DEVELOPMENT AND QUALITY EVALUATION OF THERMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.)

by

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Pritty S. Babu

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THESIS

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KERALA, INDIA

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DECLARATION

I hereby declare that this thesis entitled **"Development and Quality Evaluation of Thermally Processed Jackfruit (*Artocarpus heterophyllus* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis, entitled **"Development and Quality Evaluation of Thermally Processed Jackfruit (*Artocarpus heterophyllus* L.)"** is a record of research work done independently by **Miss. Pritty S. Babu (2010-18-101)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Tavanur **Pritty S Babu**

Date:

Dedicated to
Agricultural Engineering Profession

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SYMBOLS AND ABBREVIATIONS

%	Percentage
&	and
/	per
₹	rupee(s)
<	less than
=	equal to
>	greater than
±	plus or minus
ΔE	Total colour difference
≈	Approximate
ALP	Aluminum Laminated Polyethylene
ANOVA	Analysis of variance
AOAC	Association of the Official Agricultural Chemists
APEDA	Agricultural and Processed food products Export Development Authority
BHA	Butylated Hydroxy Anisole
BOPP	Biaxially Oriented Poly Propylene
$CaCl_2$	Calcium Chloride
CD	Critical Difference
cfu	colony forming unit
Cl.	Clostridium
CRD	Completely Randomized Design
D	Decimal reduction time
DF	Dilution Factor
et al.,	and others

etc.	etcetera
F	Thermal death time (pasteurisation)
F_0	Thermal death time (sterilisation)
FDA	Food and Drug Administration
Fig.	Figure
g	gram(s)
g^{-1}	per gram
h	hour(s)
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulfuric acid
ha	hectare
HCl	Hydrochloric acid
Hg	mercury
HTST	High Temperature Short Time
i.e.	that is
IBA	Indole-3-butyric acid
IS	Indian Standard
IU	Int. Units
K.C.A.E.T	Kelappaji College of Agricultural Engineering and Technology
KAU	Kerala Agricultural University
kg	kilogram
$kgcm^{-2}$	kilogram per square centimeter
KJ	Kilo Joules
KMS	Potassium metabisulphate
kW	kilo Watt
L	Luminosity, Litre(s)
L^{-1}	per litre
LTLT	Low Temperature Long Time

MCPP	Metalized Co-extruded Poly Propylene
mg	milligram
min	minute(s)
ml	milliliter
MOFPI	Ministry of Food Processing Industries
M-STAT	Master of Statistics
MT	Metric tones
N	Normality, Newton
NaOH	Sodium hydroxide
NHB	National Horticulture Board
NIIR	National Institute of Industrial Research
No.	Number
NS	Non Significant
^{o}B	Degree Brix
^{o}C	Degree Celsius
^{o}F	Degree Fahrenheit
P	Probability
PAU	Punjab Agricultural University
PE	Pectin Estrase
PFA	Prevention of Food Adulteration
PME	Pectin Methyl Esterase
ppm	parts per million
PPO	Polyphenol oxidase
RH	Relative Humidity
RTU	Ready-to-Use
sec	second(s)
S	Significant
SD	Standard Deviation
SHP	Slowest Heating Point

SO_2	Sulphur dioxide
SPSS	Statistical Package for the Social Sciences
SS	Stainless Steel
TPA	Texture Profile Analysis
TSS	Total soluble solids
UV	Ultra Violet
viz.,	namely
wt.	weight

INTRODUCTION

CHAPTER 1

INTRODUCTION

Fruits and vegetables are important supplements to the human diet as they provide essential minerals, nutrients including vitamin C, vitamin K, foliate, thiamin, carotene, dietary fibre and antioxidant phyto-compounds required for maintaining health. They are easily digested and exercise a cleansing effect on the blood and digestive tract (Nirmala, 2010). Fruits and vegetables have gained increasing interest among nutrition specialists, food scientists and consumers, since frequent consumption of fruits reduces the risk of certain cardiovascular diseases and cancer (Liu, 2003). In the recent years, demand for both fresh and processed fruits and vegetables have been substantial and this trend is likely to continue in future. The increasing demand can be regulated by either increasing their production or by adapting suitable processing techniques for its preservation.

India is blessed with a variety of fruits and vegetables whose production during 2010-11 was 74.87 and 146.55 MT, respectively (Kumar *et al*., 2011). The growing demand increased the fruit production to the tune of 45% between 2000 and 2007 (NHB, 2007). Fruit production contributes about 10% 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 by 31% during the period between 2005 and 2008 (APEDA, 2008).

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 (Akhila and Shareena, 2009). However, for various reasons, the abundance of production of fruits and vegetables are not efficiently utilised. According to the MOFPI (2009), the lack of processing and storage of fruits and vegetables resulted in huge waste, estimated to about 35%, which is approximately ₹ 3000 crores annually. In addition to this, the highly perishable nature of fruits and vegetables due to their high water content, make them susceptible to desiccation, mechanical injury and 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. National Institute of Nutrition (2004) cited by Akhila and Shareena (2009) states that 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.

Together with the development of techniques for efficient utilisation of fruits and vegetables, one should be very aggressive in exploiting the potential of some under utilised crops. The tropical fruit species, jackfruit (*Artocarpus heterophyllus* Lam), is a typical example of this category. The jackfruit is an important Indian seasonal fruit, also a vegetable grown in limited areas (about 26,000 ha) across the country and is believed to be the native of Western Ghats (Morton, 1987). It belongs to the family Moraceae (mulberry family) and is monoecious with both male and female inflorescences on the same tree (Bose, 1985). It is one of the important and commonly found trees in the home gardens of India and Bangladesh (Prakash *et al.*, 2009). It is the national fruit of Bangladesh and is considered to be an extremely important tree by the natives (Bose, 1985). The term jackfruit is derived from the Portugese word "Jaca", which in turn is adopted from the word "Chakka" of Malayalam (a regional Indian language) (Pradeepkumar & Kumar, 2008). Jackfruit tree produces the largest tree-borne fruits and is the largest edible fruit in the world and a mature tree can yield anywhere between ten to two hundred fruits (Haq, 2006). In India, it is grown in southern and eastern states viz., Kerala, Karnataka, Tamilnadu, West Bengal, Bihar etc. Jackfruit was considered as heavenly fruit by ancient people in Kerala and is a nutritious fruit, rich in vitamins A, B and C, potassium, β carotene, calcium, iron, proteins and carbohydrates. The antioxidant (Soong and Barlow, 2004), antibacterial (Khan *et al.*, 2003), antifungal (Trindade *et al.*, 2006) and anti-inflammatory (Wei *et al.*, 2005) effect of the extracts from jackfruit tree for pharmacological uses are well discussed. In Kerala, jackfruits are classified into two general types; 'Koozha Chakka' and 'Varikka Chakka'. The former have small, fibrous, soft, mushy, but very sweet carpel whereas the latter is more important commercially, with crisp carpel of high quality. The jackfruit has lost

its status and now it is one of the under exploited fruits of the state (Samaddar, 1985; Mitra and Mani, 2000). The fruit is frequently referred to as ‘poor man's food’, as it is cheap and plentiful during the summer season when food is scarce (Jagtap *et al*., 2010). The highly perishable nature of jackfruit due to inherent composition and textural characteristics has limited its storage for a longer time which adversely affects its market potential.

In context of jackfruit Thomas, 1980 mentioned: ‘*In a time like this, when poverty and insufficiency in food in the developing tropical countries have been matters of great concern, there is no reason why researches into such a source of food and income should be neglected’*. It speaks of the sparse research in the field of jackfruit processing and storage. Thus the lack of proper post-harvest knowledge during harvesting and storing contributes to the considerable wastage of the fruit yearly. Exploitation of the utility of jackfruit as vegetable and storage of tender jackfruit after processing may be some of the practical ways for reducing its wastage. This necessarily implies the harvesting of jackfruit at the tender stage which suits for its use as a vegetable and the need for technologies for its processing and preservation. Hence, the development and standardisation of a post-harvest technology for jackfruit that prolongs its shelf life without much alteration in the quality attributes attains utmost importance.

To avoid wastage, the surplus commodity should be processed and preserved properly. The selection of proper food processing technique plays a significant role in increasing the shelf life of the commodity while maintaining its nutritional aspects. The suitability of different processing technologies like high temperature, low temperature, high pressure, preservatives, dehydration, irradiation etc have been analysed for a variety of products. All the techniques have merits and demerits specific to the type of the commodity and the objective of processing. Among all technologies, thermal processing is found to be well suited for tender jackfruit processing as it involves heat treatments to destroy micro-organisms as well as to inactivate enzymes (Jan *et al*., 2006). One of the important advantages of thermally processed food over food processed by other

methods is its longer shelf life at room temperature. Thus, thermal processing of food helps in avoiding the cold chain, thereby bypassing the need for machinery and operational costs involved in maintaining the cold chain. Also, thermal processing is superior over other methods in the context of the destruction of anti-nutritional components, improving the digestibility of proteins, gelatinisation of starches, and the release of niacin. In thermal processing, the concept of in-container sterilisation (canning) involves the application of a high-temperature thermal treatment for a sufficiently long time to destroy micro-organisms of public health and spoilage concerns. The hermetic seal maintains an environment in the container that prevents the growth of other microorganisms of higher resistance and most importantly, prevents recontamination and pathogens from producing toxins during storage (Awuah *et al.,* 2007), which would help in extending the shelf life of tender jackfruit. The development of thermal processing and storage technologies like blanching and canning respectively, facilitates the exploitation of the market potential of jackfruit by making them available to the consumers in a ready to eat or cook form, throughout the year. Also these techniques can give quality product that fetch better price in the market and thus help to improve the financial status of the jackfruit growers in the state and ultimately contributes to state and national economy.

The present study focuses on the development and quality evaluation of thermally processed tender jackfruit for its utility as a vegetable. This will indeed prove to be a milestone in the Indian jackfruit processing industry by way of assuring year round availability of tender jackfruit. It will undoubtedly ensure the economic security of the farmer as well as establish a significant place in the international market. Hence, the present study was undertaken with the following objectives.

- Develop a hot water blancher and standardise the blanching process for tender jack fruit.
- Standardise the thermal process for tender jack fruit.
- Study the shelf life and quality parameters of canned tender jack fruit.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

This chapter deals with comprehensive review of the research work done by various research workers related to the present study that gives general information on jackfruit, its chemical composition, blanching characteristics, thermal process optimisation and its storage studies.

2.1 Jackfruit (*Artocarpus heterophyllus* L.)

2.1.1 History and distribution

Historical reports suggest jackfruit as a native of the rain forests of Western Ghats of India. However with time, the trees have been introduced to other parts of India and tropical regions of the world. Today, the trees are found widely growing in Bangladesh, Malaysia, Burma, Sri Lanka, Indonesia, Philippines, in the Caribbean islands, in the evergreen forest zone of West Africa, in northern Australia, in parts of USA (Florida and California), Brazil, Puerto Rico, Pacific Islands Palau, Yap, Pohnpei, Nauru, Tabiteuea in Kiribati, Samoa, and other islands. 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 of around 21 lakh tons (Bose, 1985; Samaddar, 1985; Narasimham, 1990; Rahman *et al*., 1995; Burkill, 1997; Elevitch & Manner, 2006; Haq, 2006; Azad *et al*., 2007).

2.1.2 Botanical aspects

Jackfruit tree is monoecious and both male and female inflorescences are found on the same tree (Bose, 1985; Morton, 1987). 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). The raw unripe jackfruits are cooked as vegetable and ripe jackfruits are consumed directly. From the time of successful

pollination, the complete process of fruit development takes about three to seven months. The time of fruiting varies in different countries (Haq, 2006) is enlisted in Table A.1 of Appendix A. Each fruit is oblong cylindrical in shape and is 30 - 40 cm in length. When ripe they are acid to sweetish in taste. The fruit consists mainly of three regions, the fruit axis, the persistent perianth and the true fruit. The axis, the core of the fruit is inedible and is rich in latex due to the presence of laticiferous cells and holds the fruits together. The most important and bulk of the fruit is the perianth. It is made up of three regions viz., the lower fleshy edible region, commonly called as the bulb; the middle fused region, that forms the rind of the syncarp and the upper free and horny non-edible region commonly known as the spikes. The ripe fruit (arils or flesh) contain well flavoured yellow sweet bulbs and seeds. Except for the thorny outer bark all parts of the fruit are edible (Prakash *et al*., 2009).

2.1.3 Propagation

Most common method of propagation followed in jackfruit is through seeds. Seeds lose viability within a short time and hence they should be sown immediately after extraction from ripe fruits. Soaking seeds in 1-naphthaleneacetic acid (25 ppm) for 24 h 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 gives 90% success when shoots are etiolated and ringed for thirty days and then treated with indole-3-butyric acid (3000 ppm) + ferulic acid (2000 ppm) (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 result in 80 to 90% success under mist in Kerala (Jose and Valsalakumari, 1991).

2.1.4 Varieties of jackfruit

As fertilization is by cross-pollination and propagation, mostly through seeds, numerous types of jackfruits are observed. This when categorized according to the phenotypic and organoleptic characteristics (like the size of the tree, structure of the leaf, fruit form, age of fruit bearing, quality of the fruit pulp,

their size, shape, density of spines, colour, texture, odour, quality and period of maturity), has accounted for a variety of fruits (Elevitch and Manner, 2006; Haq, 2006). Depending on the variety, the bulb can be cream, white, light yellow, yellow, deep yellow, lemon yellow, light saffron, saffron, deep saffron or orange in colour (Jagadeesh *et al*., 2007). When fully ripe, the intact jackfruit emits a strong disagreeable odour, resembling that of decayed onions, while the pulp of the opened fruit smells of pineapple and banana (Elevitch and Manner, 2006; Haq, 2006; Prakash *et al*., 2009).

Depending on the consistency of the fruit and its pulp, two types of morphotypes are recognized ie., one that has fruits with small, fibrous, soft and spongy flakes with very sweet carpels and good aroma, and the other which is crunchy, though not as sweet, with crisp carpels (Odoemelam, 2005; Elevitch and Manner, 2006; Shyamalamma *et al*., 2008). These types are apparently known in different areas by various local names. In Thailand they are known as Kha-nun nang (firm) and Kha-nun lamoud (soft); in Srilanka as Vela (soft) and Varaka or Waraka (firm); in Malayalam as Koozha chakka (soft) and Koozha pazham (firm); and in Konkani as tulvo (soft) and barko (firm) (Morton, 1987). Some of the famous varieties of jackfruit grown in different parts of the world are enlisted in Table A.2 of Appendix A (Morton, 1987; Haq, 2006)

2.1.5 Nutrient composition

Multiple studies carried out in the past have shown that the proximate and phytochemical composition varies with the variety of jackfruit. Studies have also shown that depending on variety of jackfruit, the concentration of carbohydrates and proteins in the seeds vary although they are from the same region. The jackfruit pulp and seeds quantitatively contains more protein, calcium, iron and thiamine than other tropical fruits like orange, banana, mango, pineapple, papaya and ber (Bhatia *et al*., 1955; Kumar *et al*., 1988; Haq, 2006). Recently, Chrips *et al*. (2008) evaluated the protein and carbohydrate concentration of different varieties of jackfruit seed isolated from the fruits growing in Kanyakumari district of India. The authors observed the highest protein concentration in Nettadivarika

(6.8%) followed by Mondan (6.5%), Venkanni (6.0%), Valayan (5.9%) and Chemparethy (5.3%). The carbohydrate concentration was highest in Mondan (42.8%) followed by Valayan (42.5%), Nettadivarika (40.3%), Venkanni (40.2%) and Chemparethy (37.4%). Variation in nutrient composition of fresh jackfruit has also been reported (Table 2.1).

2.1.6 Post harvest utility

Tender jackfruit comes to the market in spring and continues until summer and is used as a popular vegetable. Jackfruit has a storage life of about 4-5 days in ambient temperature (25-35°C) and hence consumed or marketed immediately after harvesting. Its storage life extends to six weeks under cold storage conditions at a temperature of 11.1 to 12.8^{o}C and humidity between 85 to 90% (Bose *et al*., 2003). 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). The ripe bulbs, fermented and then distilled, produce potent liquor. A number of products from jackfruit have been developed and produced on commercial scale like the squash, nectar, toffee, candy, jam, jelly, pulp, etc. Jackfruit is also preserved as pickle, dehydrated leather or thin papad (Bhatia *et al*., 1956a; Bhatia *et al*., 1956b; Teaotia and Awasthi, 1968). Shruti, 2005 developed diversified food products namely clarified juice, jackfruit nectar and jackfruit bars by applying innovative and indigenous technologies and explored the possibility of by products recovery (pectin and starch) from the waste generated after jackfruit processing. A suitable preparation technique of quality jackfruit chips and their good packaging was reported by Molla *et al*. (2008).

2.2 Blanching

It consists of a mild heat treatment (60-100^{o}C) given to plant material for inactivating enzymes and killing plant tissues to prevent enzymatic and microbial deterioration. 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. The factors

influencing blanching are size of product particle, shape of particle, heating medium and duration of the process.

Table 2.1 Nutrient composition of fresh jackfruit (per 100 g)

(Arkroyd *et al*., 1966; Narasimham, 1990; Soepadmo, 1992; Gunasena *et al*., 1996; Azad, 2000; Haq, 2006;)

Composition	Young fruit	Ripe fruit	Seed
Water (g)	76.2-85.2	72.0-94.0	51.0-64.5
Protein (g)	2.0-2.6	1.2-1.9	6.6-7.04
Fat (g)	0.1-0.6	0.1-0.4	0.40-0.43
Carbohydrate (g)	9.4-11.5	16.0-25.4	25.8-38.4
Fibre (g)	2.6-3.6	1.0-1.5	1.0-1.5
Total sugars (g)	-	20.6	-
Minerals			
Total minerals (g)	0.9	0.87-0.9	0.9-1.2
Calcium (mg)	30.0-73.2	20.0-37.0	50
Magnesium (mg)	-	27	54
Phosphorus (mg)	20.0-57.2	38.0-41.0	38.0-97.0
Potassium (mg)	287-323	191-407	246
Sodium (mg)	3.0-35.0	2.0-41.0	63.2
Iron (mg)	0.4-1.9	0.5-1.1	1.5
Vitamins			
Vitamin A (IU)	30	175-540	10.0-17.0
Thiamine (mg)	0.05-0.15	0.03-0.09	0.25
Riboflavin (mg)	0.05-0.2	0.05-0.4	0.11-0.3
Vitamin C (mg)	12.0-14.0	7.0-10.0	11
Energy (KJ)	50-210	88-410	133-139

The effect of blanching on different commodities and hence on varying sizes were discussed well in the literatures. Some of the effects include better appearance for green pepper (Thomas and Gopalakrishnan, 1993), softening the texture of vegetables (Srivastava and Sanjeev, 1994), improvement in the flavour and taste of potato slices (Karthika *et al*., 2004). Blanching is usually followed by some chemical treatment dependent on the desired attribute of the final product. Bhatia *et al*., (1956c) found that the quality and the shelf life of the jackfruit bulbs were increased after blanching associated with sulphiting (0.1% SO_2) for 30 minutes. Potassium metabisulphite (KMS) was found to be the most frequently used chemical in the post blanching treatment for enhancing the colour of the processed commodity (Karthika *et al*., 2004; Molla *et al*., 2008).

2.2.1 Methods of blanching

Based on the heating medium, various blanching methods were developed and their effects on different food commodities are discussed in the literatures.

Bognar *et al.* (2002) studied the blanching effect on spinach, carrot and bell pepper. The commodities were blanched conventionally in water and using pulsed microwave at 95^{o}C. 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. The study highlighted the potential application of microwave blanching in reducing the loss of valuable nutrients.

Kumar and Khurdiya (2002) found the effect of microwave blanching on the nutritional characteristics of banana puree when compared with conventional water bath blanching method. The blanching time for microwave heating was 3 minutes where as for conventional water bath was 8 minutes. Microwave blanched banana puree had high ascorbic acid content, TSS, total sugars and organoleptic score, but had low pH compared to conventional method. Enzymatic browning was completely retarded by both blanching treatments.

Singh and Kulshrestha (2006) studied the effect of steam blanching on the preservation of carrot powder. The peeled and grated carrots were steam blanched for 1 minute and then immersed in 0.125% KMS solution for 4 minutes.

Patricia *et al.* (2007) suggested that blanching carrot slices, particularly blanching in 0.21% to 0.3% citric acid, before drying should enhance inactivation of *Salmonella spp*. during home-type dehydration and storage.

2.2.2 Duration of blanching

The duration of blanching had significant impact on the attributes of the food commodity. Blanching time varies with type of the commodity, the nature of processed product and the temperature during the process. Hence the selection of appropriate blanching time is found to be an inevitable part in scheduling the operation.

Lin and Schyvens (1995) performed blanching for 15 selected vegetables and fruits which were processed by conventional procedures. The result showed that low temperature long time (LTLT) blanching considerably increased the final firmness of sterilised carrot and green beans.

Thomas and Gopalakrishnan (1993) noted the improvement in the colour of raw pepper blanched in boiling water for 15 minutes as against that for 2 minutes.

Del *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^{o}C, but it increased with temperature after 15 minute exposure at 65^{o}C. Samples blanched at 40^{o}C were softer than those heated at 55^{o}C in $CaCl_2$ solution, which suggested PME activation after 15 minutes at 55^{o}C.

Akhila and Shareena (2009) evaluated the effects of blanching and quick freezing on the quality of dried jackfruit and standardised a suitable packaging material for storing the products. The samples which were blanched for two minute and freezed at -10^{o}C for three hours followed by drying at 60^{o}C and packed in aluminium laminate were found to be superior**.**

Hence, it is necessary to standardise the blanching time specific for each commodity and the products made out of it. Generally the procedure to fix the blanching time is to measure the time required for the inactivation of peroxidase enzyme bacteria as indicated by a pink colour in the peroxidase test.

2.3 Thermal processing of foods

Ranganna (1974) found out that the duration of the thermal process required for 401 x 411 cans of guava pulp based on peroxidase inactivation (at F = 1.0 at pH 4.2) was found to be 8 minutes at 212^{o}F. The time found was sufficient to inactivate a strain of yeast isolated from processed can of guava pulp. The processing time commercially followed for 401 x 411 cans was 25 - 30 minutes in boiling water.

Nath and Ranganna (1983) quoted that the thermal process schedule for guava canned in sugar syrup has been evolved on the basis of inactivation of pectin estrase (PE) which was found to be more heat resistant than peroxidase. The values of thermal inactivation and thermal resistance of PE in syrup homogenate containing guava pulp and sugar syrup in the ratio of 11:6 and TSS of 20% at pH 4.0 were F = 1 and D = 0.592 respectively.

Kalpalathika *et al*. (1988) developed baby foods based on green peas. Thermal process time of 61 min was found necessary to achieve F_0 value of 4 at 115.5^{o}C. Cut-out analysis of the canned product indicated that the product was safe microbiologically. The product was found to be a good source of protein (30% on dry wt. basis), minerals and vitamins. Thermal processing caused a decrease of ascorbic acid (37%), thiamine (82%) and of essential amino acid like lysine (10%), isoleucine (19%), methionine (13%) and threonine (19%). However, the canned strained green peas based baby food showed growth promoting efficiency almost similar to that of commercial infant milk food in young weanling rats.

According to Rodriguiez and Teixeria (1988), hollow cylindrical aluminium rods were an accurate alternative to commercially available plastic rods in the microbiological validation of thermal process. Heat penetration tests were carried

out on distilled water fitted with plastic and aluminium rods instrumented with thermo couples. Test results showed that the contents of the aluminium rods followed the product temperature history very closely, while plastic units showed appreciable lag in response. The aluminium rods showed mechanical resistance to pressure induced temperature aberrations that could occur with softened plastic units at processing temperatures.

Sudhakar and Maini (1994) studied stability of carotenoids during storage of heat processed mango pulp at room temperature. Among the various treatments tried, ascorbic acid (200 mg/100 g) and 0.01% BHA (butylated hydroxy anisole) was found to be best as there was no loss of carotenoids for upto four months of storage.

Teixeira (1994) quoted that long term microbial sterility in foods could be achieved with the inactivation of the most highly heat resistant bacterial spores at temperatures in the range of 110-150^{o}C. These temperatures were well above the boiling point of water at standard conditions and could only be achieved with the use of water (or steam) under pressure in specialised equipments.

2.4 Canning of fruits and vegetables

Das *et al*. (1955) worked out a method for canning of banana fruit alone or in combination with other fruits. Of the 20 south indian varieties tried, Pachabale, Chardrabale, Nendran, Poovan, Chenganapurikodan and Vannan yielded satisfactory canned products. Cloudiness of the syrup and slight discolouration of the slices were serious problems in the case of canned bananas.

Ten varieties of apricots (Seedling, Parine Apple, Frogmare Early, New Large Early, Turkey, Moorpark, St. Ambroise, Charmaghz, Kaisha and Royal) grown in Uttar Pradesh were studied for their physico-chemical composition and suitability for canning by Rodriguez *et al.* (1971). Canned products with brix-acid ratio below 20 were categorised to acidic, between 20 and 25 belonged to moderately sweet and that above 25 were in sweet category.

Rao and Ammerman (1973) stated that the overall means for firmness of processed sweet potatoes, as measured by the firmness meter, and the shear press decreased, as time of storage of the roots prior to processing increased. Calcium treatment at higher levels increased the firmness of the sweet potatoes stored for 0, 30 or 90 days prior to canning. Higher average pectin levels added to the canning syrup increased the shear values, and a continuous positive response was observed in firmness values.

Dang *et al.* (1976) conducted studies on canning of four varieties of apples grown in Jammu and Kashmir namely, Khuru, Imperial, French and Maharaji. The process involved preparation of apple rings and treatment with 2% calcium chloride solution under vacuum at 100 mm Hg for 25 minutes. The rings were canned with a sugar solution of 45^{o}B having 0.2% citric acid using lacquered cans. The variety 'French' was found to be highly acceptable and Maharaji was fairly good for the purpose. The product resembled canned pineapple rings with a glossy translucent appearance, lucious taste and had a satisfactory storage life of one year.

Vyas and Joshi (1982) canned free stone peaches in apple juice sweetened with sugar syrup. The use of apple juice, besides increasing the nutritive value and total fruit content, reduced the sugar required.

Canning of mandarin orange segments using varying fill-in-weight of segments and covering syrup strength was tried by Beerch and Rane (1983). The drained weight was directly proportional to the fill-in-weight of segments and inversely proportional to the strength of the covering syrup. Reverse was the case with respect to cut-out syrup brix. Ascorbic acid loss was found to be 23.46% during canning and 35 - 40% on storage for 10 months. Texture suffered badly with covering syrup of higher concentrations, above 50^{o}B. Lower concentrations of covering syrup at 20 - 30^{o}B, maintained better texture but the product was poor organoleptically.

Teotia *et al.* (1983) studied the quality of canned okra and proposed that to get a firm texture with least mucilage, okra pieces should be blanched in 0.1%

citric acid simmering solution for 2 minutes followed by steeping in 1% $CaCl_2$ for 2 hours and then filling in cans and covering with simmering hot lime containing 2.5% common salt, 0.4% citric acid and 1.5% sugar. It was exhausted at 82^{o}C and later sealed and processed in boiling water for 30 minutes.

Four varieties of mangoes, *viz.,* Dashehari, Mallika, Hybrid - 165 and Amrapali were selected for finding out the suitability for canning by Khurdiya and Roy (1986). Among these, Mallika variety was found to be the best followed by Amrapali. Varieties Dashehari and Hybrid - 165 were not acceptable due to their poor flavour and texture. The colour was rated to be more or less same for all the varieties.

Kabra and Manan (1987) conducted studies on the suitability of muskmelon varieties grown in Punjab for canning. Four varieties of muskmelon, viz., Hana Madher, Fertile (MF), Punjab sunehri and Punjab hybrid obtained from PAU, Ludhiana were analysed for their physico-chemical characteristics and were canned in syrup (32^{o}B) in plain cans with and without added ascorbic acid. Punjab sunehri was found to be the best for canning in respect of colour, texture, taste and flavour and could be stored for 6 months.

Sharma *et al.* (1991) reported on osmo-canning of apple rings. The rings were dipped in 70% sugar solution at 50^{o}C for half an hour and then canned in 35^{o}B sugar syrup. Application of their new technology yielded firm texture, better quality and desired drained weight.

Effect of lowering the pH, either by adding acid or lactic fermentation, on thermal process requirements for canned vegetables was investigated by Azizi and Ranganna (1993). Malic acid was preferred for acidification of canned vegetables. Addition of acid to covering brine was preferable to the blanching in acid solution, as the acidification was uniform, and it reduced the extent of discolouration. Colour of the lactic fermented canned products was superior to canned vegetables acidified with malic acid. Both had texture similar to that of the freshly cooked vegetables. Products acidified by fermentation had minimal sour taste.

Leandro *et al.* (2009) discussed the factors affecting canning of vegetable soybean like blanching duration and brine composition in relation to the quality attributes of the product including enzyme activity, texture and colour. It was observed that the concentration of $CaCl_2$ influenced the texture and luminosity (L), while the pH affected luminosity (L) and green colour (-a/b) of the processed product. Furthermore, blanching for 90 sec before heat processing was effective to inactivate 99% of the initial lipoxygenase activity. It was found that a brine containing 150 g L^{-1} NaCl and 2.9 g L^{-1} $CaCl_2$, at pH 6.5 that was thermally treated for 9 min, generated a lethality of 4 min that is enough to produce a 12-log reduction required for low acid foods and at the same time, retaining desirable colour and texture.

2.5 Storage studies

Chakraborty *et al.* (1974) studied the prevention of pink discolouration in canned China and Shahi varieties of litchi. Both the varieties gave positive test for leucoanthocyanins and developed pink discolouration on canning. The discolouration could be prevented by canning in 30^{o}Brix syrup containing 0.1-0.15% added citric acid (depending on the initial acidity of the fruit, so that the final pH was around 4.5), processing for not more than 10 minutes in boiling water (301 x 411 size cans) and immediately cooling thereafter, preferably under chilled water. Sulphur dioxide in the covering syrup (300 ppm) was effective in preventing pink discolouration but the canned product had sulphite taste.

Saha *et al*. (1976) studied the effect of ripeness level, storage period, processing conditions and ascorbic acid on flavour retention in canned Dashehari mango. The flavour was not retained due to losses during processing and subsequent storage. HTST processing did not have any beneficial effect on flavour retention. Addition of ascorbic acid to the syrup at various levels gave better acceptability for flavour of the product.

Jaleel *et al.* (1978) quoted that addition of a preservative viz., potassium metabisulphite was found to be necessary for obtaining a quality finished product during the enzymatic processing of banana pulp.

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

Ghorai and Khurdiya (1998) conducted studies on storage of heat processed kinnow mandarin juice (90^{o}C for 10 minutes) and reported that TSS, ascorbic acid, carotenoids, free amino acids, soluble proteins and acidity decreased with increase in storage period. Storage study on osmotically dried jackfruit products were conducted by Bindu (1995) and it was reported that titrable acidity decreased with storage period.

Pua *et al*. (2008) had conducted research on storage stability of jackfruit powder packaged in aluminium laminated polyethylene (ALP) and metalized co-extruded biaxially oriented poly propylene (BOPP/ MCPP). The total colour difference, rates of adsorbed moisture and sensory attributes of drum-dried jackfruit powder packaged in ALP and BOPP/MCPP pouches stored at accelerated storage (38^{o}C, with 50, 75 and 90% relative humidity (RH)) were determined over 12 weeks period.

2.6 Quality characteristics

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

2.6.1 Total soluble solids

Increase in TSS during storage may be due to acid hydrolysis of polysaccharides especially gums and pectin (Luh and Woodroof, 1975). Singh *et al*. (1984) determined the total soluble solids of fruits in controlled atmosphere storage (CAS) using refractometer. It was observed that TSS decreased with increase in carbon dioxide concentration and storage period. Naik *et al.* (1993) observed that TSS of tomatoes increased upto 14 days of storage in polyethylene bags and there after, gradually decreased. The control showed very rapid decrease

in TSS. Fresh-cut mango cubes maintained good visual quality and there were no significant changes in soluble solids content, titrable acidity and pH up to 9 days at 5°C (Gil *et al.,* 2006).

2.6.2 pH

In the canning of jack fruit, pH plays an important role. Addition of 0.75 to 1% citric acid to the canning syrup has been found necessary for safe processing in boiling water. Canning of jack fruit in combination with more acidic fruits like Bangalora mango and pineapple achieves the same purpose and provides acceptable products (Bhatai *et al.,* 2006).

Azizi and Ranganna (1993) reported that the spores of *Clostridium botulinum* that cause spoilage in the acid food remained dormant in the heat processed food for long periods until the pH of the environment is elevated. *Clostridium botulinum* can sustain at a lowest pH of 4.6. *Bacillus licheniformis* is able to grow at pH >4.2 and elevate the pH, hence all products having pH higher than 4.2 but lower than pH 4.6 should be given thermal process, adequate enough to destroy *Bacillus licheniformis*.

Adding citric acid reduced the pH of the blanching water from 6.70 - 6.80 to 2.48 - 3.08, thus reducing the pH of carrot slices blanched in the acidic solutions. In a low pH environment, citric acid molecules are able to cross bacterial cell membranes, dissociate into charged ions, and accumulate within the cytoplasm (Booth and Kroll, 1998). Temperature and pH interact to form barriers to the survival of certain pathogens (Uljas and Ingham, 1999).

Sudheer and Indira (2007) reported that bacterial spores do not grow below pH 4.5. Thus, a canned product having pH less than 4.5 can be processed in boiling water but a product with pH above 4.5 requires processing at 115^{o}C to 121^{o}C under a pressure of 0.7 to 1.05 kg/cm^{2} till the centre of can attained these high temperatures.

2.6.3 Ascorbic acid

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

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

The jackfruit is a rich source of carotene but a poor source of vitamin C content. According to Hossain and Haque (1979) jackfruit contains 2.64 - 11.77 mg/100g of ascorbic acid.

Lee *et al.* (1982) studied the effects of post harvest handling and processing in vitamin contents of peas and reported that ascorbic acid, vitamin B6 and niacin contents decreased significantly during blanching and canning processes. Thiamin content decreased significantly as a result of canning. Riboflavin and carotene remained relatively unaffected by heat processing.

Ranote and Bains (1982) investigated on preservation of kinnow fruit juice and found that juice heated to 98^{o}C for 1 minute and storage for 3 months underwent ascorbic acid loss from 18.7 to 10.7 mg/100g.

Levi *et al.* (1985) reported that the retention of ascorbic acid was high in osmo-air dried papaya slices than sun dried slices. However, osmosis in boiling syrup caused significant discoloration and heavy losses of ascorbic acid due to prolonged heating.

Analysis of biochemical changes during the ripening of jackfruit conducted by Selvaraj and Pal (1989) showed that the low acidity level and high free sugar (sucrose, fructose and glucose) were responsible for the sweet taste and the source of energy.

Fruits and vegetables are important sources of ascorbic acid. The most satisfactory chemical methods of estimation were based on the reduction of 2, 6-

dichlorophenol indophenols dye to a colourless leuco-base (Sadasivam and Manikam, 1992). Ascorbic acid is a water-soluble antioxidant associated with inhibition of oxidative reactions and is a key marker compound for determining the extent of oxidation in fresh-cut vegetables and fruits (Barth *et al.,* 1993).

Tapadia *et al.* (1995) studied the vitamin C content of processed fruits and vegetables and reported that cooking without the use of the lid resulted in maximum loss of vitamin C.

Hussein *et al.* (2000) studied the effect of processing and packaging on vitamin C and β-carotene content of ready-to-use (RTU) vegetables. They reported that there was a significant loss in vitamin C during storage, and in most cases there was no difference in loss of vitamin C or β-carotene between the processed and unprocessed vegetables and the packaged products.

Albanese *et al*. (2007) reported that during the cold storage period at 6^{o}C, pairing of a semi-permeable film with an adsorbent material and immersion in ascorbic acid solution could extend the shelf-life of green asparagus.

Sheetal *et al.* (2008) studied the effect of different blanching treatments on ascorbic acid retention in green leafy vegetables. They reported that retention of ascorbic acid was reduced as the blanching time and temperature increased in the greens. It was comparatively higher in chemically treated samples both in conventional and steam blanched samples.

2.6.4 Microbial quality

Sharma *et al.* (1978) reviewed the organisms responsible for the microbial spoilage of canned food products (Table 2.2).

Table 2.2 Microbes responsible for spoilage of canned foods

Type of food	**Type of spoilage**	**Spoilage microorganism**
Low acid foods	Flat sour spoilage	*Bacillus stearothermophilus*
		B. pepo
	Putrefactive spoilage	*Clostridium butyricum*
		Cl. pasteurianum
		Cl. sporogenes
		Cl. putrefaciens
	Sulfur stinker	*Cl. nigrificans*
Medium acid foods	Thermophilic anaerobe	*Cl. thermosaccharolyticum*
Acid foods	Special flat sour spoilage	*Bacillus coagulans*
	Sacchmolytic spoilage	*Cl. thermosaccharolyticum*
High acid foods	Hydrogen swell	*non-microbial*
Under processed groups	Thermoduric spoilage	*Streptococcus faecalis*
		S. thermophilus
		Micrococcus sp.
	Gas formation	*Lactobacillus sp.*
		Microbacterium coliform
		B. macerans
	Non -gas spoilage	*B. polymyxa*
		Pseudomonas sp.
		Achromobacter sp.
		Micrococcus sp.
		Flavobacterium sp.
		Proteus sp.

Source: Sharma *et al.* (1978)

Adsule *et al.* (1982) studied the effects of hot water dipping on tomatoes. It was found that a dip at 70^{o}C for 5 minutes not only decreased microbial load but was also safe for seed viability.

2.6.5 Texture analysis

Textural properties may serve as an indicator of maturity or processability to the food processor and that of eating quality to the consumer. It includes those qualities that can be felt with the fingers, tongue, palate or teeth. The textural change of softening of the tissue is caused by enzymatic degradation and solubilisation of pectin materials leading to cell separation and decreased resistance to applied forces. The principle of texture profiling has been applied to instrumental texture measurements with universal testing machine using the classification and definition of textural characteristics as the sensory profiling method. In order to predict consumer response to texture via an objective test, correlation of sensory evaluation results with the results of objective test is necessary.

Jacob *et al.* (1992) conducted studies to improve the texture and sensory qualities of raw jackfruit and showed that the firmness of fried dice increased significantly as measured by peak force of 11.06 and 11.49 kg cm^{-2} compared to 0.33 kg cm^{-2} of steam cooked dice.

Ocon *et al.* (1995) analysed the suitability of instrumental techniques for the measurement of the texture of pecan nuts (*Carya illinoensis*). The following methods were applied to pecan halves from four cultivars (Western, Barton, Wichita and Mahan): 50% compression, texture profile analysis (TPA), puncture and bending. The measurements were carried out in a Texture Analyser TA.XT2 on nuts from each cultivar. Sensory hardness was assessed by means of ranking tests. The results showed that 50% compression and puncture provide the best reproducibility, variation and correlation with sensory data.

Guzman and Barrett (1997) reported that calcium chloride or calcium lactate dips (2.5%, 1 min) either alone or in combination with heat treatments maintained or improved the firmness of fruits and vegetables at 5^{o}C. Gorny *et al.* (1998)

reported that storing the products at low temperature will maintain the texture significantly.

Studies were conducted by Shult and Brusewitz (1998) to determine the effect of oil and moisture content on texture characteristics of pecans (*Carya illinonensis*). Textural profile analysis (TPA) was performed on a cylindrical core sample with a universal testing machine to quantify the texture of pecans. Less variability (13%) was obtained by compressing the samples vertically than horizontally. A change in moisture from 0.9 to 8.1% resulted in increase of hardness by 37%, reduction of cohesiveness and springiness by 70% and 56% respectively. Hardness was 41.3% less for pecans with 27.4% less oil. Chewiness and gumminess had less difference and fracturability and adhesiveness had insignificant differences.

Wellington and Badrie (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. They also conducted a study on blanched and unblanched potato slices at four oil temperatures viz., 160, 170, 180 and 190^{o}C until a moisture content of 1.7% was reached. 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 crispier than blanched chips.

Segini *et al.* (2004) 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 the texture of fried potato chips were determined at oil

temperatures of 140^{o}C and 180^{o}C. They found that the maximum force of break was in the 2 - 4% moisture region.

In the processed fruits and vegetables, changes in texture are strongly related to transformations in cell wall polymers due to enzymatic and non-enzymatic reactions. A major challenge is how to use recent advances in processing technologies and to adjust raw materials, ingredients and processes to improve texture of processed plant based foods (Sila *et al.*, 2008).

2.6.6 Colour of foods

Colour characteristic of foods are an important quality attribute resulting from both pigmented and originally non-pigmented compounds. The major causative factor of colour in most foods is due to the presence of a broad array of natural pigments. There are some notable exceptions, such as caramelisation and browning reaction that occur in the food. Natural pigments in foods are determined not only as an index of economic value but also to control colour during processing and storage. Visual perception of colour can be described by three variables namely, hue, value and chroma. Value (lightness) distinguishes between light colour and dark colour, hue distinguishes among red, yellow, green and blue and chroma (saturation or purity) distinguishes between vivid and dull colours. The visual perception of colour is represented by three axes value (L), hue (a) and chroma (b) of hunter calorimeter (Yeshajahu *et al*., 1996).

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

As stated by Ahmed *et al.* (2002), heat induces modifications on carotenoid pigment, resulting in significant vegetables colour changes.

Segini *et al*. (2004) compared the relationship between instrumental and sensory analysis of texture and colour of potato chips. Parameters like fracture force, deformation and stiffness were measured by a puncture test using an Intron Universal testing machine. The instrumental colour quantification was done by computerised 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 specially trained in evaluating potato chips.

Pua *et al.* (2008) 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^{o}C, 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.

Gomez *et al.* (2010) studied the effect of ultraviolet-C light dose on quality of cut-apple, microbial quality, colour and compression behaviour. They reported that the colour and compression parameters were found to be dependent on UV-C dose, storage time and type of pre-treatment. At the end of storage, samples exposed to only UV-C light turned darker (lower 'L' values) and less green (higher 'a' value) when compared to fresh-cut-apple slice.

2.6.7 Sensory quality

As the final criterion of food quality is human evaluation, the value of objective measurements must be evaluated by their correlation with sensory measurements. According to Kramer and Twigg (1970) a correlation of 0.90 or better is desirable, though in some cases useful information can be obtained if correlation are as low as 0.80.

Health (1978) defined flavour as a substance which may be a single chemical entity or a blend of chemicals of natural and synthetic origin whose primary purpose is to provide all or part of particular flavour.

The selection, acceptance, and digestibility of a food are largely determined by its sensory properties. Evaluation of sensory properties is, however, affected by personal preference. To minimise the effect of factor on personal preference, different procedure for safety evaluation has been devised and the results are evaluated by statistical methods. (Zeuthen, 1990)

Measuring the sensory properties of food is basic for predicting acceptance of the food by the consumer represents major accomplishments for sensory evaluation (Pal *et al.*, 1995). Sensory evaluation is the scientific discipline used to evoke measures to analyse and interpret reactions to those characteristics of food as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory attribute of quality, guide the consumer in his selection of foods, also for determining the conformity of a food with established government or trade standard and food grade. (Rao *et al.*, 1997)

Anjali *et al.* (2002) stated quality as a measure of the degree of excellence or degree of acceptability by the consumer. Quality characteristics are classified into sensory (colour, size, shape and defect, texture and flavour), hidden (nutritive value and toxicity) and quantitative (crop yield and finished product yield).

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 were 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.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the methodology adopted for satisfying the objectives of the study on thermal processing of tender jackfruit.

3.1 Jackfruit sample collection and preparation

Tender jackfruit (*Artocarpus heterophyllus* L.), which belongs to the 'Varikka' variety were procured from the K.C.A.E.T Instructional Farm, Tavanur (May-June, 2011), farmers of Wayanad district (July-August, 2011), and Pineapple Research Station, Vellanikkara, KAU (December, 2011). They were harvested 50 - 70 days after fruit formation. The collected jackfruits were washed in tap water to remove the extraneous matter. The outer skins of the fresh jackfruit were peeled off and cut into pieces of almost uniform size using a stainless steel knife and kept in stainless steel container for further analysis.

3.2 Addition of preservatives

The jackfruit pieces were dipped in 0.1% potassium metabisulphate solution for 15 minutes using 2 kg of solution per kg of bulbs to prevent browning (Molla *et al.,* 2008).

3.3 Physico-chemical characteristics estimation

The methods of estimating various attributes of jackfruit for the study are briefly described below.

3.3.1 pH

pH being the logarithm of the reciprocal of hydrogen ion concentration, is a measure of active acidity which influence the flavour or palatability of a product and also affects its processing requirements. The pH of the jackfruit samples was determined using a digital pH meter (YORCO pH meter, model: YSI - 601). The pH meter was standardised with buffer solutions of different pH (4.0, 7.0, 9.2). Each sample was replicated three times and its mean value was taken as pH of the sample.

3.3.2 Total soluble solids

Total soluble solid (TSS) was measured using a hand refractometer. Samples were crushed and made into juice. One or two drops of juice were placed on the hand refractometer for TSS measurement. It was expressed in degree Brix (Ranganna, 1995).

3.3.3 Ascorbic acid

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

$$\text{Ascorbic acid (mg/100 g)} = \frac{0.5}{V_1} \times \frac{V_2}{5} \times \frac{100}{V_s} \times 100 \qquad 3.1$$

3.3.4 Titrable acidity

The jackfruit slices were crushed and filtered through a muslin cloth. About 10 g of fresh filtered homogenised pulp were made up to 100 ml with distilled water. About 10 ml of the prepared solution was titrated against 0.1N NaOH solution using phenolphthalein as indicator. The appearance of a light pink colour was the end-point that quantifies the NaOH required to neutralise the juice. Then

the titrable acidity was calculated and expressed as per cent citric acid (Ranganna, 1986). Amount of titrable acidity (N_s) present in 100 g of sample was calculated as follows

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

3.3.5 Crude fibre content

Crude fibre consists of cellulose, variable proportion of hemicellulose and highly variable proportion of lignin along with some minerals. It was estimated by following the method suggested by AOAC (1976). About 2 g of the dried sample (W) was ground and boiled with 200 ml H_2SO_4 for 30 minutes. Then the sample was filtered through muslin cloth and washed with hot water for 2 - 3 times so that the washings were not acidic. The residue obtained was boiled with 200 ml NaOH and filtered through muslin cloth again and washed with 25 ml of 1.25% H_2SO_4, 350 ml of water and 25 ml alcohol. Then the residue was transfered to ashing dish (W_1) and dried for 2 h at 130 ± 2°C. Weight of the dish and the residue (W_2) was taken after cooling in the desiccator. Again the dish was ignited for 30 minutes at 600 ± 15°C and weighed after cooling (W_3).

$$\text{Crude fibre content (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{W} \quad 3.3$$

3.3.6 Texture analysis

This important quality parameter which affects the consumer acceptability of jackfruit was determined using Texture Analyser (Stable Micro Systems, UK; Plate 3.1). The instrument had a micro processor regulated texture analysis system interfaced to a personal computer. The instrument consists of two separate modules; the test-bed and the control console (keyboard). Both are linked by a cable which route low voltage signal and power through it. The texture analyser measures force, distance and time and hence provide a three-dimensional product analysis. Forces may be measured to achieve set distances and distances may be measured to achieve set forces.

The sample was kept on the flat platform of the instrument and was subjected to double compression by a cylindrical probe with 5 mm diameter. The

test was conducted at a speed of 10 mm/s using 50 N load cell. The sample was allowed for a double compression of 40% with trigger force of 0.5 kg during which various textural parameters were determined. From the force deformation curve, the firmness or hardness (peak force), and toughness (area under the curve) were determined.

3.3.7 Colour

Hunter Lab colourimeter (Mini Scan XE Plus) was used for the colour measurement involved in the study (Plate 3.2). It works on the principle of collecting the light and measures energy from the sample reflected across the entire visible spectrum. The meter uses filters and mathematical models which rely on "standard observer curves" that defines the amount of green, red and blue primary lights required to match a series of colours across the visible spectrum and the mathematical model used is Hunter model. It provides reading in terms of 'L', 'a' and 'b', recommended by the commission international de l' Eclairage (CIE). The 'L' coordinate measures the value or luminance of a colour and ranges from black at 0 to white at 100. The 'a' coordinate measures red when positive and green when negative and 'b' measures yellow when positive and blue when negative.

Plate 3.1 Textural Analyser

Plate 3.2 Hunter Lab colourimeter

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

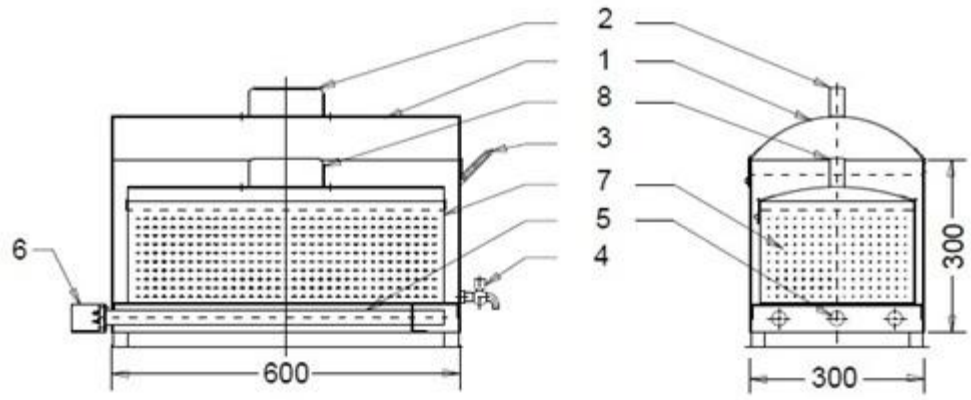
3.4 Development of a hot water blancher

A batch type hot water blancher with dimension 600 × 300 × 300 mm was developed and fabricated out of stainless steel (Plate 3.3). A thermostat arrangement was incorporated to automatically regulate the temperature from 60 to 110^{o}C. A separate tray specifically for keeping samples during blanching was designed and fixed inside the compartment. This facilitated easy loading and unloading of the samples to and from the blancher.

Plate 3.3 Hot water blancher

3.4.1 Components of the blancher

The sectional front view and side view of the developed hot water blancher are shown in Fig. 3.1 and the components of the blancher are presented below.



Sectional Front View Sectional Side View

All dimensions are in mm (Scale 1:10)

Fig. 3.1 Sectional front view and side view of hot water blancher

Table 3.1 Components of hot water blancher

Item	Description
1	SS Vessel
2	Handle for the vessel
3	Nozzle
4	Drain Valve
5	Tubular Heater
6	Terminal Cover
7	SS Perforated box
8	Handle for the box

3.4.1.1 SS Vessel

The vessel formed the main part of the blancher. It was made up of stainless steel (grade 304) with dimension 600 × 300 × 300 mm. All the other components were attached to the vessel.

3.4.1.2 Nozzle

This unit made easy for connecting inlet pipe for water entry into the blancher.

3.4.1.3 Tubular heater

Tubular heater (35 mm diameter) heats the water inside the blancher (Plate 3.4). This was connected with a thermostat arrangement for automatic temperature regulation.

3.4.1.4 Drain valve

Drain valve was provided at the bottom of the blancher for adequate drainage and for easy handling of the product after blanching.

3.4.1.5 SS perforated box

This component was designed separately and placed inside the SS vessel for keeping samples during blanching (Plate 3.5). The perforated box facilitated easy load and unload of the samples to and from the blancher. The dimension of the box was 550 × 250 × 250 mm.

3.4.2 Performance evaluation of the blancher

The performance evaluation of the blancher comprised of testing the proper functioning of thermostat arrangement, tubular heater, testing the capacity and comparing the performance of heating with that of conventional blancher (without thermostat and tubular heater set up). The sensitivity of the thermostat arrangement was validated with an external thermometer dipped into the boiling water inside the blancher. The performance was evaluated based on the difference in temperature reading in the blancher and that of external thermometer. Capacity of the blancher was also determined. A comparison between conventional and the newly fabricated blancher (Plate 3.6 & 3.7) were carried out for evaluating its

Plate 3.4 Tubular heater

Plate 3.5 SS perforated box

Plate 3.6 Testing of conventional blancher

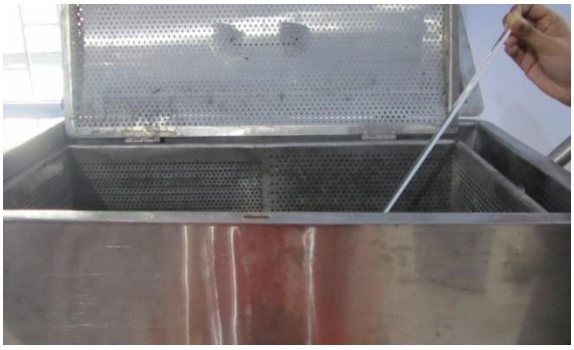


Plate 3.7 Testing of developed blancher

overall performance based on the time required to attain a particular temperature while boiling 11 litres of water in the blancher.

3.5 Standardisation of blanching time and treatment

About 250 g of the prepared samples were taken in the tray and water was added to about 2/3rd the total capacity of the blancher. The blanching of the jackfruit slices was carried out at 100^{o}C for five different durations (1, 2, 3, 4 and 5 minutes) forming five temperature-time combinations as represented by B1, B2, B3, B4 and B5.

B1: Blanching in boiling water at 100^{o}C for 1 min

B2: Blanching in boiling water at 100^{o}C for 2 min

B3: Blanching in boiling water at 100^{o}C for 3 min

B4: Blanching in boiling water at 100^{o}C for 4 min

B5: Blanching in boiling water at 100^{o}C for 5 min

The blanching time was initially standardised based on hydrogen peroxide test in which the presence of peroxidase enzyme was denoted with a pink colour on addition of H_2O_2. The time of blanching at which the pink colour disappeared was considered to be the optimum time for blanching (Sudheer and Indira, 2007). After blanching, the hot water was drained and the samples were placed on Whatman No.4 filter paper to remove the adsorbed water and were further subjected to quality analyses.

Based on the estimated quality parameters viz, texture, colour and enzyme inactivation, the most appropriate temperature-time combination was estimated. This temperature-time combination was used to standardise the blanching treatment. The different treatments were

BT1: Sample blanched in boiling water

BT2: Sample blanched in boiling water with 0.1% KMS

BT3: Sample blanched in boiling water with 0.3% citric acid

BT4: Sample blanched in boiling water with 0.3% citric acid and 0.1% KMS

The blanched samples were cooled immediately after respective treatment and subjected to texture and colour analysis for selection of the most appropriate blanching treatment.

3.6 Thermal process optimisation

Once the blanching time was standardised, optimum time to attain sterilisation and pasteurisation for canning were optimised. pH of jackfruit was below 4.5. Since a canned product having pH less than 4.5 can be processed in boiling water temperature (Srivastava and Sanjeev, 1994; Sudheer and Indira, 2007), two pasteurisation temperatures were selected along with sterilisation temperature for process optimisation. For this purpose, F and F_0 values were determined as a measure to compute the time required to heat the product at different sterilisation or pasteurisation temperatures and thereby optimise the suitable combination of time and temperature.

3.6.1 Positioning of thermocouple in cold point

The point of greatest temperature lag, i.e., the slowest heating point (SHP) inside the container (cold point) was established and the heat penetration inside the can was determined. The cans used for testing were fixed with thermocouple glands and the thermocouple probe was inserted through it. To find out the temperature at its cold point, thermocouple was inserted and fixed at 15% of total can height from bottom (Datta, 1994) and was connected to the Tump Scanner cum F-value measuring device.

3.6.2 Can filling

About 250 g of blanched samples were filled in thermocouple mounted tin cans of 900 ml volume (11.5 cm height and 10 cm diameter), in such a way that the tip of the thermocouple probe can sense the core temperature inside the sample. It was done by filling the bottom of the can with sample in closely packed manner in such a way that the sample touches the tip of the thermocouple probe.

Then the remaining portion of the can was filled with the sample with addition of about 550 ml brine solution (2%) with provision of suitable headspace (7 mm).

3.6.3 Exhausting of cans

Exhausting of cans was carried out to remove the residual air by passing the cans through a tank of hot water at 85^{o}C till the centre of cans reaches 79^{o}C (Srivastava and Sanjeev, 1994). The cans were sealed immediately after exhausting. The sealed cans leaving the sealing machine were washed as they were likely to have some brine adhering to their surface.

3.6.4 Thermal processing

The sealed cans were subjected to pasteurisation and sterilisation process. For the purpose, 96 cans were divided into four equal batches of which two batches were used for pasteurisation and the other two for sterilisation. In pasteurisation, the blanched samples were treated at 90^{o}C and 100^{o}C and the time for attaining F values of 8 and 10 were determined. Similarly, time required to heat the product for F_0 values of 1 and 2 were obtained for sterilisation at 110^{o}C and 121^{o}C. The different treatments were represented as follows,

TP1: Sample pasteurised at 90^{o}C for F value 8

TP2: Sample pasteurised at 90^{o}C for F value 10

TP3: Sample pasteurised at 100^{o}C for F value 8

TP4: Sample pasteurised at 100^{o}C for F value 10

TS1: Sample sterilised at 110^{o}C for F_0 value 1

TS2: Sample sterilised at 110^{o}C for F_0 value 2

TS3: Sample sterilised at 121^{o}C for F_0 value 1

TS4: Sample sterilised at 121^{o}C for F_0 value 2

The thermocouple output was recorded using an Ellab recorder (model TM 9608). In both cases the process times were determined using the cold point method with the help of VALSUITE software that optimise a suitable combination of time and temperature. The cans were cooled by dipping in cold

water to a core temperature of 40^{o}C to prevent the product from being overcooked. The heat penetration curve and the suitable time required for attaining the specified F or F_0 value were determined.

After thermal processing the pasteurised cans were subjected to microbial analysis by plate count method and the sterilised cans were subjected to both plate count method and commercial sterility test (Sreenath *et al.*, 2008). Finally suitable thermal processes were optimised based on the results of textural, colour and microbial analysis. Fig. 3.2 shows the flow chart for thermal process optimisation of canned tender jackfruit

3.6.5 Microbial analysis

Microbial analysis of the study involved the detection of bacteria, yeast and fungi that may spoil the jackfruit during storage. An average of three replications was chosen as the final reading for each sample. The different procedures followed for microbial analysis are detailed below.

3.6.5.1 Enumeration of micro-organisms

The shelf life and quality of products are based on number and kind of micro-organism present, which were assessed by serial dilution and plating method for enumeration of bacteria, yeast and fungus as per the procedure outlined by Anon., 1967. Bacteria were cultured using nutrient agar medium while potato dextrose medium was used for fungal and yeast culture. Appendix B gives composition of the culture media. Known quantities of nutrients respective to each microorganism were dissolved in 100 ml distilled water. The pH of the medium was adjusted using 0.1N NaOH and 0.1N HCl.

3.6.5.2 Standard plate count method

The jackfruit sample was crushed using pestle and mortar and 10 ml (W_s) of the juice extracted was added to 90 ml of sterile water (10^{-1} dilution) and shaken well for 10 to 15 minutes to assure uniform distribution of micro-organisms. Then, one ml from this diluted sample was transferred to a sterile petri dish with a sterile pipette. For sterilised samples, the diluted sample was kept in a water bath at 80°C for 10 minutes before transferring to petri dish for spore count

determination. Approximately 15 to 20 ml of molten and cooled nutrient medium (45°C) for the specific organism were added to respective petri dish. Then the plates were rotated clockwise and anticlockwise direction for thorough mixing of the diluents and the medium. After that the plates were incubated for 1 to 2 days at 37°C and 55°C for both bacterial growth and spore formation and for 3 days at 25°C for fungi and yeast growth (Rao, 1986). After the incubation period, the colonies (N_{cfu}) were counted and the number of microbial organisms per gram of sample (N_s) for dilution factor (DF) was calculated as given below.

$$N_s = \frac{N_{cfu} \times \mathrm{DF}}{W_s} \qquad 3.4$$

3.6.5.3 Commercial sterility test

The cans processed at different F_0 values were tested for commercial sterility (IS2168, 1971). About six cans were randomly selected from each batch processed to different F_0 values. Three cans from each batch were incubated at 55^oC for 4 days and the remaining was incubated at 37^oC for 14 days. After predetermined period, the incubated cans were opened in aseptic conditions and the samples were transferred to sterile thioglycollate broth tubes. Then a layer of sterile liquid paraffin wax was applied in each tube to create anaerobic conditions. The tubes were then incubated at 37^oC for 48 h and observed for development of turbidity, which indicated the survival of micro-organisms. Tubes not showing any turbidity were incubated again for 48 h at 37^oC to ascertain sterility (Sreenath *et al.,* 2008).

3.7 Standardisation of thermal process after canning

The results of the serial dilution and commercial sterility test suggested the most appropriate temperature and time (standardised) for pasteurisation (T_p) and sterilisation (T_s). After optimal blanching the samples were canned with prior addition of preservatives like brine, citric acid and KMS in different concentrations. The different treatment formulations of canned jackfruit for standardised F and F_0 value for pasteurisation and sterilisation respectively are given below.

ST1 : Canning with 2% brine and thermal processing at T_s

ST2 : Canning with 0.1% KMS and thermal processing at T_s

ST3 : Canning with 0.3% citric acid and thermal processing at T_s

ST4 : Canning with 2% brine + 0.1% KMS and thermal processing at T_s

ST5 : Canning with 0.3% citric acid + 0.1% KMS and thermal processing T_s

PT1 : Canning with 2%brine and thermal processing at T_p

PT2 : Canning with 0.1%KMS and thermal processing at T_p

PT3 : Canning with 0.3% citric acid and thermal processing at T_p

PT4 : Canning with 2%brine + 0.1% KMS and thermal processing at T_p

PT5 : Canning with 0.3% citric acid + 0.1%KMS and thermal processing at T_p

The cans were exhausted prior to sealing till the centre of cans attained a temperature of 79^{o}C while passing them through a tank of hot water at 85^{o}C. Then the cans were sealed airtight and subjected to thermal processing at optimised temperatures and finally cooled by dipping in cold water. (Plate 3.8 - 3.13)

3.8 Storage studies

The thermally processed cans were then stored at different conditions depending on the type of thermal process (Plate 3.14). The sterilised cans were kept at ambient conditions (20 to 32^{o}C and 66 to 93% relative humidity) and pasteurised cans were stored at temperature below 10^{o}C during the study period. The biochemical, textural, colour and microbial analyses were performed for canned tender jackfruit for 2 months at an interval of 15 days. Microbial analyses were performed for 10^{-1} dilution. The statistical analysis using completely randomised design (CRD) by Two Factor Completely Randomised Design technique was executed to study the influence of temperature, time of processing, type of preservative and duration of storage on biochemical, textural and microbial qualities of the canned sample. Fig. 3.3 shows the flowchart for canning of tender jackfruit.

Plate 3.8 Cans for thermal processing

Plate 3.9 Can filling

Plate 3.10 Cans after exhausting

Plate 3.11 Can seamer

Plate 3.12 Retort

Plate 3.13 Cooling of cans

Plate 3.14 Thermal processed cans

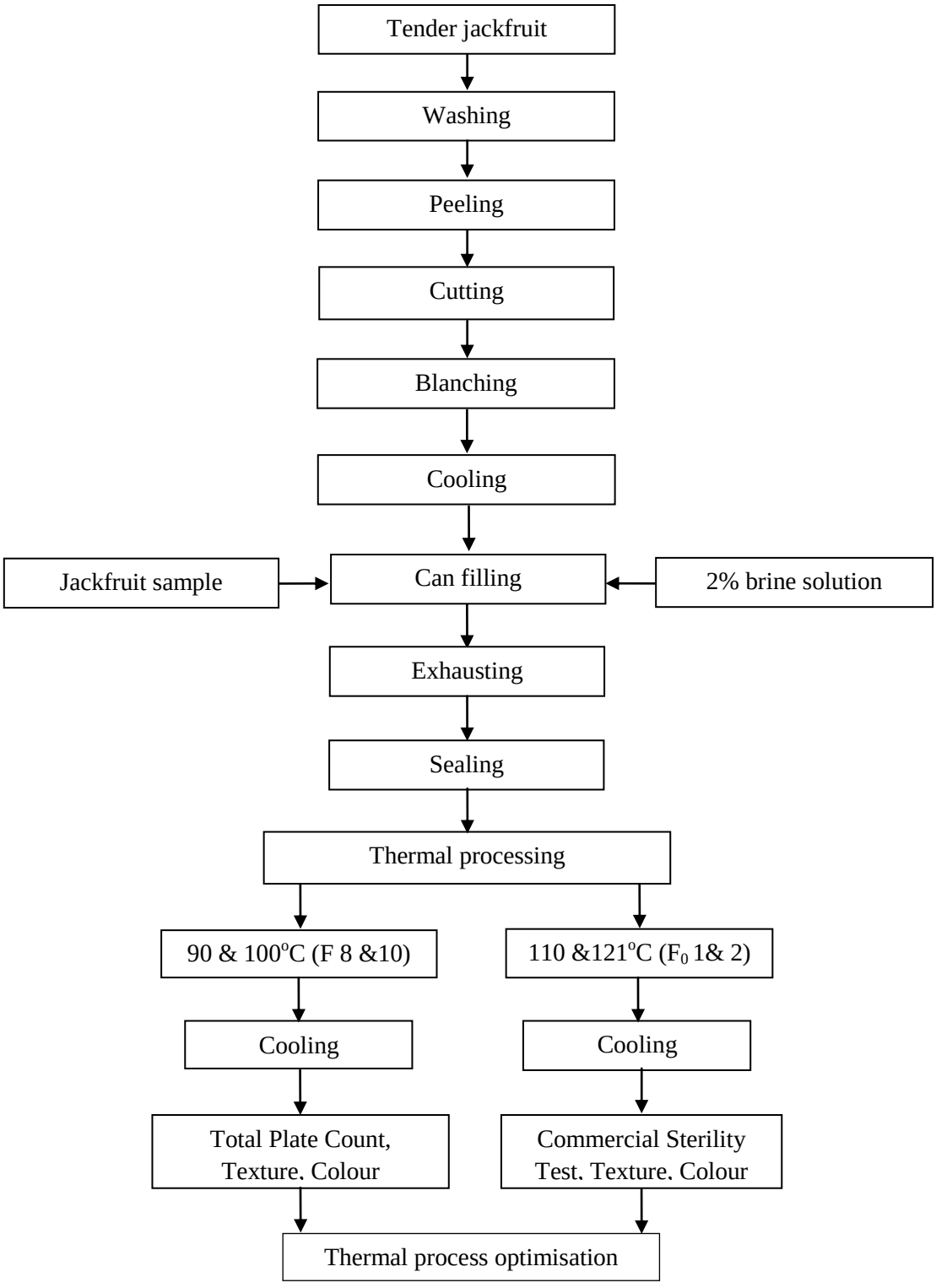


Fig. 3.2 Flow chart for thermal process optimisation of canned tender jackfruit

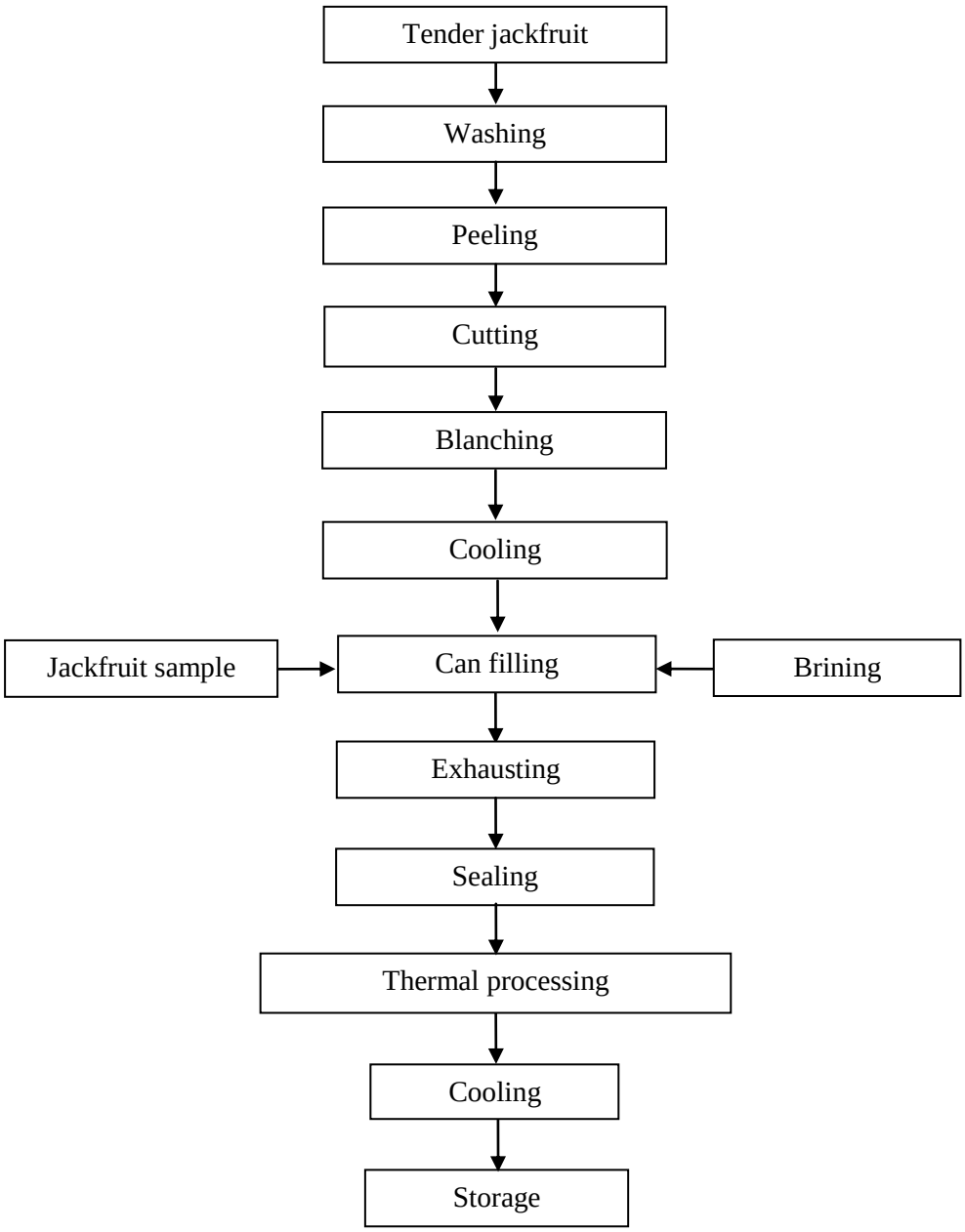


Fig. 3.3 Flow chart for canning of tender jackfruit

3.9 Sensory analysis

Organoleptic evaluation of thermally processed tender jackfruit with respect to colour, flavour, texture and overall acceptability was adjudged on a 9 point hedonic scale (Ranganna, 1986) by a panel of 12 untrained judges. The 9 point hedonic scale used for the sensory evaluation is shown below.

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

The evaluation session was carried out after 2 months of storage. The samples were arranged in tables with specific codes. The scale was easily understood by each of the panellist and their response was converted to numerical values for computation purposes. Final results were obtained by calculating the average of the points given by all panellists and the results were statistical analysed using Kendall's coefficient of concordance. The specimen evaluation card is shown Appendix C.

3.10 Cost analysis

The cost of thermal processing of tender jackfruits was determined with suitable assumptions using standard procedure. The estimation of cost of processing is given in Appendix D.

3.11 Statistical analysis

Statistical analyses were carried out to study the effect of different parameters on all the dependent variables. Analysis of variance (ANOVA) was conducted with Completely Randomised Design (CRD) for optimisation of different parameters involved in this study and Kendall's coefficient of concordance test for assessing the significant agreement among the judges during sensory evaluation using SPSS software. The quality of canned samples during storage were analysed by Two Factor Completely Randomised Design using M-STAT software.

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The outcomes of the various experiments conducted to standardise the thermal process and the various quality parameters involved are enunciated and discussed in this chapter.

4.1 Physico-chemical characteristics of tender jackfruit

The estimated composition and quality parameters before canning of the 'Varikka' variety of tender jackfruit are presented in Table 4.1. The average values of the chemical components viz., TSS, ascorbic acid, titrable acidity and crude fibre content were estimated to be 4.1^{o}B, 8.57 mg/100 g, 0.13% and 2.16 respectively.

Table 4.1 Physico-chemical characteristics of fresh tender jackfruit

Chemical characteristics		**Mean ± SD***
TSS (^{o}B)		4.10 ± 0.047
pH		4.01
Ascorbic acid (mg/100 g)		8.57 ± 0.189
Titrable acidity (%)		0.13 ± 0.003
Crude fibre content (%)		2.16 ± 0.041
Physical characteristics		
Texture	Firmness (N)	82.97 ± 0.984
	Toughness (N.sec)	185.10 ± 0.703
Colour value	L	60.32 ± 0.008
	a	-1.35 ± 0.050
	b	16.08 ± 0.086

*SD : Standard Deviation

The texture analyser estimation of firmness and toughness were found to be 83.00 N and 185.10 N.sec respectively. The colour values of the tender jackfruit

gave 60.32, -1.35 and 16.08 respectively for ‘L’, ‘a’, and ‘b’ values in Hunter colour lab measurement scheme. These values especially ‘L’ value, gave the impression that the colour of the fresh tender jackfruit would tend towards white colour.

4.2 Testing of developed hot water blancher

The newly developed hot water blancher was tested for the performance of the thermostat arrangement, capacity of the blancher, and the time consumed for attaining a particular temperature.

4.2.1 Testing of thermostat arrangement

The performance of the thermostat arrangement was tested by comparing the temperature indicated by the set up, with that of an external thermometer dipped in boiling water in the SS vessel. The external thermometer gave values that were almost similar to different set temperatures (40 to 110^{o}C at an interval of 10^{o}C) in the thermostat arrangement. The maximum difference between both the readings was in the order of 1^{o}C for the entire analyses which exhibited good performance of the thermostat arrangement.

4.2.2 Capacity of the developed hot water blancher

The capacity of the SS vessel to hold water and SS perforated box to hold the samples for the hot water blancher were calculated as 54 L/h and 34 kg/h respectively.

4.2.3 Comparison of conventional and developed hot water blancher

The time required to attain a particular temperature while boiling 11 litres of water in the blancher was evaluated by comparison with a conventional (without thermostat and tubular heater set up) blancher (Table 4.2).

Table 4.2 Comparison of conventional and developed hot water blancher

Temperature (^oC)	Time taken (min)		% time reduction
	Conventional method	Developed blancher	
40	5.04	3.51	30.35
50	9.59	5.6	41.61
60	15.18	7.37	51.45
70	20.37	9.52	53.33
80	27.16	12	55.82
90	34.41	15.2	55.83
100	46.05	18.47	59.90
Average time reduction			49.76

As illustrated in the above table, conventional method of blanching required 46.05 minutes to attain a temperature of 100^oC, whereas the newly developed blancher required only 18.47 minutes for the purpose under the same condition. In general, the performance of the new blancher in terms of time consumption was nearly double that of the conventional one. Also, the heating was more or less uniform in the newly fabricated blancher machine. Blanching by conventional method may require two labourers at a time; one for blanching the product and other for noting the temperature using thermometer. The developed hot water blancher was simple in construction and operation, and required only one person to operate it.

4.3 Standardisation of blanching time

Blanching time was standardised based on the result of hydrogen peroxide test, and the quality parameters like texture and colour. Jackfruit slices of uniform thickness which were subjected to blanching at different duration (B1, B2, B3, B4 and B5, see section 3.5) showed negative result for hydrogen peroxide test. The hydrogen peroxide test shows the presence of peroxidase enzyme indicated by a

pink colour on addition of a drop of H_2O_2 into the blanching water. The time required to inactivate this enzyme so that the pink colour disappears could be considered as the optimum time for blanching. All other enzymes would have been inactivated at this particular time and temperature combination (Srivastava and Sanjeev, 1994; Sudheer and Indira, 2007). In our case, the complete inactivation of the high heat resistant enzymes in the sample was observed within one minute of blanching and thus B1 was considered as the optimum time for tender jackfruit blanching.

The texture of blanched tender jackfruit slices subjected to compression tests on the texture analyser are shown in Fig. 4.1. The texture was defined by two general terms namely, firmness and toughness. The firmness and toughness for blanched samples were lower than that of fresh samples. From the figure it is evident that both of them have shown a decreasing trend with the blanching time. Similar trend was reported by Goncalves *et al*., 2010 in blanching of raw carrots. The values were higher for one minute and lower for five minute blanched samples. The firmness (N) and toughness (N.sec) values for the fresh tender jackfruit sample was 76.11 ± 0.349 and 97.14 ± 0.123 respectively. The firmness reduced in the order of 14% and 34% for samples blanched one minute and five minute respectively, while the percent reduction in toughness was found to be about 20% and 48% for the same samples. It indicated that one minute blanching already softens the tissues of samples to facilitate easy filling during canning process and was similar to that of the fresh sample.

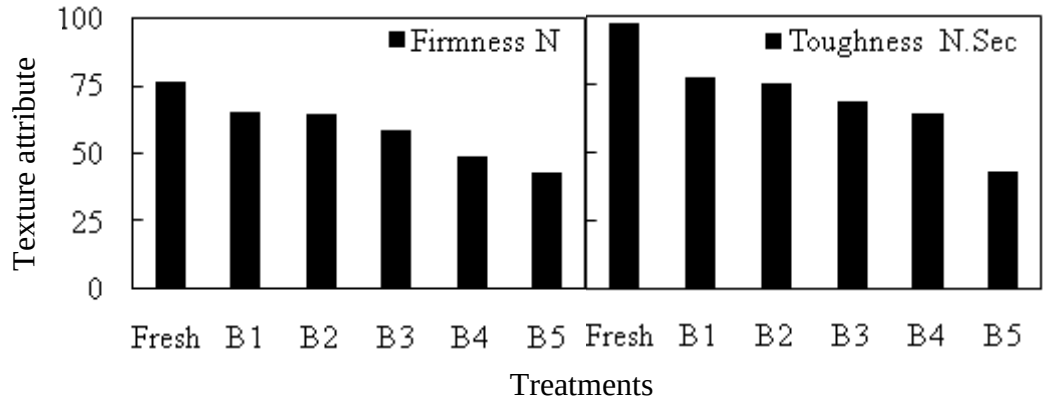


Fig. 4.1 Textural characteristics of blanched tender jackfruit

The Hunter colorimeter colour values (Fig. 4.2) showed that one minute blanched samples retain the colour more often than for other duration. The average CIE colour values viz., 'L', 'a' and 'b' of the reference raw sample were 83.74, 0.36 and 18.93 respectively. While increasing the processing time, 'L' and 'b' values were decreased, while slight loss in greenness by increment in 'a' value was noted. Similar changes in colour alteration were explained by Sims *et al.* (1993), Bao and Chang (1994), Barreiro *et al*. (1997) & Avila and Silva (1999).

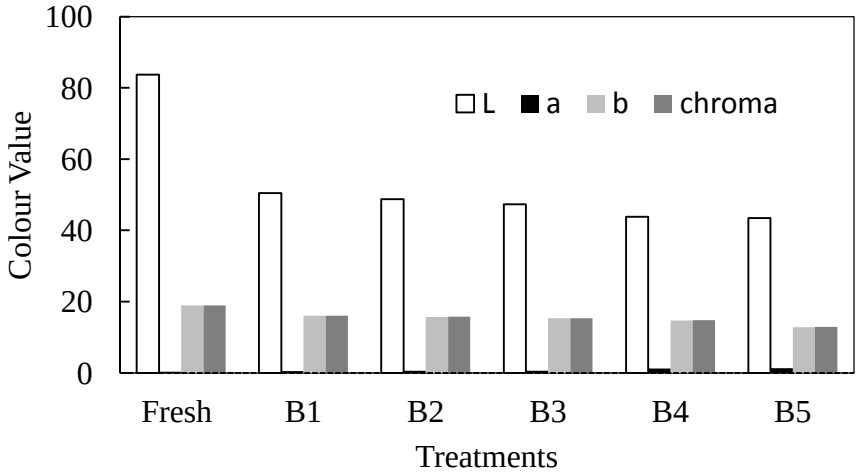


Fig. 4.2 Colour changes due to blanching of tender jackfruit

The change in colour (ΔE) was found to be higher for five minute blanching and minimum for one minute blanched samples (40.76 ± 0.174 and 33.44 ± 0.185 respectively). Chroma is the indicator of colour saturation and intensity. The higher its values are, the more desirable a food product is. The decrease in chroma values with rise in temperature and processing time revealed the effect of blanching on the colour of the commodity. Similar findings were reported by Vina *et al.* (2007) and Lespinard *et al*. (2009).

The results obtained for blanching time optimisation were statistically analysed. The analysis of variance (ANOVA) associated with Duncan's simple Completely Randomised Design (CRD) was implemented to find the most suitable combination (Table 4.3). It was observed that the texture and colour were significantly influenced by the time of blanching chosen for the study at 0.1% significant level.

Table 4.3 ANOVA table for blanching time optimisation

Quality attribute	Source of variation	SS	df	MSS	F	Sig.
Firmness	Between Groups	1598.75	4	399.69	619.66	0.001
	Within Groups	9.68	15	0.65		
	Total	1608.42	19			
Toughness	Between Groups	3123.50	4	780.87	1558.20	0.001
	Within Groups	7.52	15	0.50		
	Total	3131.01	19			
'L' (black - white)	Between Groups	149.83	4	37.46	651.71	0.001
	Within Groups	0.86	15	0.06		
	Total	150.69	19			
'a' (green - red)	Between Groups	2.30	4	0.57	158.50	0.001
	Within Groups	0.05	15	0.00		
	Total	2.35	19			
'b' (blue - yellow)	Between Groups	26.31	4	6.58	35.02	0.001
	Within Groups	2.82	15	0.19		
	Total	29.13	19			

SS: Sum of squares; MSS: Mean sum of squares; df: Degrees of freedom; F: F-ratio

Table 4.4 shows the effect of blanching time on the texture and colour of samples with the results of Duncan's multiple range test for treatment comparison. As discussed before, a better treatment would be the one with least deviation (minimum ΔE) in the quality characteristics as that of the fresh sample. This restricted us to focus only on the first two treatments (B1 and B2). These two treatments were on par for most of the texture and colour values. Among these two treatments, B1 (blanching at 100^{o}C for one minute) was chosen as the best

treatment because the quality characteristics stood next to fresh sample and also the least blanching time amongst all treatments.

Table 4.4 Effect of blanching time on the texture and colour of samples

Sl.No.	Treatment	Firmness	Toughness	'L'	'a'	'b'
1	B1	65.48^{a}	77.44^{a}	50.42^{a}	0.54^{a}	16.08^{a}
2	B2	64.68^{a}	75.45^{b}	48.75^{b}	0.58^{a}	15.73^{ab}
3	B3	58.46^{b}	68.55^{c}	47.28^{c}	0.61^{a}	15.32^{bc}
4	B4	48.60^{c}	63.99^{d}	43.78^{d}	1.21^{b}	14.71^{c}
5	B5	42.82^{d}	42.53^{e}	43.45^{d}	1.32^{c}	12.83^{d}

4.4 Standardisation of blanching treatment

The tender jackfruit samples were blanched (in boiling water (BT1); 0.1% KMS (BT2); 0.3% citric acid (BT3); combination of 0.1% KMS and 0.3% citric acid (BT4)) for the standardised time (B1) of one minute at 100^{o}C as described in section 3.5. The effect of those treatments on the quality attributes namely texture and colour of the samples were examined.

4.4.1 Effect of preservatives on textural qualities of blanched tender jackfruit

The effect of different preservatives used in blanching on texture in terms of firmness and toughness of the blanched samples are shown in Fig. 4.3.

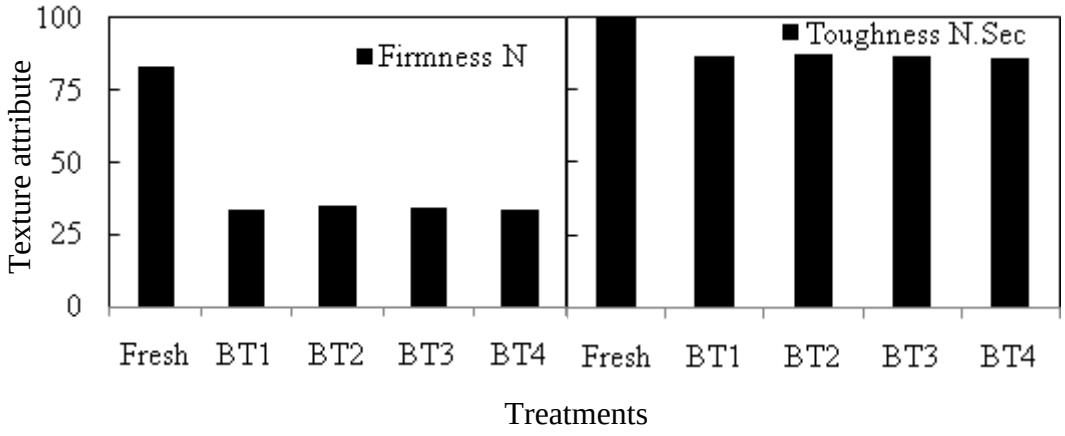


Fig. 4.3 Effect of preservatives on texture of blanched tender jackfruit

It was observed that the textural attributes were not much affected by the addition of preservative (Chowdhury *et al.*, 2009) justified with their similar values for all treatments. The firmness for the treatments BT1, BT2, BT3 and BT4 were 33.39 ± 0.68, 34.87 ± 0.31, 34.42 ± 0.46 and 33.16 ± 0.53, respectively. Similarly less significant difference was found for toughness of treatment BT4. For the treatments BT1, BT2, BT3 and BT4, the values of toughness were estimated to be 86.64 ± 0.57, 87.18 ± 0.37, 86.6 ± 0.23 and 85.95 ± 0.36 respectively. The ANOVA analysis for the effect of preservatives used in blanching on textural properties is shown in the Tables 4.5 and 4.6. It could be inferred that the treatments BT2 and BT3 were on par for both the textural attributes. Further, the texture for these treatments was on the acceptance level. Hence they were considered as the best treatments for blanching based on texture.

4.4.2 Effect of preservatives on colour of blanched tender jackfruit

The Hunter colour parameters ('L', 'a', 'b' and chroma) of tender jackfruit samples due to the effect of different blanching treatments are presented in Fig.4.4. The difference in colour (ΔE) values for each treatment from fresh samples was also recorded.

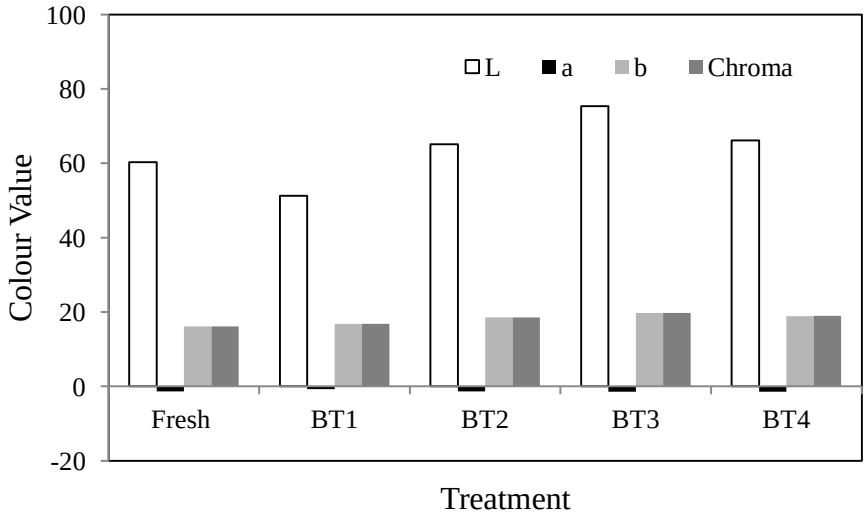


Fig. 4.4 Effect of preservatives on colour of blanched tender jackfruit

As illustrated in the Fig. 4.4, the colour values followed the same trend for the treatment BT1 as discussed in the section 4.3 (blanching time optimisation). The pattern was typically opposite in case of treatments with preservatives in which 'L'-value increased (lighter than the standard sample), 'a'-value decreased (gain in greenness) and 'b'-value increased (gain in yellowness). The gain in green colour of the fresh sample is because the chemicals like KMS and citric acid raises the pH of the blanching water and prevents the change of fresh green colour of chlorophyll into pheophytin which is unattractive brownish green in colour. (NIIR Board, 2003). The maximum value for 'L' and 'b' were found in treatment BT3 and minimum in treatment BT1. On the other hand 'a' was highest in BT1 and lowest in BT3 with values -0.74 and -1.48, respectively. Most desirable product represented by its highest chroma value was found in treatment BT3 and lowest in BT1 with values 19.78 ± 0.374 and 16.80 ± 0.472, respectively. Hence the blanching in 0.3% citric acid (BT3) seems to be better in terms of colour parameters. The ANOVA for the effect of preservatives used in blanching on the Hunter colour and textural values were shown in the Table 4.5 and 4.6. Blanching treatment significantly affected the texture and colour at 0.1% significant level.

Table 4.5 ANOVA table for blanching treatment optimisation

Quality attribute	Source of variation	SS	df	MSS	F	Sig.
Firmness	Between Groups	8.03	3	2.68	10.05	0.001
	Within Groups	3.19	12	0.27		
	Total	11.23	15			
Toughness	Between Groups	3.02	3	1.01	6.30	0.008
	Within Groups	1.92	12	0.16		
	Total	4.93	15			
'L' (black - white)	Between Groups	1189.14	3	396.38	3938.37	0.001
	Within Groups	1.21	12	0.10		
	Total	1190.35	15			

Table 4.5 continued

Quality attribute	Source of variation	SS	df	MSS	F	Sig.
'a' (green - red)	Between Groups	1.45	3	0.48	48.12	0.001
	Within Groups	0.12	12	0.01		
	Total	1.57	15			
'b' (blue - yellow)	Between Groups	18.42	3	6.14	6.13	0.009
	Within Groups	12.02	12	1.00		
	Total	30.44	15			
Chroma	Between Groups	18.95	3	6.32	6.30	0.008
	Within Groups	12.029	12	1.00		
	Total	30.977	15			

SS: Sum of squares; MSS: Mean sum of squares; df: Degrees of freedom; F: F-ratio

It was noted that the treatments BT2 and BT3 were on par except for 'L' values (Table 4.6). Based on the colour values and with the statistical results, BT3 was chosen as an appropriate treatment satisfying all the conditions.

Table 4.6 Effect of blanching preservatives on texture and colour of samples

Treatment	Firmness (N)	Toughness (N.sec)	'L'	'a'	'b'	Chroma
BT1	33.39^{b}	86.64^{a}	51.21^{d}	-0.74^{b}	16.79^{b}	16.80^{b}
BT2	34.87^{a}	87.18^{a}	65.14^{c}	-1.36^{a}	18.51^{a}	18.56^{a}
BT3	34.42^{a}	86.60^{a}	75.34^{a}	-1.47^{a}	19.73^{a}	19.78^{a}
BT4	33.16^{b}	85.95^{b}	66.13^{b}	-1.46^{a}	18.90^{a}	18.95^{a}

4.5 Optimisation of thermal process time and temperature

The time required to process the cans with tender jackfruit samples to pasteurisation temperatures for F values 8 and 10 and to sterilisation temperatures for F_0 values 1 and 2 were determined as mentioned in section 3.6. Heat penetration curve was recorded using thermocouple outputs. The time-

temperature combinations of thermal process were standardised for tender jackfruit based on commercial sterility, permissible limit of micro-organisms, spore count in sterilised products, texture and colour.

4.5.1 Commercial sterility test for sterilised products

The cans processed to sterilisation temperatures of 110^{o}C and 121^{o}C for F_0 values 1 and 2 were subjected to commercial sterility test (Plates 4.1). Processed cans of all the batches except TS1 (110^{o}C for F_0 value 1) were found to be commercially sterile (Plates 4.2 and 4.3), indicating that the thermal processing was sufficient to bring about commercial sterility in those three batches.

4.5.2 Microbial analysis for pasteurised and sterilised products

The total bacterial, yeast and fungal count in the tender jackfruit samples at two pasteurisation (90 and 100^{o}C; F values 8, 10) and two sterilisation temperatures (110 and 121^{o}C; F_0 values 1, 2) were examined. The sterilised products were analysed according to the standard plate count method for spores as per section 3.6.5.2. The results of microbial analysis are listed in Table 4.7.

Table 4.7 Microbial analysis of processed cans

Treatment	Microbial load (10^1 cfu g^{-1})					
	Bacteria		Fungi	Yeast	Spore count	
	(55^{o}C)	(37^{o}C)			(55^{o}C)	(37^{o}C)
TP1	5	4	0	0	-	-
TP2	0	0	0	0	-	-
TP3	4	4	0	0	-	-
TP4	0	0	0	0	-	-
TS1	0	0	0	0	2	1
TS2	0	0	0	0	0	0
TS3	0	0	0	0	0	0
TS4	0	0	0	0	0	0

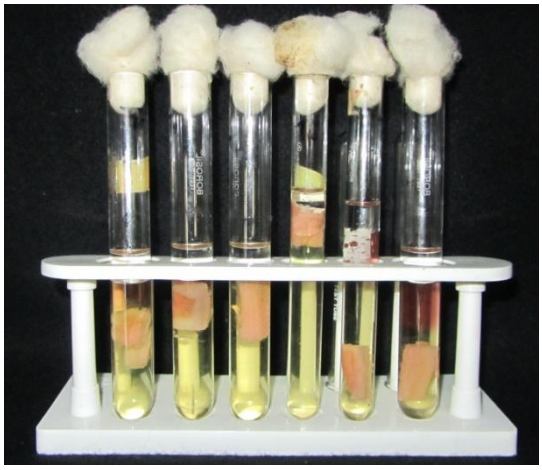


Plate 4.1 Commercial sterility test

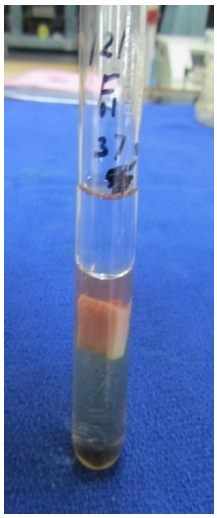


Plate 4.2 Sterility test for tender jackfruit processed at 121^{o}C (F_0 1)

Plate 4.3 Sterility test for tender jackfruit processed at 110^{o}C (F_0 1)

The microbial counts in all the treatments were within the permissible limit (not more than 50/ml) prescribed by PFA, 1956. It was found that for tender jackfruit pasteurised for F10 and sterilised for F_0 1 at 121^oC and F_0 2 for both 110^oC and 121^oC were microbiologically safe for further storage. Hence the pasteurisation process with F value 8 for both 90^oC and 100^oC (TP1 and TP3 respectively) and the sterilisation process of F_0 1 for 110^oC (TS1) were eliminated from further studies of thermal process optimisation for canned tender jackfruit.

4.5.3 Effect of thermal processing on texture of the canned tender jackfruit

Table 4.8 shows the effect different thermal treatments viz., pasteurisation and sterilisation on textural properties like firmness and toughness of the canned tender jackfruit.

Table 4.8 Effect of pasteurisation and sterilisation on texture

Treatment	Firmness (N)	Toughness (N.sec)
Fresh sample	82.97 ± 1.136	185.10 ± 0.812
TP2	68.48 ± 0.49	63.95 ± 0.553
TP4	53.49 ± 0.715	43.04 ± 1.04
TS2	5.46 ± 0.884	3.38 ± 0.619
TS3	15.29 ± 0.453	6.78 ± 0.349
TS4	4.46 ± 0.943	2.73 ± 0.172

It could be seen from the table that the firmness and toughness were decreased with increase in thermal process, time and temperature. Among the two pasteurisation treatments, maximum value of 68.48 ± 0.49 N and 63.95 ± 0.553 N.sec for firmness and toughness respectively were recorded for the treatment at 90^oC for F value 10 (TP2). Similarly, in sterilisation, the maximum value for firmness and toughness were 15.29 ± 0.453 N and 6.78 ± 0.349 N.sec respectively for samples processed at 121^oC for F_0 value 1 (TS3). As against the expectation, the value of TS3 was sufficiently greater than that TS2. The treatment of low temperature for long time adversely affected the texture of the product which resulted in the lower values of texture for TS2. The difference in textural attribute

values from fresh samples was due to a range of enzymatic and chemical reactions during thermal processing, which altered the texture of processed fruits and vegetables. The chemical changes, such as solubilisation and depolymerisation of pectic polysaccharides, affected the constituents of the cell wall and middle lamella, thereby resulting in a major change in the firmness of fruits and vegetables (Nisha *et al*., 2006). Hence thermal processing for 90^{o}C for F value 10 and 121^{o}C for F_0 value 1 were found to be best pasteurisation and sterilisation time-temperature combination for canning tender jackfruit based on texture.

4.5.4 Effect of thermal processing on colour of the canned tender jackfruit

Change in food colour is associated with heat treatment of the food. Retention of food colour after thermal processing may be used to predict the extent of quality deterioration of food resulting from exposure to heat (Seonggyun and Santi, 1995). Thermal processing brought about variations in colour of canned tender jackfruit which were observed with Hunter colour measurements as enlisted in Table 4.9.

Table 4.9 Effect of pasteurisation and sterilisation on colour

Treatment	'L'	'a'	'b'	ΔE
Fresh sample	60.32 ± 0.01	-1.35 ± 0.06	16.09 ± 0.01	-
TP2	50.49 ± 0.25	0.46 ± 0.06	15.88 ± 0.55	10 ± 0.23
TP4	50.42 ± 0.78	2.28 ± 0.24	11.79 ± 0.18	11.39 ± 0.77
TS2	37.84 ± 1.44	15.59 ± 0.27	8.39 ± 0.22	29.19 ± 0.94
TS3	48.76 ± 2.71	5.28 ± 0.21	10.77 ± 0.36	14.41 ± 2.22
TS4	38.61 ± 1.11	15.83 ± 0.26	8.36 ± 0.06	28.75 ± 0.72

It is inferred from the table that colour variation was higher in case of sterilisation than pasteurisation as denoted by ΔE value which may be the effect of temperature on the colour. Among the pasteurised treatments, the colour values (especially ΔE value) of TP2 were comparatively nearer to fresh sample. Similarly in case of sterilised samples, TS3 showed a minimum ΔE value of 14.41 ± 2.22. The 'L' values for the treatments with low ΔE values were estimated to be 50.49 ±

0.25 and 48.76 ± 2.71 for pasteurisation and sterilisation respectively. The 'a' value was observed to be minimum and 'b' value to be maximum for these treatments in respective thermal processing category.

The results of the statistical analysis by simple CRD, performed separately for pasteurised and sterilised products to study the effect of different thermal processing time-temperature combination on the dependent variables like texture and colour are presented in Table 4.10. The results showed that the selected treatments from each group were significantly different (0.1% level) from others in the same category.

Table 4.10 Effect of pasteurisation and sterilisation on texture and colour of samples

Treatment	Firmness	Toughness	'L'	'a'	'b'	ΔE
Pasteurisation						
TP2	68.48^{a}	63.95^{a}	50.49^{a}	0.46^{a}	15.88^{a}	10.00^{a}
TP4	53.49^{b}	43.04^{b}	50.42^{b}	2.28^{b}	11.79^{b}	11.39^{b}
Sterilisation						
TS2	5.46^{b}	3.38^{b}	37.84^{b}	15.59^{b}	8.39^{b}	29.19^{b}
TS3	15.29^{a}	6.78^{a}	48.76^{a}	5.28^{a}	10.77^{a}	14.41^{a}
TS4	4.46^{b}	2.73^{c}	38.61^{b}	15.83^{b}	8.36^{b}	28.75^{b}

The combined results of microbial, texture and colour analysis suggested that pasteurisation at a temperature of 90^{o}C for F value 10 and sterilisation at 121^{o}C for F_0 1 is safe and may be used as an optimum thermal process for canned tender jackfruit. From the heat penetration curves given in Fig. 4.5 and 4.6, it was found that time taken for pasteurisation at 90^{o}C to reach F value 10 was 19 minutes and for sterilisation at 121^{o}C for attaining F_0 value 1 was 38 minutes.

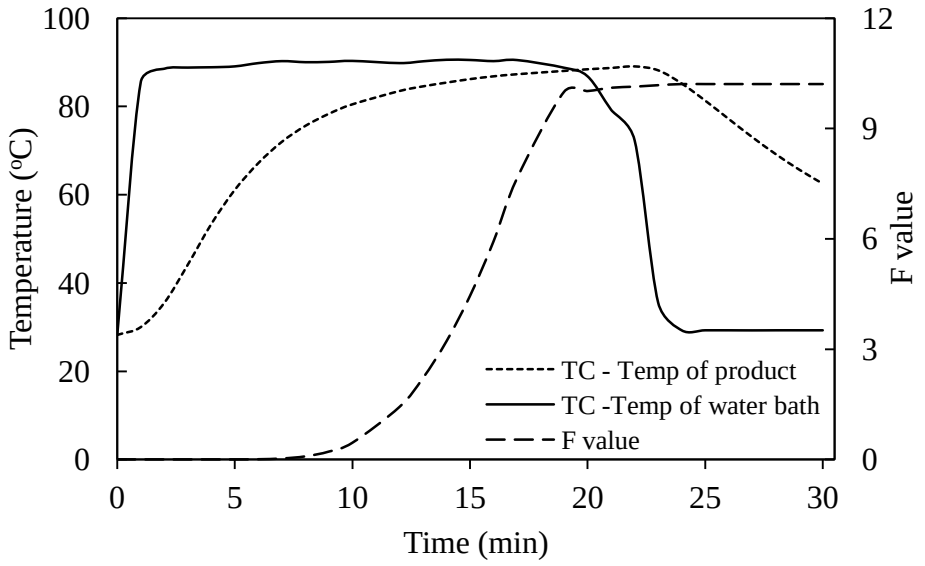


Fig. 4.5 Heat penetration characteristics for 90^{o}C, F10

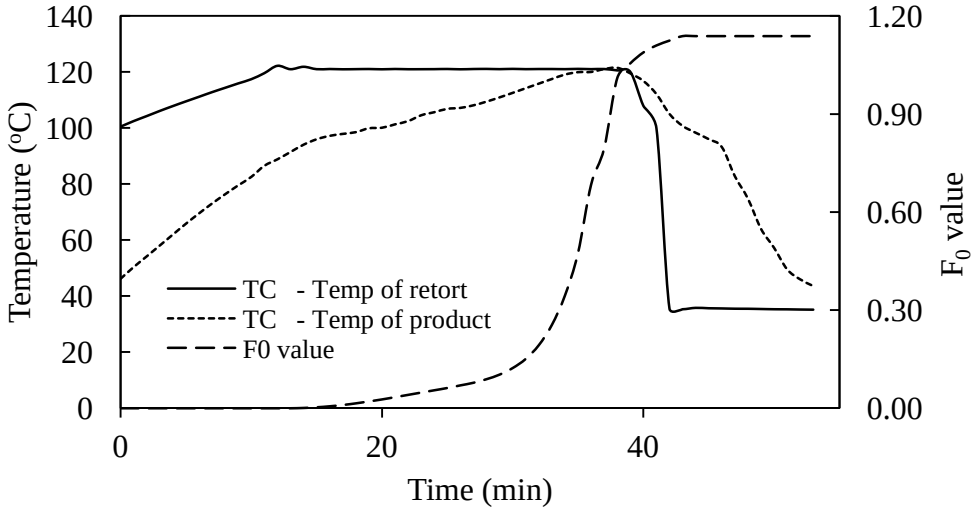


Fig. 4.6 Heat penetration characteristics for 121^{o}C, $F_0$1

4.6 Canning of tender jackfruit

Different quality analyses of canned tender jackfruit in different preservatives were carried out at 15 days interval in order to standardise the suitable preservation technique for tender jackfruit. Products on first day after thermal processing, and at 60th day of storage were presented in Plates 4.4 and 4.5 respectively.

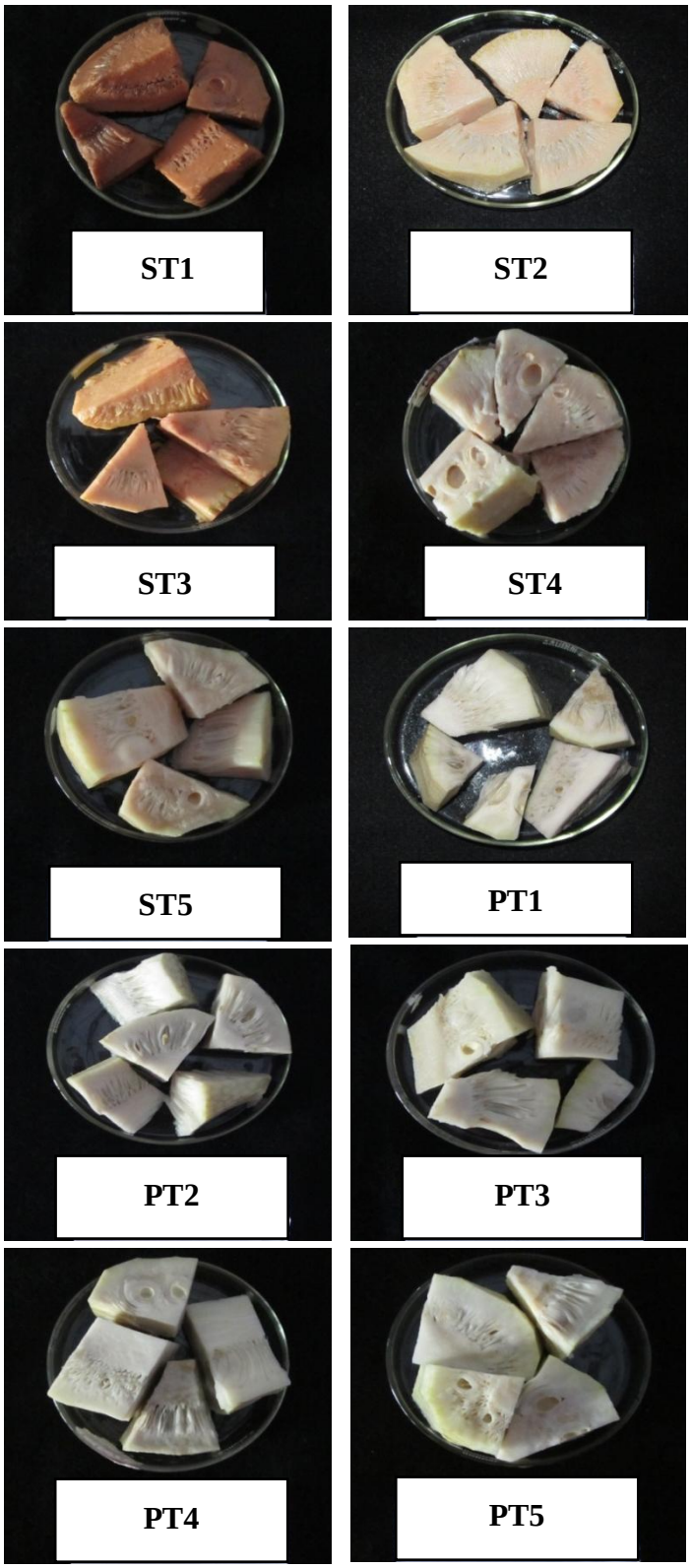


Plate 4.4 Tender jackfruit on first day of storage

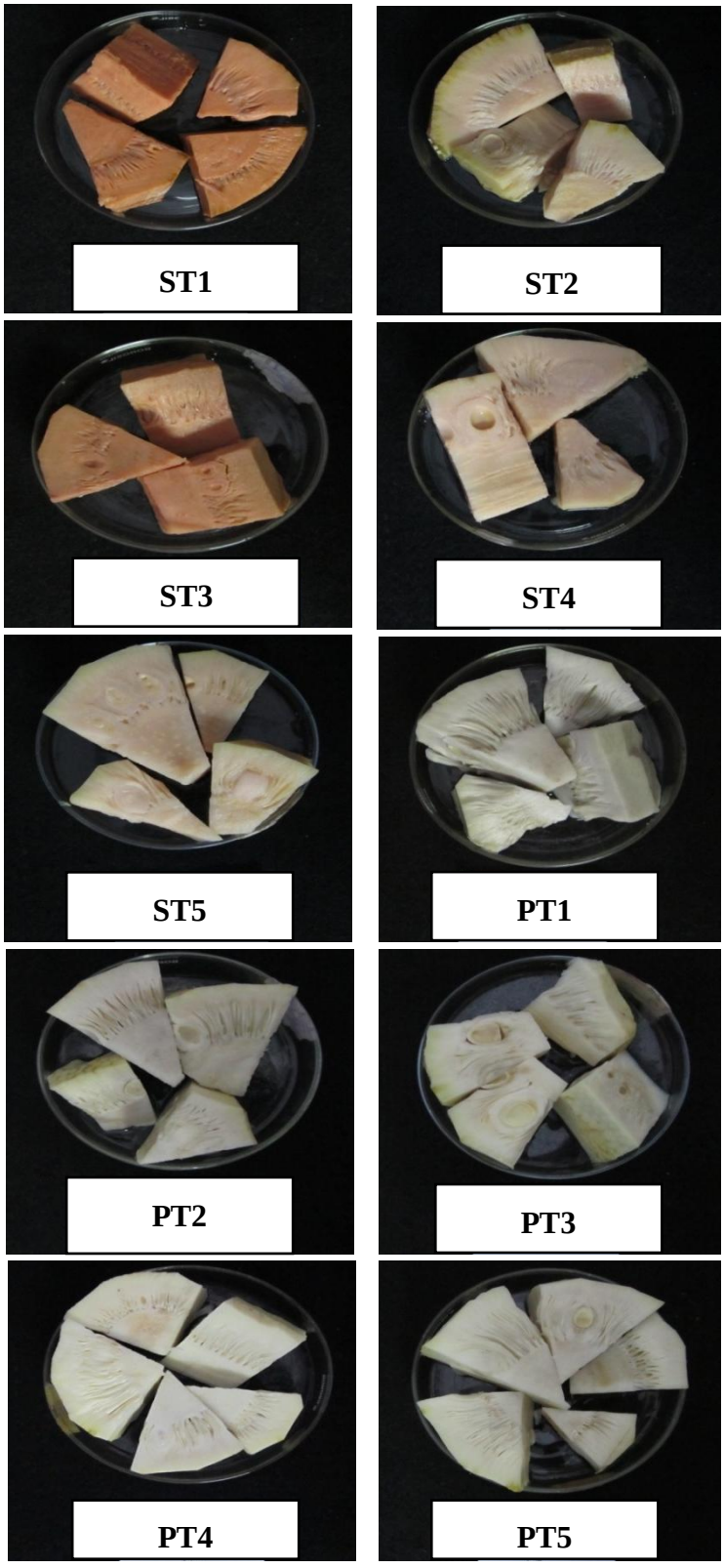


Plate 4.5 Tender jackfruit on 60th day of storage

4.6.1 Total soluble solids of canned tender jackfruit

The TSS of canned tender jackfruit during the cut-out analysis after every 15 days of storage is shown in the Fig. 4.7 - 4.8. Results showed no significant changes in the amount of TSS both in sterilised and pasteurised treatments during storage period.

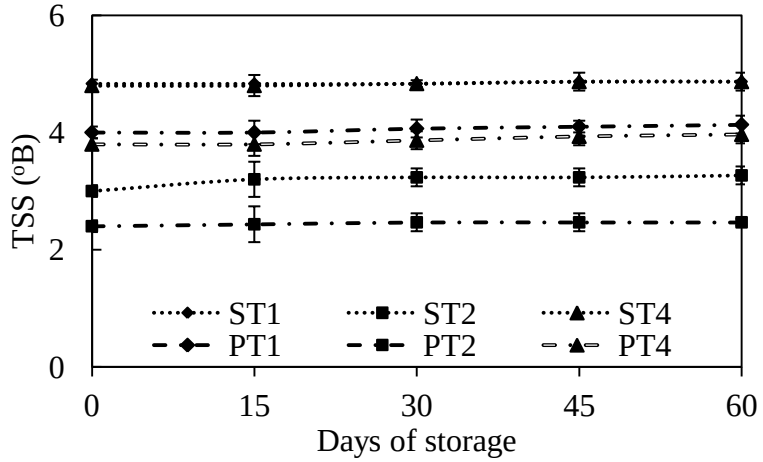


Fig. 4.7 Effect of filling solutions (brine and KMS) and storage on TSS of thermally processed tender jackfruit

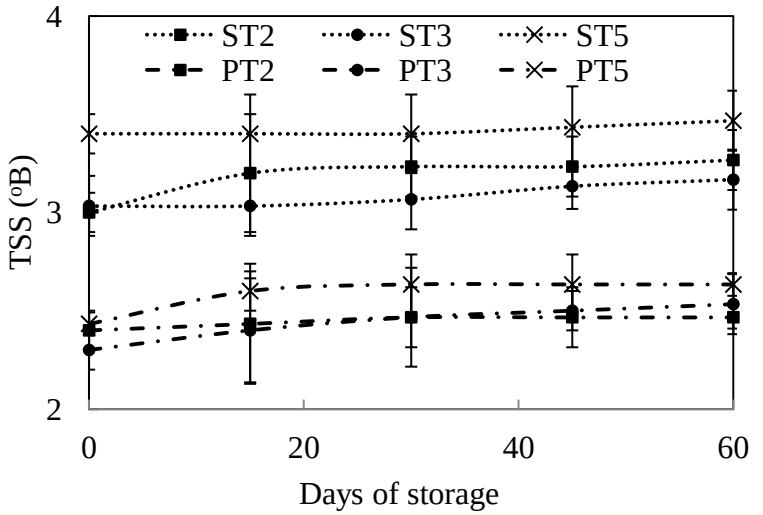


Fig. 4.8 Effect of filling solutions (KMS and citric acid) and storage on TSS of thermally processed tender jackfruit

In some cases there was a slight decrement in the TSS value during the initial stage of storage influenced by the type of filling solution (KMS and citric

acid) and remained almost constant throughout the study period. This may possibly be due to the leaching of some of the soluble solids in water (Jamal and Chieri, 2006). The results obtained were statistically analysed and listed in Table E.1 and E.12 of Appendix E. It is found that there was a significant difference between sterilisation and pasteurisation with regard to the TSS of the canned tender jackfruit. The differential response of the treatments under the two methods was non significant except in case of initial day of storage after processing with CD value 0.186. Among pasteurisation and sterilisation, the minimum TSS value, 2.30^{o}B during initial stage of storage was for samples pasteurised in citric acid solution (PT3) and maximum, 4.83^{o}B for samples sterilised in brine solution (ST1). A similar trend in the TSS composition was reported by Wills and Ku, 2002 & Kagan-Zur and Mizrahi, 1993. In sterilised samples, the treatment ST3 was on par with ST2 and for pasteurisation, the treatments PT4 and PT5 were on par with PT3.

4.6.2 Titrable acidity of canned tender jackfruit

The titrable acidity of canned tender jackfruit exhibited a decreasing trend after 30 days of storage (Fig. 4.9 and 4.10). The mean values decreased from 0.61 ± 0.49 to 0.19 ± 0.12 and 0.69 ± 0.6 to 0.23 ± 0.14 for sterilisation and pasteurisation respectively. The maximum reduction in titrable acidity (75%) was noted in ST1 and minimum of about 50% decline for ST2, ST4, PT1, PT2 and PT4.

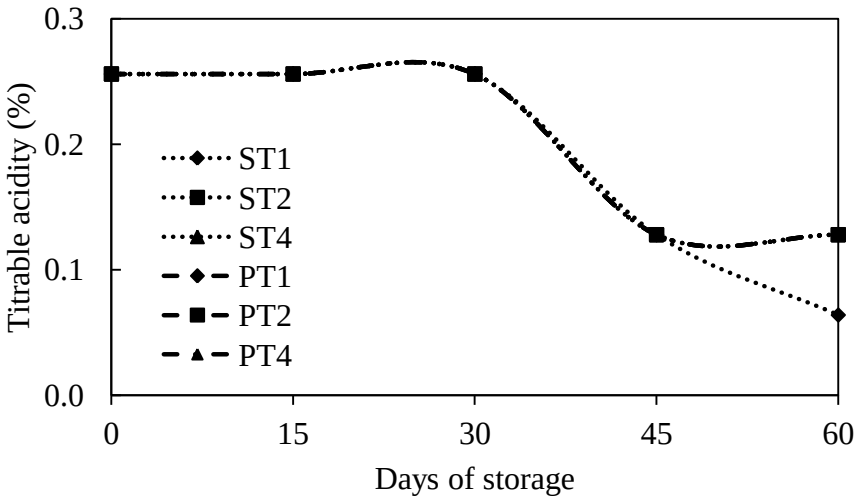


Fig. 4.9 Effect of filling solutions (brine and KMS) and storage on titrable acidity of thermally processed tender jackfruit

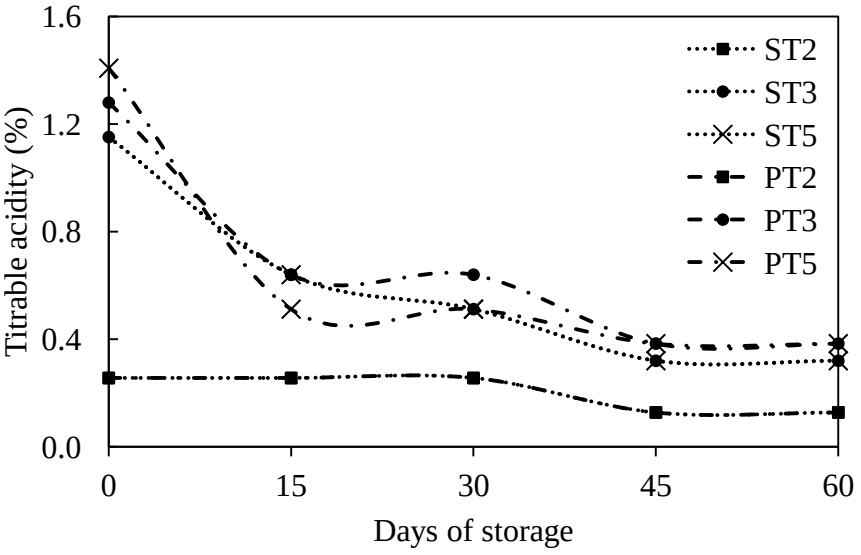


Fig. 4.10 Effect of filling solutions (KMS and citric acid) and storage on titrable acidity of thermally processed tender jackfruit

In case of canned tender jackfruit samples which were preserved in citric acid or combination of citric acid with KMS, initial values of titrable acidity was comparatively higher than that of treatments without citric acid. For treatments with citric acid, an exponential decay in the titrable acidity values was noted

during initial 15 days of storage. This may be due to utilisation of citric acid during hydrolysis of polysaccharides and non-reducing sugars to hexose sugars as reported by Dev *et al.,* 2006 in storage study of onion rings. The value increased slightly during the next phase (15 - 30 days) followed by a decreasing trend thereafter.

Statistical analysis using ANOVA by Two Factor Completely Randomised Design (Table E.2 and E.13 of Appendix E) shows that the titrable acidity was not affected by the type of thermal processing viz., pasteurisation and sterilisation. The observation among the differential response of the treatment under the two processing methods revealed that there was a significant effect (CD = 0.043) after 15 days of storage.

4.6.3 pH of canned tender jackfruit

The nature of variation in pH of canned tender jackfruit during 2 months of storage is shown in the Fig. 4.11 & 4.12. The mean values of both sterilised and pasteurised tender jackfruit increased from 4.06 to 4.11 and 4.06 to 4.10 respectively. Maximum pH was recorded in treatment T1 (4.41) and minimum in treatment T3 (3.61). During storage, maximum increase was observed in sample ST4 (2.19%) followed by ST1 (1.54%), Meanwhile, minimum increase was observed in PT3 (0.64%) followed by PT5 (0.71%). The statistical analysis showed that storage intervals and treatments had a significant ($P < 0.05$) effect on the pH content of canned tender jackfruit during storage (Table E.3 and E.14 of Appendix E).

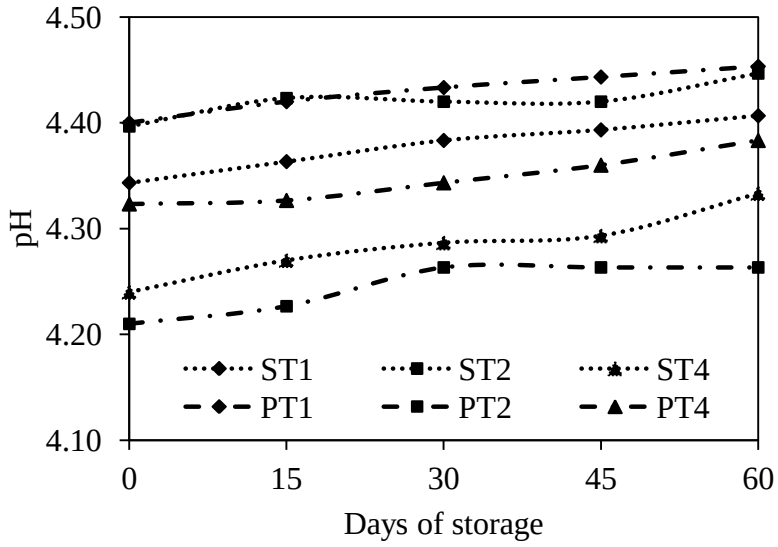


Fig. 4.11 Effect of filling solutions (brine and KMS) and storage on pH of thermally processed tender jackfruit

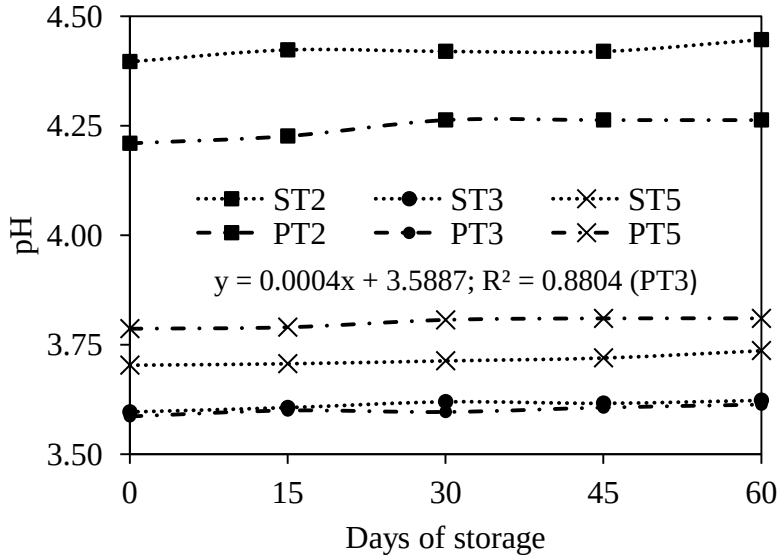


Fig. 4.12 Effect of filling solutions (KMS and citric acid) and storage on pH of thermally processed tender jackfruit

Fig. 4.12 revealed that the pH of the canned tender jackfruit at its initial stage of storage was less as compared to fresh tender jackfruit. It was reported that the influence of temperature decreases pH (Muhammad *et al*., 2010). It was observed that there is a significant variation in the pH of thermally processed

jackfruit having citric acid as preservative, since acidity lowers the pH value. Lowering the pH of the syrup by addition of citric acid was recommended by Berry and Kalra (1983) for safe processing of jackfruit.

4.6.4 Ascorbic acid of canned tender jackfruit

The ascorbic acid content of canned tender jackfruit during 2 months of storage is listed in Fig. 4.13 - 4.14. The mean values of ascorbic acid content significantly decrease from 6.09 ± 0.78 to 5.92 ± 0.87 and 6.13 ± 0.75 to 5.97 ± 0.83 mg/100 g for sterilised and pasteurised tender jackfruit during storage. There was a significant difference was observed between sterilisation and pasteurisation process of canning of tender jackfruit. Pasteurisation was found to be superior as regards vitamin C (CD = 0.029). For treatments maximum mean values were recorded in sample PT2 (6.94) followed by ST2 (6.91) mg/100 g, while minimum mean values were recorded in sample ST1 (5.28) followed by PT1 (5.49) mg/100g. Maximum decrease was observed in sample ST1 (4.64%) followed by ST5 (4.45%), while minimum decrease was recorded in sample PT2 (0.82%) followed by ST2 (0.93%). The losses in ascorbic acid may be due to high temperature and light during storage.

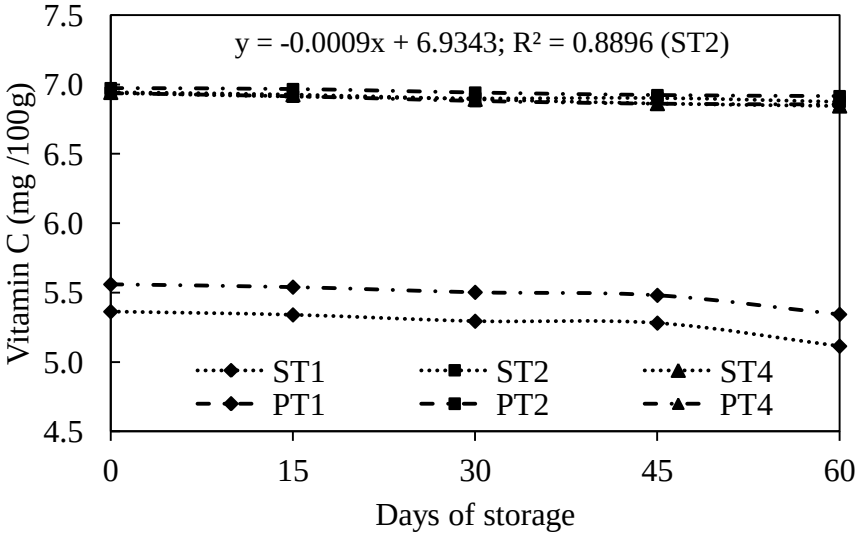


Fig. 4.13 Effect of filling solutions (brine and KMS) and storage on vitamin C of thermally processed tender jackfruit

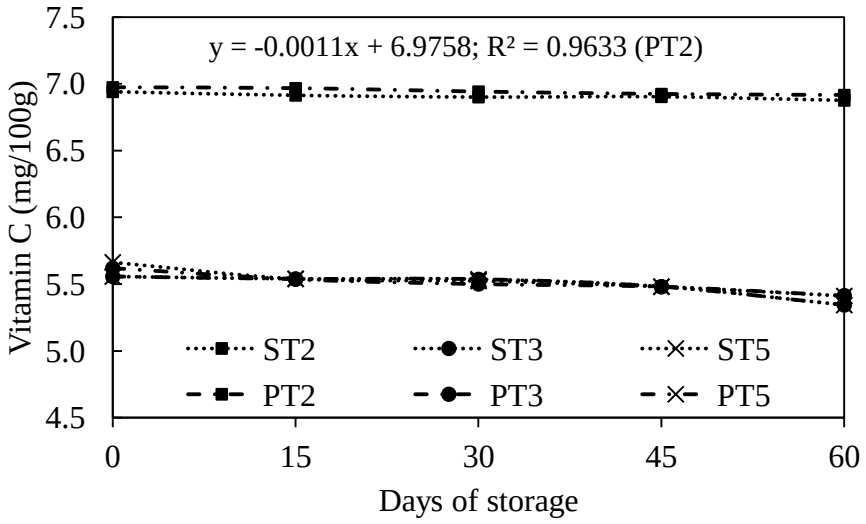


Fig. 4.14 Effect of filling solutions (KMS and citric acid) and storage on vitamin C of thermally processed tender jackfruit

Results showed that samples PT2 and ST2 having potassium metabisulphite retain maximum ascorbic acid. It may be due to better anti-oxidant property of KMS alone that reduced the loss of ascorbic acid during storage (Negi and Roy, 2000; Dev *et al*., 2006). The statistical analysis showed that storage intervals and treatments had a significant effect on the ascorbic acid content of canned tender jackfruit during storage (Table E.4 and E.15 of Appendix E). The treatments having filling solution as brine and KMS (ST4 and PT4) in both sterilised and pasteurised samples were on par with treatments PT2 and ST2 due to anti-oxidant effect of KMS.

4.6.5 Crude fibre content of canned tender jackfruit

The effect of different treatments, type of thermal processing and storage period on crude fibre content of both pasteurised and sterilised tender jackfruit are shown in Table 4.11. Fibre content of fresh tender jackfruit was found to be 2.16%. It was evident that there was no very high variation in fibre content during the storage period and is generally stable during processing, storage and cooking as reported by Joy *et al*., 2007.

Table 4.11 Crude fibre content of pasteurised and sterilised tender jackfruit

Treatments	Storage Interval (days)									
	0		15		30		45		60	
	S	P	S	P	S	P	S	P	S	P
T1	2.27	2.23	2.17	2.23	2.17	2.23	2.15	2.21	2.13	2.18
T2	2.38	2.40	2.29	2.26	2.27	2.30	2.27	2.27	2.25	2.28
T3	2.34	2.44	2.26	2.24	2.24	2.20	2.23	2.16	2.23	2.16
T4	2.34	2.45	2.32	2.38	2.29	2.30	2.27	2.23	2.27	2.23
T5	2.35	2.44	2.35	2.38	2.32	2.33	2.32	2.30	2.31	2.28

S - sterilised and P - pasteurised

Generally fibre content appears to be lower in fresh tender jackfruit than in canned tender jackfruit in many instances. The reason may be that the temperature for blanching canned tender jackfruit was different from that of fresh tender jackfruit and lower temperatures of blanches used for canned products actually increase percentage of cell-wall substances that are indigestible by alkali when using the FDA method for fibre determination. A similar observation was noted by Sistrunk *et al*., 1958 in his laboratory study on the storage of canned beans at different temperatures.

The results obtained were statistically analysed using Two Factorial Completely Randomised Design (Table E.5 and E.16 of Appendix E) and shows that there was no significant difference between sterilisation and pasteurisation as regards to the crude fibre content and also not significantly affected by the differential response of treatments. Hence all treatments are considered as on par with each other.

4.6.6. Texture of canned tender jackfruit

The firmness and toughness of canned tender jackfruit found to be decreasing during the storage period and is presented in Fig. 4.15 – 4.18. (Table E.6 - E.7 and E.17 - E.18 of Appendix E).

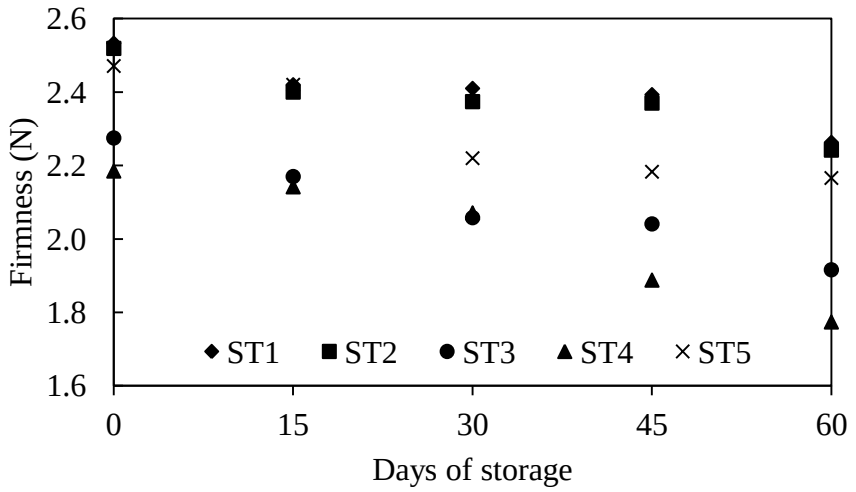


Fig. 4.15 Effect of chemical preservatives and storage period on firmness of sterilised tender jackfruit

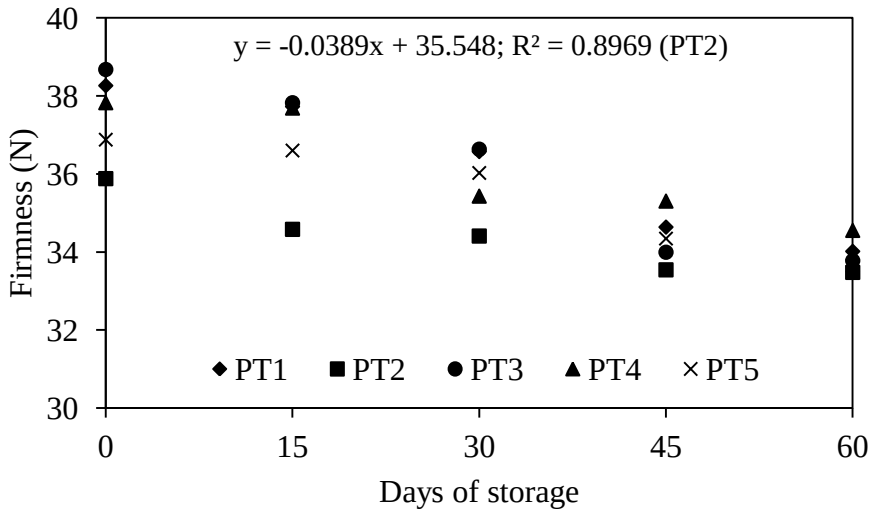


Fig. 4.16 Effect of chemical preservatives and storage period on firmness of pasteurised tender jackfruit

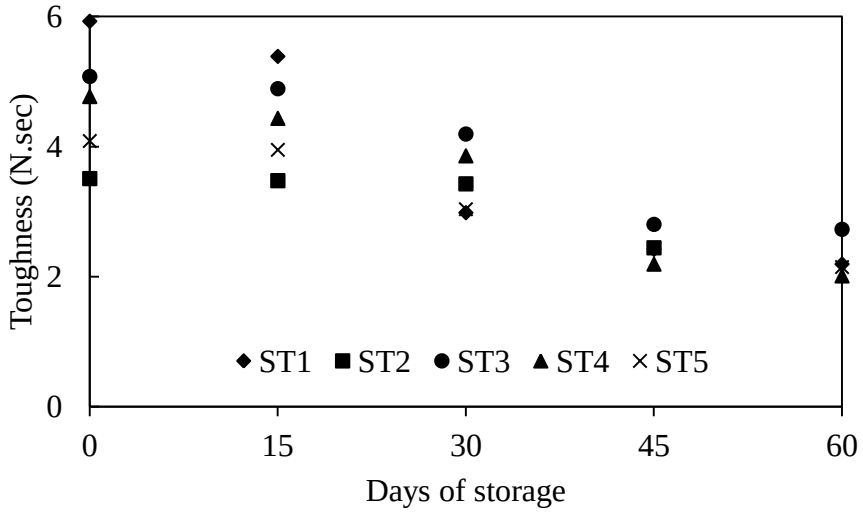


Fig. 4.17 Effect of chemical preservatives and storage period on toughness of sterilised tender jackfruit

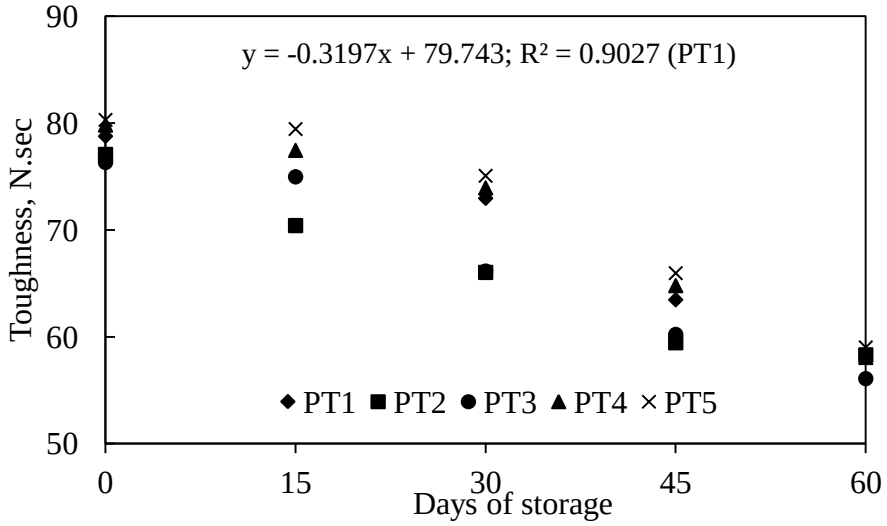


Fig. 4.18 Effect of chemical preservatives and storage period on toughness of pasteurised tender jackfruit

During storage, maximum decrease in firmness was observed in sample ST4 (18.81%) followed by ST3 (15.78%). In case of toughness, the maximum value was for ST1 (62.98%) followed by ST4 (57.82%). The minimum decrease in firmness was observed in pasteurised samples PT2 (6.69%) and that of toughness was for PT1 (22.82%). It may be noted that thermal processing alter the texture of

processed fruits and vegetables (mentioned in section 4.5.3) which is in agreement with the findings of Nisha *et al.,* 2006. The mean values of firmness and toughness were decreased from 2.40 ± 0.16 to 2.07 ± 0.22 N, 37.51 ± 1.13 to 33.9 ± 0.42 N and 4.67 ± 0.93 to 2.27 ± 0.27 N.sec, 78.45 ± 1.72 to 58.46 ± 1.7 N.sec for both sterilised and pasteurised tender jackfruit respectively.

From statistical analysis (Table 4.12 and 4.13), it was observed that significant difference was found between pasteurisation and sterilisation process on firmness and toughness of canned tender jackfruit. The pasteurisation method was found to be best among the treatments with CD, 1.07 and 0.78 respectively for firmness and toughness. The differential response of the treatment under the two methods was analysed statistically and found as significant. Maximum mean value for firmness were recorded in sample PT1 (36.25 N) and that of toughness was PT5 (71.96 N.sec), while minimum mean values were observed in sample PT2 for both firmness (34.38 N) and toughness (66.25 N.sec). The treatment PT4 and PT5 were found to be on par with the treatment PT1 in case of firmness.

Table 4.12 Effect of preservatives and storage period on firmness of pasteurised tender jackfruit

Treatments	Storage Interval (days)					% decrease	Mean
	0	15	30	45	60		
PT1	38.26^{ab}	37.73^{ab}	36.58^{ab}	34.64^{ab}	34.02^{ab}	11.1	36.25
PT2	35.88^{b}	34.58^{c}	34.41^{d}	33.54^{b}	33.48^{b}	6.69	34.38
PT3	38.68^{a}	37.83^{a}	36.64^{a}	34.00^{b}	33.78^{ab}	12.66	36.19
PT4	37.83^{ab}	37.69^{abc}	35.43^{abcd}	35.31^{a}	34.56^{a}	8.65	36.16
PT5	36.88^{ab}	36.60^{abc}	36.03^{abc}	34.35^{ab}	33.65^{ab}	8.75	35.5
Mean	37.51	36.89	35.82	34.37	33.9		

Table 4.13 Effect of preservatives and storage period on toughness of pasteurised tender jackfruit

Treatments	Storage Interval (days)					% decrease	Mean
	0	15	30	45	60		
PT1	78.78^{abc}	74.99^{c}	72.96^{c}	63.47^{c}	60.8^{a}	22.82	70.20
PT2	77.07^{cd}	70.41^{e}	66.03^{d}	59.45^{d}	58.31^{bc}	24.33	66.25
PT3	76.32^{d}	74.97^{cd}	66.15^{d}	60.22^{d}	56.09^{e}	26.51	66.75
PT4	79.82^{ab}	77.45^{b}	73.93^{b}	64.79^{b}	58.07^{bcd}	27.24	70.81
PT5	80.3^{a}	79.45^{a}	75.07^{a}	65.96^{a}	59.01^{ab}	26.51	71.96
Mean	78.45	75.45	70.83	62.78	58.46		

4.6.7 Colour of canned tender jackfruit

The retention of total colour of food may be used as an indicator of the extent of heat damage to the quality of the canned foods due to thermal processing.

4.6.7.1 ‘L’ (black - white) value

The ‘L’ value of thermally processed tender jackfruit obtained for different treatments is shown in Table E.8 (Appendix E) and graphical representation is given in Fig. 4.19 – 4.20. The initial ‘L’ value of fresh tender jackfruit was recorded as 70.62. The ‘L’ value showed a gradual decrease with increase in storage period, from 54.16 ± 4.92 to 48.09 ± 7.33 and 74.93 ± 4.2 to 70.12 ± 5.69 for sterilised and pasteurised samples respectively. There was a significant difference observed between sterilised and pasteurised tender jackfruit (CD = 0.29). From the Table E.8 and E.19 of Appendix E, it can be seen that rate of decrease was minimum for pasteurised tender jackfruit sample, PT5 (3.66%) and maximum in sterilised sample, ST1 (21%). Comparing the effect of different preservatives used as filling solution, combination of KMS and citric acid solution used in pasteurisation (PT5) was found to be the best in reducing the rate of decrease of ‘L’ value.

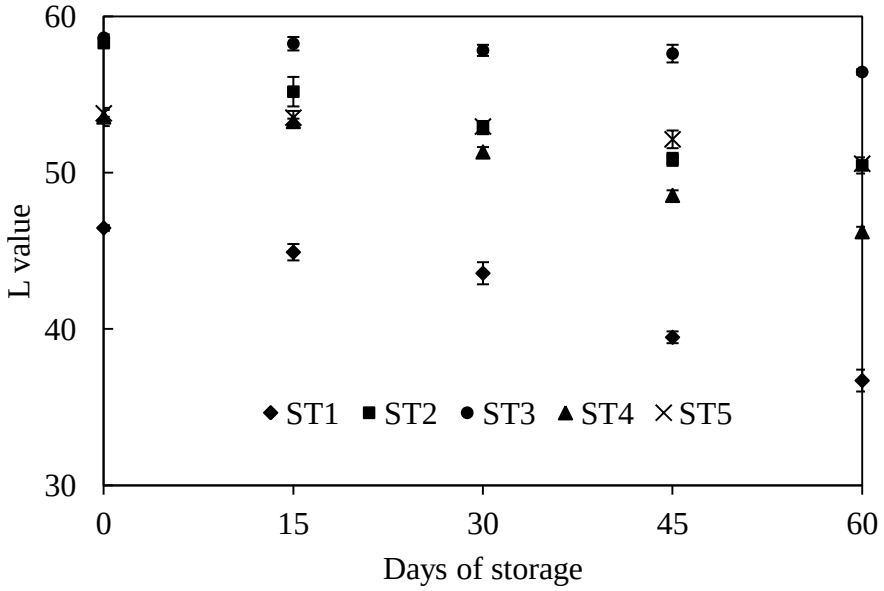


Fig. 4.19 Effect of chemical preservatives and storage period on 'L' value of sterilised tender jackfruit

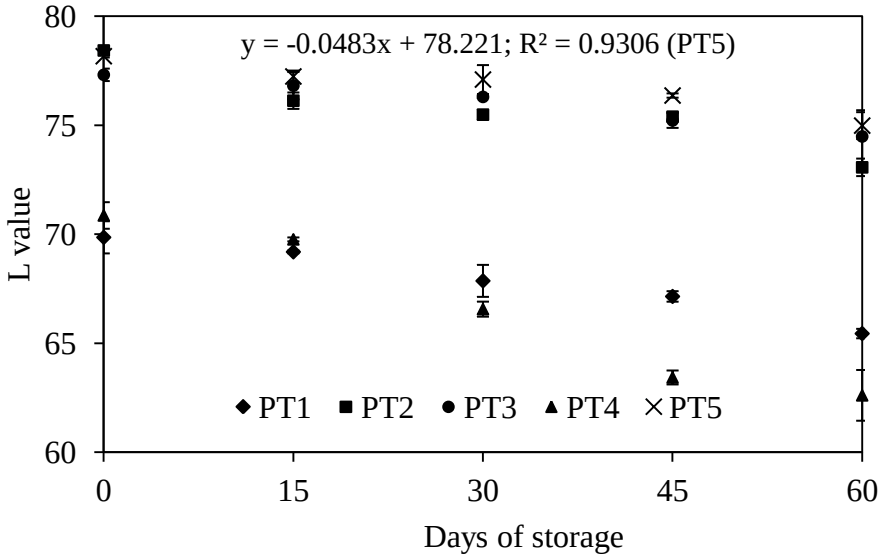


Fig. 4.20 Effect of chemical preservatives and storage period on 'L' value of pasteurised tender jackfruit

From the graph it was found that addition of citric acid, KMS and its combination as filling solution yielded higher 'L' value than that of fresh tender jackfruit. ANOVA (Table E.19) for the effect of thermal processing and storage

period on ‘L’ value of canned tender jackfruit revealed that the differential response of treatments under the two methods of processing significantly influenced the ‘L’ values ($P \leq 0.01$). The maximum ‘L’ value was found in treatment PT5 (76.03) and the treatments PT3 was found to be on par with PT5. From the results obtained, it could be concluded that the change in ‘L’ value was less in PT5. The decrease in ‘L’ value was more in brine preserved sterilised tender jackfruit (ST1) compared to other treatments, this was due to the absence of (colour retaining) preservatives like KMS and citric acid and also due to the high sterilisation temperature.

4.6.7.2 ‘a’ (green - red) value

The colour parameter representing redness, ‘a’ value of thermally processed tender jackfruit canned in different treatments with reference to storage periods are furnished in Table E.9 and E.20 (Appendix E) and graphical representation is given in Fig. 4.21 – 4.22. The initial ‘a’ value of fresh tender jackfruit was recorded as -1.15. The table revealed that ‘a’ value increases with increase in thermal process time-temperature combination from 9.95 ± 4.66 to 12.06 ± 5.84 and 0.95 ± 0.43 to 1.05 ± 0.47 for sterilised and pasteurised samples respectively. The statistical analysis of ANOVA using Two Factor Completely Randomised Design revealed that ‘a’ value of the canned tender jackfruit was found to increase significantly with storage. As inferred from CD value (0.082), significant difference in the ‘a’ value was observed between the type of processing viz., sterilisation and pasteurisation. Pasteurisation was found to be superior with regard to ‘a’ value of the product. Rate of increase was minimum for pasteurised tender jackfruit filled with KMS and citric acid as filling solution, PT5 (6.42%) followed by PT3 (8.69%) having citric acid alone as filling solution and maximum in sterilised tender jackfruit having brine as filling solution, ST1 (27.34%) followed by ST4 (25.82%). The differential response of the treatment under the two methods of processing was observed and the interaction was significant. Comparing the effect of different preservatives used as filling solution, combination of KMS and citric acid solution used in pasteurisation (PT5) was found to be the best in reducing the rate of increase of ‘a’ value.

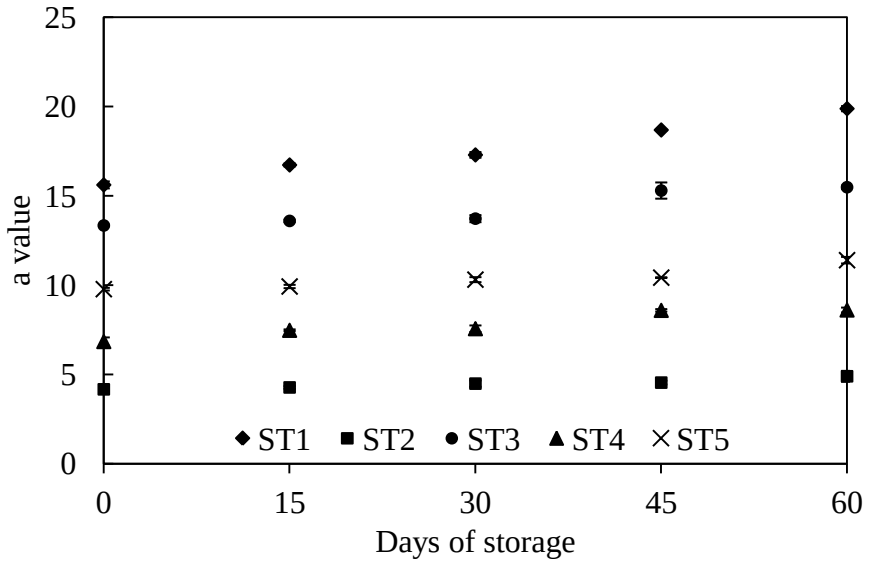


Fig. 4.21 Effect of chemical preservatives and storage period on ‘a’ value of sterilised tender jackfruit

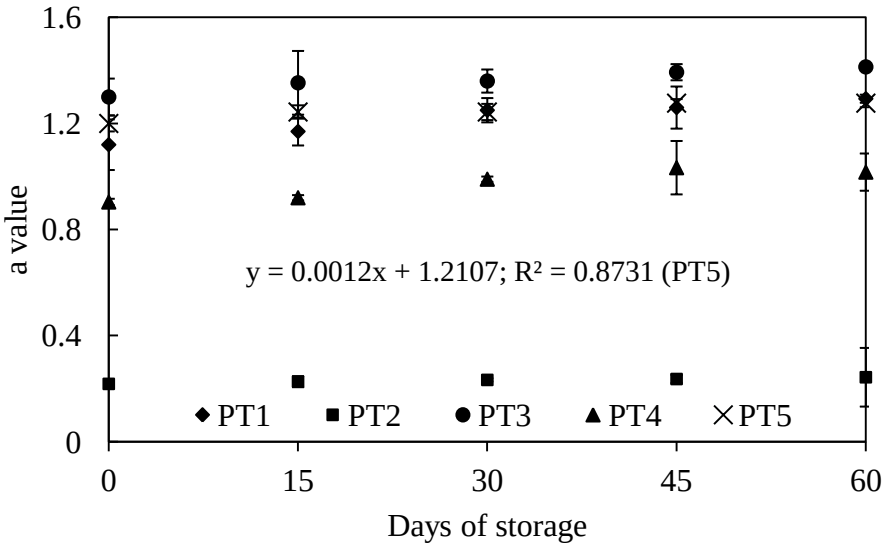


Fig. 4.22 Effect of chemical preservatives and storage period on ‘a’ value of pasteurised tender jackfruit

From the graph it was found that addition of citric acid as filling solution showed a lower ‘a’ value compared to that of other treatments. From the results obtained, it could be concluded that the change in ‘a’ value was less in PT5. The increase in ‘a’ value was more in brine preserved sterilised tender jackfruit (ST1) compared to other treatments.

4.6.7.3 ‘b’ (blue – yellow) value

The effect of different treatments, type of thermal processing and storage period on colour parameter representing the yellowness or blueness, ‘b’ value of both pasteurised and sterilised tender jackfruit are shown in Table E.10 and E.21 (Appendix E) and can be visualised in Fig. 4.23 – 4.24. The initial ‘b’ value of fresh tender jackfruit was recorded as 15.19. It was observed that as regard ‘b’ value significant difference was found between pasteurisation and sterilisation process (CD = 0.087). The table revealed that ‘b’ value decreases with increase in storage period from 13.06 ± 2.13 to 12.14 ± 2.41 and 14.83 ± 1.89 to 13.83 ± 1.96 for sterilised and pasteurised samples respectively. Pasteurisation was found to be the best when ‘b’ value of the canned product during storage is concerned. The rate of decrease was minimum for pasteurised tender jackfruit filled with citric acid as filling solution, PT3 (0.67%) followed by that of sterilised sample ST3 (0.91%) and maximum in sterilised tender jackfruit having brine as filling solution, ST1 (15.26%) followed by ST4 (11.28%).

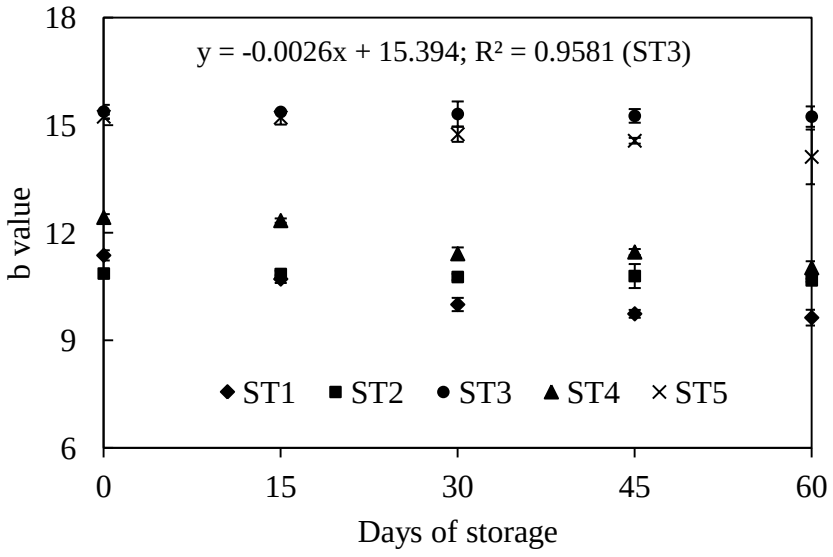


Fig. 4.23 Effect of chemical preservatives and storage period on ‘b’ value of sterilised tender jackfruit

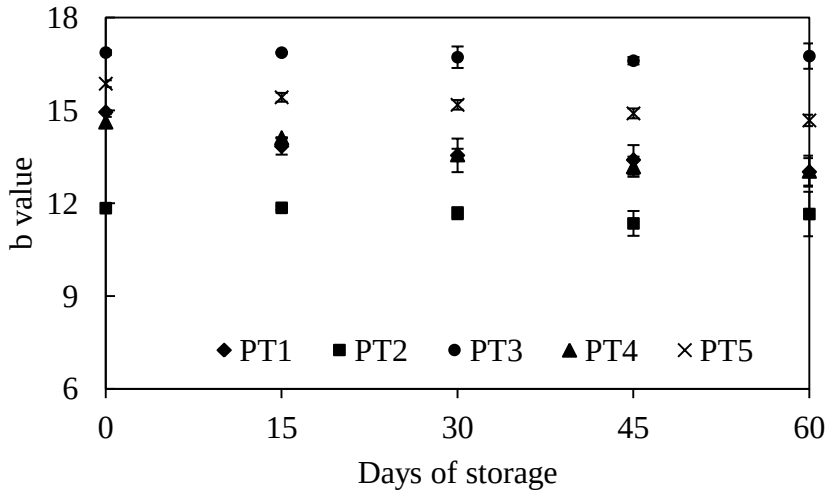


Fig. 4.24 Effect of chemical preservatives and storage period on 'b' value of pasteurised tender jackfruit

The graphical illustration showed that by comparing the effect of different preservatives used as filling solution, citric acid solution used in pasteurisation and sterilisation, PT3 and ST3 respectively, was found to be the best in reducing the rate of decrease of 'b' value. ANOVA (Table E.21 of Appendix E) for the differential response of the treatment under sterilisation and pasteurisation showed a significant effect on 'b' values ($P \leq 0.01$).

4.6.7.4 'ΔE' value

The ΔE of tender jackfruit after thermal processing and storage is illustrated in Table 4.14. The total colour difference (ΔE) in sterilised tender jackfruit samples ranged from 17.26 to 34.41 whereas in pasteurised samples, it ranged from 4.06 to 6.86. From the table given below, it is evident that on comparing the treatments, the change in colour increased during storage except in samples pasteurised or sterilised in KMS, citric acid and combination of KMS and citric acid.

Table 4.14 ΔE value of thermally processed canned tender jackfruit

Treatment	Storage Interval (days)					Mean	S.D	Increase %
	0	15	30	45	60			
ST1	29.65	32.73	32.06	37.33	40.30	34.41	4.31	35.91
ST2	14.09	16.92	19.12	21.03	21.52	18.54	3.07	52.66
ST3	22.20	22.58	23.09	24.75	26.05	23.73	1.62	17.33
ST4	19.03	19.57	21.50	24.40	26.60	22.22	3.23	39.76
ST5	16.21	16.60	17.18	17.41	18.89	17.26	1.03	16.53
PT1	2.47	3.04	4.04	4.60	6.12	4.06	1.42	147.45
PT2	8.61	6.59	6.16	6.30	4.57	6.45	1.45	-46.99
PT3	8.12	7.28	7.13	6.45	5.32	6.86	1.05	-34.51
PT4	2.20	2.48	4.86	7.77	8.57	5.18	2.94	288.93
PT5	7.13	6.66	6.17	5.22	4.63	5.96	1.03	-35.13

S.D: Standard Deviation

The retention of colour during storage was better in pasteurised samples having KMS or citric acid as filling solution. The sterilised samples showed a drastic change in (ΔE) values after thermal processing and storage. The results obtained were statistically analysed and presented in Table E.11 and E.22 of Appendix E. It was observed that with regard to change in colour (ΔE values), significant difference was observed between the sterilisation and pasteurisation process (CD = 0.142).

Pasteurisation was found to be superior in reducing the colour deviation. The differential response of the treatment under the pasteurisation and sterilisation process have significantly affected ΔE. In general, ‘L’ value and ‘b’ value decreased and ‘a’ value increased during storage which is similar to the findings as mentioned in section 4.5.4 of this study.

4.7 Sensory evaluation

The scores given for different treatments on different organoleptic traits namely, colour, flavour, texture and overall acceptability are presented in Table 4.15.

Table 4.15 Mean scores for sensory evaluation

Treatment	Mean Scores			
	Colour	Flavour	Texture	Overall acceptability
ST1	5.33	5.58	5.58	5.54
ST2	5.58	5.33	5.50	5.38
ST3	5.08	5.17	5.25	5.21
ST4	5.92	5.92	5.00	5.67
ST5	5.58	5.33	5.50	5.08
PT1	7.33	7.17	7.00	7.17
PT2	7.25	6.67	6.67	6.75
PT3	7.54	7.21	7.42	7.25
PT4	7.08	6.58	6.42	6.67
PT5	7.00	7.08	6.92	6.83

From the sensory scores, it was observed that pasteurised tender jackfruit having citric acid as filling solution; PT3 received maximum scores followed by that of brine solution, PT1. Pasteurised (90^{o}C for 19 minutes) tender jackfruit canned in citric acid solution was adjudged to be the best canned product for tender jackfruit in terms of organoleptic traits. The statistical analysis using Kendall's coefficient of concordance was applied to the all scores obtained for each samples and are presented in the Table 4.16. It was observed that organoleptic traits colour, flavour, texture and overall acceptability were found to significant.

Table 4.16 Kendall's coefficient of concordance test for mean rank for sensory evaluation

Treatment	Mean Rank			
	Colour	Flavour	Texture	Overall acceptability
ST1	3.71	4.21	4.29	4.21
ST2	4.00	3.96	4.46	4.21
ST3	3.21	3.71	4.13	3.88
ST4	4.79	4.79	3.54	4.33
ST5	3.96	3.96	4.38	3.58
PT1	7.67	7.21	7.13	7.71
PT2	7.17	6.21	6.21	6.88
PT3	7.92	7.42	8.13	7.42
PT4	6.13	6.00	5.63	6.29
PT5	6.46	7.54	7.13	6.50
Test Statistics				
N	12	12	12	12
Kendall's W	0.38	0.30	0.31	0.32
Chi - Square	41.15	32.85	33.13	34.86
df	9	9	9	9

4.7.1 Colour

Table 4.16 reveals that various treatments followed had a significant effect on colour and there was significant difference between sterilised and pasteurised canning of tender jackfruit. The colour of the pasteurised samples received higher score compared to other samples. Among the pasteurised samples, the colour of canning of tender jackfruit with 0.3% citric acid for 90^{o}C for 19 min processed samples (PT3) was found to be superior to other treatments. The colour of sterilised samples was darker when compared to pasteurised samples. Peterson and Johnson (1979) were of the opinion that if the colour of the product is judged unacceptable the food is summarily rejected.

4.7.2 Flavour

Flavour is commonly defined as being the sensation arising from the integration or interplay of signals produced as a consequence of sensing smell, taste and irritating stimuli from a food or a beverage (Shankaracharaya, 2002). From the table 4.15 and 4.16, it was found that the flavour of pasteurised samples were acceptable than those of sterilised samples. Pasteurised tender jackfruit treated with a combination of citric acid and KMS as filling solution (PT5) received higher score followed by the treatment with citric acid as filling solution (PT3). The improvement in organoleptic properties of the product is mainly related to pretreatment with citric acid preservative.

4.7.3 Texture

According to Matz (1962), texture has long been recognised as an important element in the total sensory impression obtained during the consumption of the food. It is becoming increasingly evident that some form of texture measurement is highly desirable in the grading of all foods. Results of the table showed that the texture attributes of pasteurised samples were better than sterilised samples. This superior nature of the texture of the pasteurised sample may be due to the effect of low temperature treatment which does not significantly alter the texture. The pasteurised sample, PT3 received high score followed by PT5 and PT1 due to the retention of texture during the storage period.

Kendall's W test was conducted for assessing the significant agreement among the judges with regard to colour, flavour, texture etc. The results indicated that all the Kendall wall coefficient of colour, flavour, texture and overall acceptability character was significant. Hence the mean rank scores of pasteurisation (PT3, followed by PT5) could be taken to judge the superiority of one treatment over the other. Among sterilised treatment ST4 was given higher preference. The samples selected by the panel of judges after organoleptic and statistical analyses are shown in Plate 4.6.

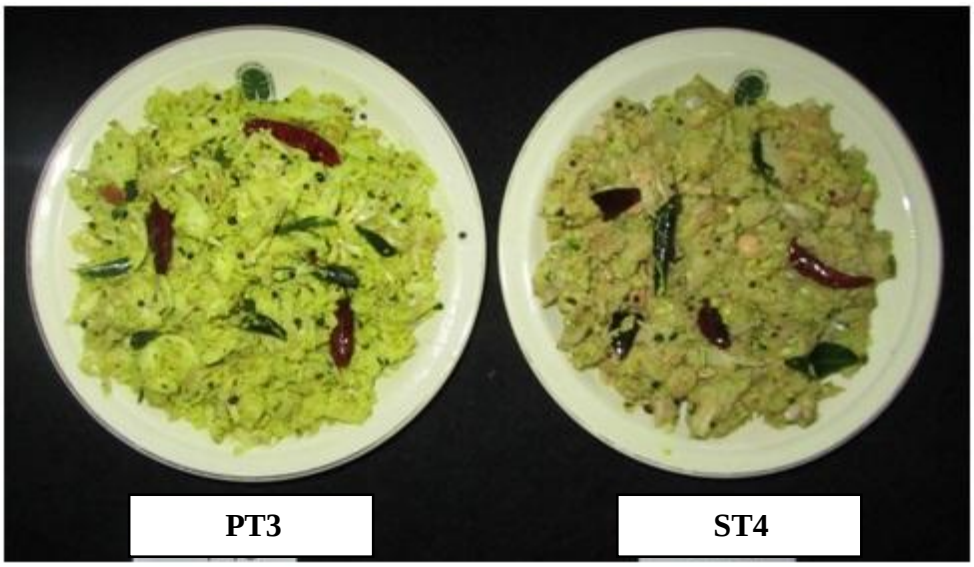


Plate 4.6 Selected samples after sensory analyses

4.8 Microbiological studies on canned jackfruit

The results of the total bacterial, yeast and fungal count in the pasteurised and sterilised canned tender jackfruit are shown in Table E.23 and E.24 of Appendix E. The microbial load in terms of bacteria, spore, yeast and fungi were found to be zero $cfug^{-1}$ except in case of sample PT3 (Plate 4.7). Bacterial count of 20/ml was observed in PT3 after 2 months storage (Plate 4.8), which was within the permissible limit of not more than 50/ml prescribed by Prevention of Food Adulteration Rules, 1956 (PFA, 2000). Even though, the bacterial count of canned tender jackfruit treated with both sterilisation and pasteurisation for the optimised time-temperature combination were within the permissible limits, the sample PT3 were avoided for safe processing of canned tender jackfruit since there is a possibility for bacterial multiplication during further storage. Hence all samples except PT3 could be considered as microbiologically safe.

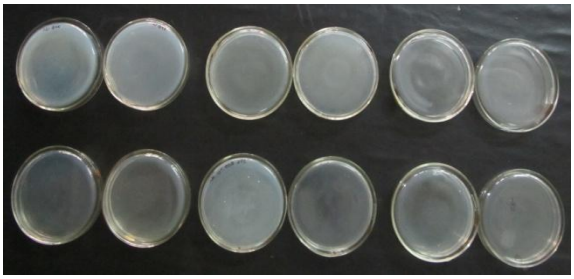


Plate 4.7 Microbial studies on canned product

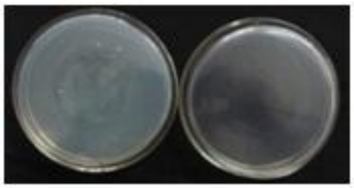


Plate 4.8 Microbes in PT3

4.9 Cost of canning

The computation for cost of canning is given in Appendix D. The cost of production of thermally processed tender jackfruit per can was found to be ₹ 25/-. This represents the economic viability and enhanced potential of value addition of tender jackfruit. The extended shelf life of canned jackfruit also makes it a viable exportable commodity.

SUMMARY AND CONCLUSIONS

CHAPTER 5

SUMMARY AND CONCLUSIONS

India is blessed with a variety of fruits and vegetables whose production during 2010 - 11 was 74.87 and 146.55 MT, respectively. 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. 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. However, it is an under exploited fruit. The highly perishable nature of jackfruit due to inherent composition and textural characteristics has limited its storage for a longer time which adversely affects its market potential. Proper postharvest technology for prolonging shelf life is necessary to ensure its availability throughout the year. In order to extend the shelf life, proper post harvest technology or preservation technique is the need of the hour in jackfruit industry.

Canning is an age old practice in which the foods are preserved in hermetically sealed containers that has been sterilised by heat so that they may remain shelf stable over long periods of storage at normal non-refrigerated conditions. Since there has been a minimum research in the field of jackfruit processing and storage, the present study of "Development and quality evaluation of thermally processed jackfruit" was under taken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to find out the suitability of canned tender jackfruit for its utility as a vegetable. This will assure year round availability of tender jackfruit. It will undoubtedly ensure the economic security of the farmer as well as establish a significant place in the international market.

Tender jackfruits, which belong to the 'Varikka' variety, were used for the study. The suitable pretreatments such as blanching time and blanching treatment required and the time required to heat the product for attaining the required lethality for pasteurisation and sterilisation temperature were investigated for optimising the main canning process of tender jackfruit.

To make the blanching process less tedious, a new blancher was developed and it was found from the performance evaluation of conventional and newly developed blancher that the performance of the new blancher in terms of time consumption for heating was nearly double than that of the conventional one. Also, heating was more or less uniform in the newly fabricated blancher machine and was simple in construction and operation, and requires only one person to operate. Blanching was carried out at 100^{o}C for one minute to five minute. Blanching time of one minute for tender jackfruit was standardised based on the negative result obtained in hydrogen peroxide test and the results of the quality parameters like texture and colour. Firmness and toughness values of one minute blanched samples were 65.48 and 77.44 respectively and the change in colour (ΔE) was found to be low for one minute blanched samples. i.e., blanching for one minute at 100^{o}C softens the tissues of samples to facilitate easy filling during canning process and has better appeal to the consumers and was similar to that of the fresh sample. This time-temperature combination of blanching was used to standardise the suitable treatment used in the blanching process for retaining better colour and antimicrobial action. The texture and colour of jackfruit samples blanched in boiling water with 0.1% KMS, 0.3% citric acid and combination of KMS and citric acid were analysed. Samples blanched in boiling water without any preservatives was taken as control sample i.e., without any preservatives. It was observed that the addition of preservatives does not have much effect on the textural properties of the samples, but the treatment BT3 (blanching in 0.3% citric acid) seems to be better with 'L', 'a', 'b' values, 75.35, -1.48, 19.73 respectively which is higher than that of fresh tender jackfruit. This implies that addition of citric acid improves the colour, and thereby the appearance of the products.

The blanched samples were subjected to the pasteurisation temperatures of 90^{o}Cand 100^{o}C for F value 8 and 10 and similarly sterilisation temperatures of 110^{o}C and 121^{o}C for F_0 values 1 and 2 and the time required to heat the product for particular F and F_0 values were obtained from heat penetration curve. From the heat penetration characteristics of tender jackfruit, pasteurisation temperature of 90^{o}C for 19 minutes and sterilisation temperature of 121^{o}C for 38 minutes were

found to be optimum based on separate microbial (within permissible limit prescribed by PFA Rules,1956), textural and colour analyses.

After optimal blanching, the samples were put in tin cans and preservatives like brine, citric acid and KMS in different concentrations were added into the cans as covering solution. The filled cans were exhausted in hot water bath till the can centre reached 79^{o}C. The exhausted cans were immediately seamed using can seamer. The cans were processed with the optimised pasteurisation (90^{o}C for 19 minutes) and sterilisation (121^{o}C for 38 minutes) time temperature combination. The processed cans were cooled and stored in clean and dry place.

Storage study of the thermally processed canned tender jackfruit was conducted for two months. The quality of the processed samples was assessed in terms of TSS, titrable acidity, pH, vitamin C, texture and colour. There was a significant difference between sterilisation and pasteurisation with regard to TSS of the canned tender jackfruit. The TSS value decreased during the initial stage of storage due to the leaching of some of the soluble solids in water. Minimum TSS values were obtained for samples pasteurised in citric acid solution and maximum, for samples sterilised in brine solution.

The titrable acidity of canned tender jackfruit exhibited a decreasing trend, but value of titrable acidity was higher in samples which were preserved in citric acid or combination of citric acid with KMS. Later, an exponential decay was noted after 15 days of storage due to utilisation of citric acid during hydrolysis of polysaccharides and non-reducing sugars. Since acidity lowers the pH value, its value was low in samples having citric acid. The mean values of ascorbic acid content significantly decreased from 6.09 ± 0.78 to 5.92 ± 0.87 and 6.13 ± 0.75 to 5.97 ± 0.83 mg/100 g for sterilised and pasteurised tender jackfruit during storage. The losses in ascorbic acid may be due to high temperature and light during storage. The losses were reduced in samples having potassium metabisulphite due to better anti-oxidant property of KMS. There was no very high variation in crude fibre content during the storage period since it is generally stable to processing, storage and cooking. The firmness and toughness were low in sterilised samples

as compared with pasteurised samples. The mean values of firmness and toughness decreased from 2.40 ± 0.16 to 2.07 ± 0.22 N, 37.51 ± 1.13 to 33.9 ± 0.42 N and 4.67 ± 0.93 to 2.27 ± 0.27 N.sec, 78.45 ± 1.72 to 58.46 ± 1.7 N.sec for both sterilised and pasteurised tender jackfruit respectively. The Hunter parameters ('L', 'a', 'b') of canned jackfruit were investigated. The 'L', 'a', 'b' values of fresh sample were 70.62, -1.15, 15.185 9.61, -0.17, 14.69 and that of sterilised and pasteurised samples were 54.16, 9.95, 13.06 and 74.93, 0.95, 14.83 respectively.

From the microbial analysis it was inferred that there was no microbial contamination except in case of one sample (PT3), which was within the permissible limit as prescribed by Prevention of Food Adulteration Rules, 1956. Even though, the bacterial count of canned tender jackfruit treated with both sterilisation and pasteurisation for the optimised time-temperature combination were within the permissible limits, the sample PT3 were avoided for safe processing of canned tender jackfruit since there is a possibility for bacterial multiplication during further storage. Hence all samples except PT3 could be considered as microbiologically safe.

Apart from the quality evaluation, microbial and sensory analyses were done at the end of two months of storage. From the sensory analysis it was confirmed that the pasteurised samples may be taken to judge the superiority of one treatment over the sterilized samples.

Operating cost per kg of canned tender jackfruit was calculated. The cost of production per can of tender jackfruit is ₹ 25/-.

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APPENDICES

APPENDIX A

Table A.1 Main season(s) of availability of jack fruit in different countries (Haq, 2006)

Country	Month of Year
Australia	June–April
Bangladesh	June–August
Brazil	January–March, August–October
Colombia	January–December
India	April–July
Indonesia	August–January
Jamaica	January–July
Kenya	June–October
Malaysia	April–August, September–December
Philippines	March–August
Sri Lanka	February–November
Thailand	January–May, October–December
Uganda	January–December
USA (Florida)	May–August, September–October

Table A.2 List of different cultivars of jack fruit available in the various countries ((Morton, 1987; Haq, 2006)

Country	Cultivar names
Australia	Golden nugget, Black gold, Honey gold, Lemon gold, Cheena, Chompa Gob, Coching, Galaxy, Fitzroy, Nahen, Kapa, Mutton, Varikkha.
Bangladesh	Topa, Hazari, Chala, Goal, Koa, Khaja
India	Khujja or Karcha, Ghila, or Ghula, Hazari, rudrakshi, gulabi, hazar, jackfruit NJT 1, jackfruit NJT 2, jackfruit NJT 3, jackfruit NJT 4, koozha navarikka or pazam varikka, safeda, khaja, bhusila, bhadaiyan, handia, mammoth, everbearer, rose-scented, Kooli, Varikka, Gerissal, Barica, T-Nagar jak, Velipala, Singapore or the Ceylon Jack
Indonesia	Kandel, Mini, Tabouey
Malaysia	J-30, J-31, NS-1, Na2, Na29, Na31
Myanmar	Talaing, Kala
Philippines	J-01, J-02, TVC, Torres
Singapore	Jak/Ceylon jak
Sri Lanka	Vela, Varaka (Waraka), Peniwaraka, Kuruwaraka, Singapore or the Ceylon Jack
Jamaica	Peniwaraka or honey jack, Kuruwaraka
Thailand	Dang rasimi, Kun Wi Chan, Kha-num nang, Kha-num lamoud
USA (Florida)	Black gold, Cheena, Dang Rasimi, Galaxy, Golden Nugget, Honey Gold, Lemon Gold, J-30, J-31, NS-1, Tabouey, Delightful

APPENDIX B

Composition of Nutrient Agar Medium

Peptone	-	5 g
Yeast extract	-	2 g
Beef extract	-	1 g
Sodium chloride	-	5 g
Agar	-	15 g
pH	-	6.5 -7.5
Distilled water	-	1000 ml

Composition of Potato Dextrose Medium

Potatoes infusion	- 200 g
Dextrose	- 20 g
Agar	- 15 g
Distilled water	- 1000 ml

APPENDIX C

Sensory Evaluation Card

Samples	Colour	Flavour	Texture	Overall acceptability
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				

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

Name of examiner: Signature of the examiner:

Date:

APPENDIX D

Cost of Canning

1. Cost of operation of plant/hr

Cost of machineries

i) Canning machineries (reformer & seamer)	:	₹ 1,00,000
ii) Exhaust box	:	₹ 50,000
iii) Retort	:	₹ 5,00,000
Initial cost (C)	:	₹ 6,50,000

Assumptions

Useful life	:	15 years
Annual working hours, T	:	2000 hours
Salvage value, S	:	10% of initial cost
Interest on initial cost, r	:	12% annually
Repairs and maintenance	:	5% of initial cost
Insurance and taxes	:	2% of initial cost
Electricity charge	:	₹ 5.5/unit
Labour wages (8 working hours/day)	:	₹ 200/day
Cost of a can	:	₹ 18/-
Time for peeling, cutting and blanching of a tender jack fruit (t_1)	:	15 min
Time for filling and sealing the cans (t_2)	:	3 min

a. Fixed cost

i) Depreciation	:	$\frac{C - S}{L}$
	:	₹ 39000/year
ii) Interest on average investment	:	$\frac{C + S}{2} \times r$

: ₹ 42900/year

iii) Insurance and taxes : ₹ 13000/year

Total fixed cost : ₹ 94,900/year

b. Variable cost

i) Repair and Maintenance : ₹ 32500/-

ii) Electricity cost

Total power consumption : 8 HP = 6 kW

Cost of energy consumption/ year : $\frac{\text{Power} \times \text{duration} \times \text{cost of 1 unit}}{1000}$

: ₹ 66,000/-

iii) Annual labour cost : ₹ 50,000/year

Total variable cost : ₹ 1,48,500/year

Total cost : Fixed cost + Variable cost

: ₹ 2,43,400/year

Cost of operation of plant/hr (C_{oper}) : $\frac{\text{Total cost}}{\text{T}}$

: ₹ 121.7/-

Number of batches required for canning 100 cans (n) : 2

Time required for canning under pasteurization temperature (t_p) : 19 min

Time required for canning under sterilization temperature (t_s) : 38 min

Total cost of canning operation (C_{can}) : $\frac{C_{oper} \times \text{n} \times t_p \text{ (or } t_s)}{60}$

: $\frac{121.7 \times 1 \times 19 + 121.7 \times 1 \times 38}{60}$

≈ ₹ 116/-

2. Labor cost for tender jackfruit

Cost of 100 cans (C_C)	:	₹ 1800/-
Quantity of tender jack fruit bulbs	:	25 kg
Number of tender jackfruits required (N_j)	:	32
Cost of tender jackfruit, C_{TJ} (₹ 10/ kg)	:	₹ 250/-
Time required for peeling, cutting and blanching	:	$\frac{t_1 \times N_j}{60}$
	:	8 hrs
Total number of cans (N_c)	:	100
Time required for filling and sealing the cans	:	$\frac{t_2 \times N_c}{60}$
	:	5 hrs
Total working hours	:	13 hrs
Labour cost wages (C_L)	:	$\frac{C \times 200}{8}$
	:	₹ 325/-
Total expenditure for canning 100 cans of tender jackfruit	:	$C_L + C_C + C_{TJ} + C_{can}$
	:	₹ 2491/-
Total expenditure for canning single tender jackfruit can	≈	**₹ 25/-**

APPENDIX E

Table E.1 Changes in TSS (^{o}B) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage Interval										% increase		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	4.83	4.00	4.83	4.00	4.83	4.07	4.87	4.10	4.87	4.13	0.70	3.33	4.85	4.06
T2	3.00	2.40	3.20	2.43	3.23	2.47	3.23	2.47	3.27	2.47	8.90	2.79	3.19	2.45
T3	3.03	2.30	3.03	2.40	3.07	2.47	3.13	2.50	3.17	2.53	4.42	10.13	3.09	2.44
T4	4.80	3.80	4.80	3.80	4.83	3.87	4.87	3.93	4.87	3.97	1.40	4.39	4.83	3.87
T5	3.40	2.43	3.40	2.60	3.40	2.63	3.43	2.63	3.47	2.63	1.97	8.22	3.42	2.58
Mean	3.81	2.99	3.85	3.05	3.87	3.10	3.91	3.13	3.93	3.15	S : Sterilisation			
CV (%)	0.93	0.84	0.89	0.79	0.88	0.80	0.88	0.82	0.86	0.83	P : Pasteurisation			

Table E.2 Changes in titrable acidity (%) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage Interval										% increase		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	0.26	0.26	0.26	0.26	0.26^{b}	0.26^{c}	0.13^{b}	0.13^{b}	0.06^{c}	0.13^{b}	75.00	50.00	0.19	0.20
T2	0.26	0.26	0.26	0.26	0.26^{b}	0.26^{c}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	50.00	50.00	0.20	0.20
T3	1.15	1.28	0.64	0.64	0.51^{a}	0.64^{a}	0.32^{a}	0.38^{a}	0.32^{a}	0.38^{a}	72.22	70.00	0.59	0.67
T4	0.26	0.26	0.26	0.26	0.26^{b}	0.26^{c}	0.13^{b}	0.13^{b}	0.13^{b}	0.13^{b}	50.00	50.00	0.20	0.20
T5	1.15	1.41	0.64	0.51	0.51^{a}	0.51^{b}	0.32^{a}	0.38^{a}	0.32^{a}	0.38^{a}	72.22	72.73	0.59	0.64
Mean	0.61	0.69	0.41	0.38	0.36	0.38	0.20	0.23	0.19	0.23	S : Sterilisation			
CV (%)	0.49	0.60	0.21	0.18	0.14	0.18	0.11	0.14	0.12	0.14	P : Pasteurisation			

Table E.3 Changes in pH of canned tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage Interval										% increase		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	4.34^{d}	4.40^{e}	4.36	4.42	4.38	4.43	4.39	4.44	4.41	4.45	1.54	1.20	4.38	4.43
T2	4.40^{e}	4.21^{c}	4.42	4.23	4.42	4.26	4.42	4.26	4.45	4.26	1.14	1.26	4.42	4.25
T3	3.60^{a}	3.59^{a}	3.61	3.60	3.62	3.60	3.62	3.61	3.62	3.61	0.72	0.64	3.61	3.60
T4	4.24^{c}	4.32^{d}	4.27	4.33	4.29	4.34	4.29	4.36	4.33	4.38	2.19	1.20	4.28	4.34
T5	3.70^{b}	3.79^{b}	3.71	3.79	3.71	3.81	3.72	3.81	3.74	3.81	0.95	0.71	3.72	3.80
Mean	4.06	4.06	4.08	4.07	4.08	4.09	4.09	4.10	4.11	4.10	S : Sterilisation			
CV (%)	0.38	0.36	0.38	0.35	0.37	0.35	0.36	0.34	0.36	0.33	P : Pasteurisation			

Table E.4 Changes in vitamin C (mg 100 g^{-1}) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	5.36^{d}	5.56^{c}	5.34^{c}	5.54^{c}	5.29^{e}	5.50^{c}	5.28^{e}	5.48^{c}	5.11^{e}	5.34^{c}	4.64	3.90	5.28	5.48
T2	6.94^{a}	6.97^{a}	6.91^{ab}	6.97^{a}	6.90^{a}	6.94^{a}	6.90^{a}	6.92^{a}	6.88^{a}	6.92^{a}	0.92	0.82	6.91	6.94
T3	5.56^{c}	5.62^{c}	5.54^{c}	5.54^{c}	5.54^{c}	5.50^{c}	5.48^{d}	5.48^{d}	5.34^{cd}	5.42^{c}	3.85	3.65	5.49	5.51
T4	6.94^{a}	6.94^{ab}	6.93^{a}	6.92^{ab}	6.89^{ab}	6.88^{ab}	6.86^{abc}	6.86^{ab}	6.85^{ab}	6.86^{ab}	1.40	1.17	6.89	6.89
T5	5.66^{b}	5.56^{d}	5.54^{c}	5.54^{c}	5.52^{cd}	5.54^{c}	5.48^{d}	5.48^{c}	5.41^{c}	5.34^{c}	4.45	3.85	5.52	5.49
Mean	6.09	6.13	6.05	6.10	6.03	6.07	6.00	6.05	5.92	5.97	S : Sterilisation			
CV (%)	0.78	0.75	0.80	0.77	0.80	0.77	0.81	0.77	0.87	0.83	P : Pasteurisation			

Table E.5 Changes in crude fibre (%) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	2.27	2.23	2.17	2.23	2.17	2.23	2.15	2.21	2.13	2.18	6.30	2.16	2.18	2.22
T2	2.38	2.40	2.29	2.26	2.27	2.30	2.27	2.27	2.25	2.28	5.67	5.12	2.29	2.30
T3	2.34	2.44	2.26	2.24	2.24	2.20	2.23	2.16	2.23	2.16	4.49	11.51	2.26	2.24
T4	2.34	2.45	2.32	2.38	2.29	2.30	2.27	2.23	2.27	2.23	2.78	8.70	2.3	2.32
T5	2.35	2.44	2.35	2.38	2.32	2.33	2.32	2.30	2.31	2.28	1.91	6.91	2.33	2.34
Mean	2.33	2.39	2.28	2.30	2.26	2.27	2.25	2.23	2.24	2.23	S : Sterilisation			
CV (%)	0.04	0.09	0.07	0.08	0.06	0.05	0.07	0.05	0.07	0.05	P : Pasteurisation			

Table E.6 Changes in firmness (N) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	2.53	38.26	2.42	37.73	2.41	36.58	2.39	34.64	2.26	34.02	10.66	11.10	2.40	36.25
T2	2.52	35.88	2.40	34.58	2.37	34.41	2.37	33.54	2.24	33.48	11.00	6.69	2.38	34.38
T3	2.28	38.68	2.17	37.83	2.06	36.64	2.04	34.00	1.92	33.78	15.78	12.66	2.09	36.19
T4	2.19	37.83	2.14	37.69	2.07	35.43	1.89	35.31	1.77	34.56	18.81	8.65	2.01	36.16
T5	2.47	36.88	2.42	36.60	2.22	36.03	2.18	34.35	2.17	33.65	12.34	8.75	2.29	35.50
Mean	2.40	37.51	2.31	36.89	2.23	35.82	2.18	34.37	2.07	33.90	S : Sterilisation			
CV (%)	0.16	1.13	0.14	1.38	0.16	0.92	0.22	0.67	0.22	0.42	P : Pasteurisation			

Table E.7 Changes in toughness (N.sec) of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	5.93	78.78	5.39	74.99	2.98	72.96	2.42	63.47	2.19	60.80	62.98	22.82	3.78	70.20
T2	3.51	77.07	3.48	70.41	3.43	66.03	2.44	59.45	2.29	58.31	34.66	24.33	3.03	66.25
T3	5.08	76.32	4.89	74.97	4.19	66.15	2.80	60.22	2.73	56.09	46.28	26.51	3.94	66.75
T4	4.77	79.82	4.44	77.45	3.86	73.93	2.19	64.79	2.01	58.07	57.82	27.24	3.45	70.81
T5	4.09	80.30	3.95	79.45	3.04	75.07	2.44	65.96	2.15	59.01	47.43	26.51	3.13	71.96
Mean	4.67	78.45	4.43	75.45	3.50	70.83	2.46	62.78	2.27	58.46	S : Sterilisation			
CV (%)	0.93	1.72	0.75	3.38	0.52	4.39	0.22	2.84	0.27	1.70	P : Pasteurisation			

Table E.8 Changes in ‘L’ (black - white) value of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	46.47^{e}	69.86^{e}	43.57^{e}	69.20^{d}	44.92^{e}	67.87^{d}	39.47^{e}	67.15^{d}	36.70^{e}	65.45^{d}	21.01	6.32	42.23	67.91
T2	58.30^{ab}	78.43^{a}	55.19^{b}	76.13^{bc}	52.89^{bc}	75.49^{c}	50.86^{c}	75.40^{b}	50.47^{bc}	73.07^{c}	13.43	6.83	53.54	75.70
T3	58.64^{a}	77.32^{c}	58.26^{a}	76.82^{ab}	57.83^{a}	76.30^{ab}	57.63^{a}	75.22^{abc}	56.45^{a}	74.49^{ab}	3.73	3.66	52.60	76.77
T4	53.57^{cd}	70.87^{d}	53.28^{cd}	69.77^{d}	51.33^{d}	66.57^{e}	48.55^{d}	63.44^{e}	46.23^{d}	62.62^{e}	13.71	11.64	50.59	66.65
T5	53.80^{c}	78.17^{ab}	53.53^{c}	77.24^{a}	52.96^{b}	77.10^{a}	52.14^{b}	76.37^{a}	50.58^{b}	74.99^{a}	5.99	4.07	57.76	76.03
Mean	54.16	74.93	52.77	73.83	51.99	72.67	49.73	71.52	48.09	70.12	S : Sterilisation			
CV (%)	4.92	4.20	4.95	3.99	5.17	5.03	6.63	5.84	7.33	5.69	P : Pasteurisation			

Table E.9 Changes in ‘a’ (green - red) value of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% increase		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	15.62^{e}	1.12^{c}	16.73^{e}	1.17^{c}	17.30^{e}	1.25^{c}	18.69^{c}	1.26^{bc}	19.89^{e}	1.29^{c}	27.34	15.45	17.65	1.22
T2	4.17^{a}	0.22^{a}	4.27^{a}	0.23^{a}	4.49^{a}	0.23^{a}	4.54^{a}	0.24^{a}	4.90^{a}	0.24^{a}	17.52	11.47	4.47	0.23
T3	13.34^{d}	1.30^{c}	13.60^{d}	1.35^{d}	13.73^{d}	1.36^{c}	15.30^{d}	1.39^{c}	15.49^{d}	1.41^{c}	16.07	8.69	14.29	1.36
T4	6.84^{b}	0.90^{b}	7.47^{b}	0.92^{b}	7.56^{b}	0.99^{b}	8.59^{b}	1.03^{b}	8.61^{b}	1.02^{b}	25.82	12.50	7.82	0.97
T5	9.78^{c}	1.20^{c}	9.93^{c}	1.24^{cd}	10.31^{c}	1.24^{c}	10.42^{c}	1.28^{bc}	11.40^{c}	1.28^{c}	16.60	6.42	10.37	1.25
Mean	9.95	0.95	10.40	0.98	10.68	1.02	11.51	1.04	12.06	1.05	S : Sterilisation			
CV (%)	4.66	0.43	4.92	0.45	5.03	0.46	5.57	0.47	5.84	0.47	P : Pasteurisation			

Table E.10 Changes in ‘b’ (blue - yellow) value of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% decrease		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	11.37^{d}	14.95^{c}	10.71^{c}	13.84^{d}	10.00^{e}	13.55^{cd}	9.74^{e}	13.40^{c}	9.64^{e}	13.01^{cd}	15.26	12.94	10.29	13.75
T2	10.87^{e}	11.84^{e}	10.85^{e}	11.85^{e}	10.77^{d}	11.68^{e}	10.80^{d}	11.35^{e}	10.68^{cd}	11.65^{e}	1.75	1.60	10.79	11.67
T3	15.38^{a}	16.87^{a}	15.37^{a}	16.87^{a}	15.32^{a}	16.72^{a}	15.26^{a}	16.61^{a}	15.24^{a}	16.76^{a}	0.91	0.67	15.32	16.76
T4	12.43^{c}	14.63^{d}	12.34^{c}	14.11^{c}	11.42^{c}	13.57^{c}	11.47^{c}	13.18^{cd}	11.03^{c}	13.04^{c}	11.28	10.87	11.74	13.70
T5	15.24^{ab}	15.86^{b}	15.22^{ab}	15.42^{b}	14.75^{b}	15.18^{b}	14.57^{b}	14.90^{b}	14.12^{b}	14.68^{b}	7.35	7.48	14.78	15.21
Mean	13.06	14.83	12.90	14.42	12.45	14.14	12.37	13.89	12.14	13.83	S : Sterilisation			
CV (%)	2.13	1.89	2.28	1.87	2.42	1.9	2.42	1.98	2.41	1.96	P : Pasteurisation			

Table E.11 Changes in ‘ΔE’ (Total colour difference) value of canned tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage Interval										% increase		Mean	
	0		15		30		45		60					
	S	P	S	P	S	P	S	P	S	P	S	P	S	P
T1	29.65^{e}	2.47^{ab}	32.73^{e}	3.04^{ab}	32.06^{e}	4.04^{a}	37.33^{e}	4.60^{a}	40.30^{e}	6.12^{cd}	35.92	147.45	34.41	4.06
T2	14.09^{a}	8.61^{e}	16.92^{ab}	6.59^{c}	19.12^{b}	6.16^{c}	21.03^{b}	6.30^{c}	21.52^{b}	4.57^{a}	52.65	-46.99	18.54	6.45
T3	22.20^{d}	8.12^{d}	22.58^{d}	7.28^{d}	23.09^{d}	7.13^{e}	24.75^{cd}	6.45^{c}	26.05^{c}	5.32^{abc}	17.33	-34.51	23.73	6.86
T4	19.03^{c}	2.20^{a}	19.57^{c}	2.48^{a}	21.50^{c}	4.86^{b}	24.40^{c}	7.77^{d}	26.60^{cd}	8.57^{e}	39.75	288.88	22.22	5.18
T5	16.21^{b}	7.13^{c}	16.60^{a}	6.66^{cd}	17.18^{a}	6.17^{d}	17.41^{a}	5.22^{b}	18.89^{a}	4.63^{ab}	16.52	-35.13	17.26	5.96
Mean	20.24	5.71	21.68	5.21	22.59	5.67	24.98	6.07	26.67	5.84	S : Sterilisation			
CV (%)	6.08	3.12	6.63	2.26	5.76	1.22	7.51	1.22	8.26	1.65	P : Pasteurisation			

Table E.12 ANOVA Table of changes in TSS of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	18.63	4.66	388.12	S^{**}
	Factor B	1	5.13	5.13	427.11	S^{**}
	AB	4	0.17	0.04	3.43	S^{*}
	Error	20	0.24	0.01		
15	Factor A	4	16.79	4.20	90.76	S^{**}
	Factor B	1	4.88	4.88	105.52	S^{**}
	AB	4	0.11	0.03	0.57	NS
	Error	20	0.93	0.05		
30	Factor A	4	16.91	4.23	156.56	S^{**}
	Factor B	1	4.49	4.49	166.12	S^{**}
	AB	4	0.10	0.03	0.94	NS
	Error	20	0.93	0.05		
45	Factor A	4	17.30	4.32	199.58	S^{**}
	Factor B	1	4.56	4.56	210.60	S^{**}
	AB	4	0.07	0.02	0.79	NS
	Error	20	0.43	0.02		
60	Factor A	4	17.16	4.29	221.87	S^{**}
	Factor B	1	4.56	4.56	236.02	S^{**}
	AB	4	0.06	0.02	0.80	NS
	Error	20	0.39	0.02		

S^{**} - Significant at 1% level, S^{*} - Significant at 5% level, NS- not significant

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.13 ANOVA Table of changes in titrable acidity of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	7.10	1.77	72.10	S^{**}
	Factor B	1	0.04	0.04	1.80	NS
	AB	4	0.08	0.02	0.80	NS
	Error	20	0.49	0.03		
15	Factor A	4	0.90	0.23	98.71	S^{**}
	Factor B	1	0.01	0.01	2.15	NS
	AB	4	0.02	0.01	2.15	NS
	Error	20	0.05	0.00		
30	Factor A	4	0.61	0.15	237.86	S^{**}
	Factor B	1	0.01	0.01	7.67	S^{**}
	AB	4	0.02	0.01	7.67	S^{**}
	Error	20	0.01	0.00		
45	Factor A	4	0.36	0.09	214.22	S^{**}
	Factor B	1	0.01	0.01	11.66	S^{**}
	AB	4	0.01	0.00	4.37	S^{**}
	Error	20	0.01	0.00		
60	Factor A	4	0.40	0.10	218.66	S^{**}
	Factor B	1	0.01	0.01	24.15	S^{**}
	AB	4	0.01	0.00	4.02	S^{**}
	Error	20	0.01	0.00		

S^{**} - Significant at 1% level, NS- not significant

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.14 ANOVA Table of changes in pH of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	3.14	0.79	2508.68	S^{*}
	Factor B	1	0.00	0.00	0.68	NS
	AB	4	0.08	0.02	62.12	S^{**}
	Error	20	0.01	0.00		
15	Factor A	4	3.13	0.78	84.13	S^{**}
	Factor B	1	0.00	0.00	0.06	NS
	AB	4	0.08	0.02	2.02	NS
	Error	20	0.19	0.01		
30	Factor A	4	3.04	0.76	14.98	S^{**}
	Factor B	1	0.00	0.00	0.00	NS
	AB	4	0.05	0.01	0.24	NS
	Error	20	1.02	0.05		
45	Factor A	4	2.88	0.72	24.04	S^{**}
	Factor B	1	0.00	0.00	0.00	NS
	AB	4	0.05	0.01	0.43	NS
	Error	20	0.60	0.03		
60	Factor A	4	2.88	0.72	257.58	S^{**}
	Factor B	1	0.00	0.00	0.48	NS
	AB	4	0.06	0.01	5.04	NS
	Error	20	0.06	0.00		

S^{**}- Significant at 1% level, S^{*}- Significant at 5% level, NS- not significant

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.15 ANOVA Table of changes in vitamin C of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	14.09	3.52	2457.43	S**
	Factor B	1	0.01	0.01	6.78	S**
	AB	4	0.07	0.02	12.75	S**
	Error	20	0.03	0.00		
15	Factor A	4	14.65	3.66	25.36	S**
	Factor B	1	0.02	0.02	0.12	S*
	AB	4	0.05	0.01	0.08	S*
	Error	20	2.89	0.14		
30	Factor A	4	14.62	3.66	205.27	S**
	Factor B	1	0.01	0.01	0.77	S*
	AB	4	0.06	0.01	0.79	S*
	Error	20	0.36	0.02		
45	Factor A	4	14.98	3.74	3463.07	S**
	Factor B	1	0.01	0.01	13.16	S**
	AB	4	0.05	0.01	10.74	S**
	Error	20	0.02	0.00		
60	Factor A	4	17.28	4.32	1695.93	S**
	Factor B	1	0.02	0.02	9.39	S**
	AB	4	0.07	0.02	7.05	S**
	Error	20	0.05	0.00		

S** - Significant at 1% level, S* - Significant at 5% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.16 ANOVA Table of changes in crude fibre of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	0.10	0.03	2.39	NS
	Factor B	1	0.03	0.03	2.43	NS
	AB	4	0.03	0.01	0.64	NS
	Error	20	0.21	0.01		
15	Factor A	4	0.11	0.03	0.20	NS
	Factor B	1	0.00	0.00	0.02	NS
	AB	4	0.01	0.00	0.02	NS
	Error	20	2.81	0.14		
30	Factor A	4	0.07	0.02	1.34	NS
	Factor B	1	0.00	0.00	0.12	NS
	AB	4	0.01	0.00	0.19	NS
	Error	20	0.25	0.01		
45	Factor A	4	0.07	0.02	2.43	NS
	Factor B	1	0.00	0.00	0.16	NS
	AB	4	0.02	0.00	0.52	NS
	Error	20	0.14	0.01		
60	Factor A	4	0.07	0.02	2.34	NS
	Factor B	1	0.00	0.00	0.09	NS
	AB	4	0.02	0.00	0.50	NS
	Error	20	0.16	0.01		

NS- not significant

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.17 ANOVA Table of changes in firmness of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	6.72	1.68	0.85	NS
	Factor B	1	9244.92	9244.92	4679.65	S^{**}
	AB	4	2.21	1.12	0.38	NS
	Error	20	39.51	1.98		
15	Factor A	4	10.33	2.58	4.27	S^{**}
	Factor B	1	8965.83	8965.83	14829.98	S^{**}
	AB	4	12.80	3.20	5.29	S^{**}
	Error	20	12.09	0.61		
30	Factor A	4	4.84	1.21	2.36	NS
	Factor B	1	8461.96	8461.96	16486.14	S^{**}
	AB	4	5.73	1.43	2.79	NS
	Error	20	10.27	0.51		
45	Factor A	4	1.97	0.49	1.02	S^{*}
	Factor B	1	7771.86	7771.86	16058.71	S^{**}
	AB	4	3.90	0.98	2.02	NS
	Error	20	9.68	0.48		
60	Factor A	4	0.58	0.15	0.46	NS
	Factor B	1	7596.04	7596.04	24050.03	S^{**}
	AB	4	2.07	0.52	1.64	S^{*}
	Error	20	6.32	0.32		

S^{**} - Significant at 1% level, S^{*} - Significant at 5% level, NS- not significant

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.18 ANOVA Table of changes in toughness of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	23.58	5.89	5.63	S^{**}
	Factor B	1	40827.27	40827.27	38997.75	S^{**}
	AB	4	22.37	5.59	5.34	S^{**}
	Error	20	20.94	1.05		
15	Factor A	4	78.87	19.72	15.11	S^{**}
	Factor B	1	37834.98	37834.98	28985.27	S^{**}
	AB	4	65.41	16.35	12.53	S^{**}
	Error	20	26.11	1.31		
30	Factor A	4	102.76	25.69	84.52	S^{**}
	Factor B	1	33997.34	33997.34	111850.70	S^{**}
	AB	4	131.83	32.96	108.43	S^{**}
	Error	20	6.08	0.30		
45	Factor A	4	44.33	11.08	37.77	S^{**}
	Factor B	1	27284.97	27284.97	92989.19	S^{**}
	AB	4	53.02	13.25	45.17	S^{**}
	Error	20	5.87	0.29		
60	Factor A	4	14.09	3.52	5.01	S^{**}
	Factor B	1	23672.45	23672.45	33645.67	S^{**}
	AB	4	21.50	5.38	7.64	S^{**}
	Error	20	14.07	0.70		

S^{**} - Significant at 1% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.19 ANOVA Table of changes in 'L' (Lightness) value of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	447.54	111.88	769.59	S**
	Factor B	1	3236.69	3236.69	22263.65	S**
	AB	4	55.03	13.76	94.63	S**
	Error	20	2.91	0.15		
15	Factor A	4	473.27	118.32	581.39	S**
	Factor B	1	3328.32	3328.32	16354.84	S**
	AB	4	82.57	20.64	101.43	S**
	Error	20	4.07	0.20		
30	Factor A	4	479.28	119.82	584.01	S**
	Factor B	1	3207.26	3207.26	15632.45	S**
	AB	4	83.00	20.75	101.13	S**
	Error	20	4.10	0.21		
45	Factor A	4	767.81	191.95	1027.33	S**
	Factor B	1	3559.29	3559.29	19049.27	S**
	AB	4	170.19	42.55	227.71	S**
	Error	20	3.74	0.19		
60	Factor A	4	885.25	221.31	484.71	S**
	Factor B	1	3642.33	3642.33	7977.30	S**
	AB	4	148.23	37.06	81.16	S**
	Error	20	9.13	0.46		

S** - Significant at 1% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.20 ANOVA Table of changes in ‘a’ (greenness) value of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	150.70	37.68	3261.30	S**
	Factor B	1	607.62	607.62	52596.23	S**
	AB	4	111.81	27.95	2419.66	S**
	Error	20	0.23	0.01		
15	Factor A	4	167.43	41.86	8606.82	S**
	Factor B	1	665.34	665.34	136805.98	S**
	AB	4	125.05	31.26	6427.96	S**
	Error	20	0.10	0.01		
30	Factor A	4	175.48	43.87	2828.57	S**
	Factor B	1	700.06	700.06	45136.11	S**
	AB	4	130.84	32.71	2108.98	S**
	Error	20	0.31	0.02		
45	Factor A	4	212.46	53.11	2198.96	S**
	Factor B	1	822.15	822.15	34037.28	S**
	AB	4	162.79	40.70	1684.87	S**
	Error	20	0.48	0.02		
60	Factor A	4	233.00	58.25	3028.03	S**
	Factor B	1	908.71	908.71	47238.45	S**
	AB	4	179.64	44.91	2334.56	S**
	Error	20	0.39	0.02		

S** - Significant at 1% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.21 ANOVA Table of changes in ‘b’ (yellowness) value of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	89.08	22.27	1696.93	S**
	Factor B	1	23.50	23.50	1790.46	S**
	AB	4	8.19	2.05	156.05	S**
	Error	20	0.26	0.01		
15	Factor A	4	97.41	24.35	1518.38	S**
	Factor B	1	17.30	17.30	1078.47	S**
	AB	4	6.97	1.74	108.56	S**
	Error	20	0.32	0.02		
30	Factor A	4	104.70	26.18	347.40	S**
	Factor B	1	21.32	21.32	282.95	S**
	AB	4	8.89	2.22	29.50	S**
	Error	20	1.51	0.08		
45	Factor A	4	106.59	26.65	375.25	S**
	Factor B	1	17.31	17.31	243.80	S**
	AB	4	10.48	2.62	36.88	S**
	Error	20	1.42	0.07		
60	Factor A	4	108.41	27.10	141.70	S**
	Factor B	1	21.30	21.30	111.38	S**
	AB	4	7.16	1.79	9.36	S**
	Error	20	3.83	0.19		

S** - Significant at 1% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.22 ANOVA Table of changes in 'ΔE' (Total colour difference) value of canned tender jackfruit

Days	Source	DF	SS	MS	F	Sig
0	Factor A	4	145.03	36.26	1050.84	S**
	Factor B	1	1583.29	1583.29	45887.03	S**
	AB	4	415.33	103.83	3009.30	S**
	Error	20	0.69	0.04		
15	Factor A	4	203.60	50.90	327.24	S**
	Factor B	1	2034.63	2034.63	13080.80	S**
	AB	4	385.40	96.35	619.44	S**
	Error	20	3.11	0.16		
30	Factor A	4	152.95	38.24	279.30	S**
	Factor B	1	2146.30	2146.30	15677.31	S**
	AB	4	262.31	65.58	478.99	S**
	Error	20	2.74	0.14		
45	Factor A	4	306.72	76.68	790.90	S**
	Factor B	1	2684.13	2684.13	27684.85	S**
	AB	4	388.49	97.12	1001.75	S**
	Error	20	1.94	0.10		
60	Factor A	4	485.92	121.48	318.87	S**
	Factor B	1	3253.98	3253.98	8541.35	S**
	AB	4	366.03	91.51	240.20	S**
	Error	20	7.62	0.38		

S** - Significant at 1% level

Factor A - Treatments

Factor B - Sterilisation and Pasteurisation

AB - Interactive mode (Differential response of the five treatments over the two methods)

Table E.23 Bacterial count (10^1 cfu g^{-1}) during the storage period

Treatments	0^{th} day		15^{th} day		30^{th} day		45^{th} day		60^{th} day	
	55^oC	37^oC	55^oC	37^oC	55^oC	37^oC	55^oC	37^oC	55^oC	37^oC
ST1	0	0	0	0	0	0	0	0	0	0
ST2	0	0	0	0	0	0	0	0	0	0
ST3	0	0	0	0	0	0	0	0	0	0
ST4	0	0	0	0	0	0	0	0	0	0
ST5	0	0	0	0	0	0	0	0	0	0
PT1	0	0	0	0	0	0	0	0	0	0
PT2	0	0	0	0	0	0	0	0	0	0
PT3	0	0	0	0	0	0	0	1	0	2
PT4	0	0	0	0	0	0	0	0	0	0
PT5	0	0	0	0	0	0	0	0	0	0

Table E.24 Fungus and Yeast count (10^1 cfu g^{-1}) during the storage period

Treatments	0^{th} day		15^{th} day		30^{th} day		45^{th} day		60^{th} day	
	F	Y	F	Y	F	Y	F	Y	F	Y
ST1	0	0	0	0	0	0	0	0	0	0
ST2	0	0	0	0	0	0	0	0	0	0
ST3	0	0	0	0	0	0	0	0	0	0
ST4	0	0	0	0	0	0	0	0	0	0
ST5	0	0	0	0	0	0	0	0	0	0
PT1	0	0	0	0	0	0	0	0	0	0
PT2	0	0	0	0	0	0	0	0	0	0
PT3	0	0	0	0	0	0	0	0	0	0
PT4	0	0	0	0	0	0	0	0	0	0
PT5	0	0	0	0	0	0	0	0	0	0

F - Fungus, Y – Yeast

DEVELOPMENT AND QUALITY EVALUATION OF THERMALLY PROCESSED JACKFRUIT (*Artocarpus heterophyllus* L.)

by

Pritty S. Babu

ABSTRACT OF THE THESIS REPORT

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ABSTRACT

Jackfruit (*Artocarpus heterophyllus* Lam.) is an important nutritious tropical fruit of India. Its availability is seasonal and could not be stored as such for longer periods under ambient or refrigerated conditions which results in its wastage. Therefore, to increase the shelf life of jackfruit, an investigation has been taken up to develop and standardise a process protocol, which could contribute to jackfruit based industries. 'Varikka' variety of tender jackfruit was used for the study. A hot water blancher was fabricated and blanching time was standardised (one minute) based on enzyme inactivation, colour and texture. Standardisation of thermal processes viz. pasteurisation and sterilisation time-temperature combination for different F and F_0 values respectively were performed and pasteurisation temperature of 90^{o}C for 19 minutes and a sterilisation temperature of 121^{o}C for 38 minutes were found to be optimum based on lethality, texture and colour. After optimal blanching, the samples were canned with prior addition of preservatives like brine, citric acid and KMS using the optimized thermal process time-temperature. Storage study and quality evaluation in terms of TSS, titrable acidity, pH, vitamin C, crude fibre, texture and colour were done. The samples preserved in KMS or citric acid exhibited good property in most cases of quality evaluation. Apart from quality evaluation, microbial and sensory analyses were done at every 15 days interval. The cost of operation per can for tender jackfruit was calculated as ₹ 25/-. The study concluded that the samples which were blanched for one minute at 100^{o}C and pasteurised at 90^{o}C for F value 10 were found to be superior. The optimised treatment resulted in a product which resembled the fresh sample, available to the consumers in a ready to cook form throughout the year.