversification of jackfruit

By
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ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfillment of the Requirement for the degree

Bachelor of Technology
in
Agricultural Engineering

Faculty of Agricultural Engineering
Kerala Agricultural University

Department of
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2009

ABSTRACT

Jackfruit has enumerable health benefits and healing properties. A considerable amount of jackfruit, specially obtained in the glut season (June-July) goes waste due to its perishability in nature. It has to be processed to make its availability throughout the year. *Varika* variety of jackfruit in different maturity level-tender, mature and ripe stage was used for the study. The effects of pretreatments viz., blanching and quick freezing on quality of dried jackfruit were investigated. Quality evaluation of the dried products in terms of vitamin content, protein content, rehydration ratio, tannin, texture and colour were done. The treated sample exhibits good rehydration ratio, colour and firmness retention as compared with the control sample. In order to standardize a suitable packaging material for the stored products three packaging materials viz., LDPE, PP and aluminum laminates of different gauges were studied. The packaging techniques used were active MAP, passive MAP and vacuum packaging. Apart from quality evaluation microbial and sensory analysis were done in every 15 days interval. Operating cost/kg for drying of tender, mature and ripe samples were calculated. The cost of operation/kg for tender, mature and ripe samples are Rs.20.87/-, Rs.12.43/- and Rs.10.09/- respectively .The study concluded that the samples which were blanched for two min. and freezed at -10^0C for three hour followed by drying at 60^0C and packed in aluminium laminate were superior