DEVELOPMENT AND QUALITY EVALUATION OF RETORT POUCH PACKED TENDER JACKFRUIT (*Artocarpus heterophyllus* L.).

By

Praveena. N

(2013-18-103)

THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Development and quality evaluation of retort pouch packed tender jackfruit (*Artocarpus heterophyllus* L.)"** is 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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Dedicated to My Teachers

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SYMBOLS AND ABBREVIATIONS

%	Percentage
&	and
/	per
<	less than
=	equal to
>	greater than
±	plus or minus
≈	Approximate
β	Beta
ANOVA	Analysis of variance
AO	Antioxidant
AOAC	Association of the Official Agricultural Chemists
CA	Controlled atmospheric
CD	Critical Difference
cc	cubic centimeters
cfu	colony forming unit
Cl.	Clostridium
CIFT	Central Institute of Fisheries Technology
CRD	Completely Randomized Design
DF	Dilution Factor
et al.,	and others
etc.	etcetera
F	Thermal death time (pasteurization)
F_0	Thermal death time (sterilization)
FDA	Food and Drug Administration
Fig.	Figure
g	gram(s)

g^{-1}	per gram
h	hour(s)
HP	High pressure
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
IS	Indian Standard
IU	International Units
KCAET	Kelappaji College of Agricultural Engineering and Technology
KAU	Kerala Agricultural University
kg	kilogram
$kgcm^{-2}$	kilogram per square centimeter
kJ	kilo Joules
KMS	Potassium metabisulphite
kW	kilo Watt
L	Litre(s)
L^{-1}	per litre
LTLT	Low Temperature Long Time
m	metric
mg	milligram
min	minute(s)
ml	millilitre
mt	million tonnes
mT	Metric tonnes
N	Normality, Newton

NaOH	Sodium hydroxide
NIST	National Institute of Science and Technology
No.	Number
NS	Non Significant
^oB	Degree Brix
^oC	Degree Celsius
^oF	Degree Fahrenheit
P	Probability
PPs	Polyphenols
PFA	Prevention of Food Adulteration
ppm	parts per million
PO	peroxidase
PPO	Polyphenol oxidase
PLS	Partial Least Squares
RH	Relative Humidity
RTU	Ready-to-Use
sec	second(s)
S	Significant
SA	Salicylic acid
SSC	Soluble solid content
SNI	Sucrose neutral invertase
SD	Standard Deviation
SHP	Slowest Heating Point
SSC	Soluble solid content
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 I

INTRODUCTION

Though India is the largest producer of several fruits and vegetables, there is a huge gap between supply and per capita demand. Around 162.187 mT of vegetables and 81.285 mT fruits are produced in India, which accounts for nearly 14% of country's share in the world production of vegetables (Rais and Sheoran, 2015). Due to lack of cold chain facility, unavailability of temperature controlled vehicle, improper bagging, and lack of proper processing techniques nearly 25 - 30% of produce is wasted every year (Rais and Sheoran, 2015). To meet the country's demand of fruits and vegetables, one need to adopt best global practices in storage, packaging, handling, transportation and value addition.

Jackfruit is a seasonal organic fruit and it is popularly used as vegetable in its tender stage. This under exploited fruit is considered as heavenly fruit by the ancient people in Kerala because of its nutritive composition. This fruit contains protein, fat, carbohydrate, fibre, ash, vitamins (vitamin A, vitamin C, thiamine, riboflavin, niacin) minerals such as calcium, iron, phosphorus, potassium and sodium (Manjeshwar *et al,* 2011). Though it is a highly nutritious commodity, the post harvest wastage is huge due to its perishable nature. There are two types of jackfruits namely 'Koozha' and 'Varikka'. 'Koozha' is a thin and fibrous nature with mushy edible pulp, usually very sweet and emitting strong odour. In contrast 'Varikka' is thick, firm, crisp and has less fragrant pulp. The wastage of 'Koozha' jackfruit is more compared to 'Varikka' and the former has a less consumer acceptance due to its poor texture after ripening. So 'Koozha' jackfruit can be better used in tender stage before ripening.

Traditional processing technologies like freezing, thermal processing (bottling and canning), dehydration (brining, salting and candying) drying and fermentation are widely used in the fruits and vegetables processing at various technology levels (artisanal, intermediate and high) and production scales (cottage, small, medium and large). Tomato paste, canned and dried mushroom, fruit juices and fruit pulps, canned pine apple etc. are the examples of some internationally accepted processed products.

Life style and food habits have undergone drastic changes in India during the last 15 years. Liberalization, dual income, nuclear family, innovative kitchen applications, media proliferation etc., increased the demand of ready to cook and ready to eat products. Modern life style often demanded the adoption of fast food culture either due to the time constraints or due to the dislike towards traditional and time consuming cooking practices. This has contributed to several health issues like obesity, diabetes, high cholesterol, and heart problems. Hence it is imperative to design a safe alternative to fast food which could be both nutritious and time saving.

Canned tender jackfruit ('Varikka') had been proved to be a good ready to cook option available for consumers throughout the year (Pritty and Sudheer, 2014). The high cost of canning necessitated to explore an alternative to the canning system, which should be not only economical but also ensure longer shelf life. Retort pouch packaging system is an ideal alternative to metal cans to achieve these goals. It is a flexible, laminated package that can withstand thermal processing temperatures and combines the advantages of both metal cans and plastic packages. Easy bulk packing, less transportation and material cost, rapid heat penetration, easy disposal without environmental pollution and heat sealability are the major advantages of retort pouch packaging. Moreover it does not affect odour, flavour, texture, colour and food value. It is either three or four ply laminate usually consisting of polypropylene, polyethylene, aluminum, nylon, polyester etc. (Donald and Ricardo, 2007).

The retort pouch packed product needs significantly less heat than cans to achieve same level of commercial sterility, and thus reduces the cooking time and energy cost by half. They have a shorter cooking time owing to a high ratio of surface area to volume which results in better taste, improved nutritional value and less moisture loss. The reduced heat penetration offers better quality processed product especially for heat sensitive products (Donald and Ricardo, 2007).

Due to significant wastage of 'Koozha' variety of jackfruit, this was selected for studies with retort pouching in the tender stage. In the light of growing demand for ready to cook products in both developing and developed countries, production of good quality, safe and ready to cook vegetable in retort pouch, in affordable price assumes prime importance in food technology research. Present study focusses on development and quality evaluation of retort pouch packed tender jackfruit (*Artocarpus heterophyllus* L.) using 'Koozha' variety with the following specific objectives.

- Standardization of blanching process for 'Koozha' tender jackfruit.
- Standardization of thermal processing parameters for retort pouch packaging.
- Shelf life study and quality evaluation of retort pouch packed tender jackfruit.

Review of literature

CHAPTER II
REVIEW OF LITERATURE

This chapter provides an overview of related knowledge and previous research work done which forms the basis of the present study. It deals with the framework for the case study that comprises the main focus of the research described in this thesis.

2.1 Jackfruit

2.1.1 Origin

Jack tree (*Artocarpus heterophyllus* L.), belonging to the family Moraceae is thought to have originated in India and gradually spreaded to South East Asia and now grows wild in the tropical regions throughout the world. The jack tree is widely cultivated in tropical regions of India, Bangladesh, Nepal, Sri Lanka, Vietnam, Thailand, Malaysia, Indonesia and the Philippines. It is also found across Africa, e.g., in Cameroon, Uganda, Tanzania, and Mauritius, as well as throughout Brazil and Caribbean nations such as Jamaica. In India, Kerala, Tamil Nadu, Karnataka, Goa, coastal Maharashtra, Assam, Bihar, Tripura, Uttar Pradesh and foothills of Himalayas are the main jackfruit cultivated areas (Priya *et al.,* 2014). This seasonal organic fruit is highly perishable in nature and has limited storage life. Spoilage begin within a week after ripening, leading to significant wastage of jackfruit. Now the commodity has lost its status and is treated as one of the under exploited fruits of the state.

2.1.2 Varieties

The two main varieties of jackfruit available are 'Koozha' and 'Varikka'. The variety 'Koozha' is thin, fibrous and has mushy edible pulp, usually very sweet and emitting strong odour. But 'Varikka' is thick, firm, crisp and has less fragrant pulp.

Thamara chakka, Nadavalam varikka, Vakathanam varikka, Muttom varikka, then varikka, Aathimathuram koozha, Rudrakshi, Ceylon varikka, Then varikka, Thenga varikka are the main jackfruit varieties in Kerala. Konkan Prolific, Singapore (or) Ceylon Jack, Hybrid Jack, Burliar-1, PLR-1, PPI-1 are few important varieties introduced by and released from various organizations (Priya *et al.,* 2014).

2.1.3 Harvesting

Jackfruit is used as a vegetable after 50 - 70 days of fruit formation. It is used as a fruit when colour changes from pale green to a darkish green brown, the spines flatten out and there is a characteristic aroma (Priya *et al.,* 2014).

2.1.4 Nutritional aspects and health benefits

It is a nutritious fruit, rich in carbohydrates, proteins, potassium, calcium, iron, and vitamins A, B, and C. The flesh of jackfruit is starchy and fibrous, and is a source of dietary fibre.

Table 1. Nutrient composition of fresh jackfruit (per 100 g)

(Arkroyd *et al.*, 1966; Narasimham, 1990; Gunasena *et al.*, 1996; Azad, 2000; Manjeshwar *et al.*, 2011;)

Composition	Young fruit	Ripe fruit	Seed
Water (g)	76.20 - 85.20	72.00 - 94.00	51.00 - 64.50
Protein (g)	2.00 - 2.60	1.20 - 1.90	6.60 - 7.04
Fat (g)	0.10 - 0.60	0.10 - 0.40	0.40 - 0.43
Carbohydrate (g)	9.40 - 11.50	16.00 - 25.40	25.80 - 38.40
Fibre (g)	2.60 - 3.60	1.00 - 1.50	1.00 - 1.50
Total sugars (g)	-	20.60	-
Minerals			
Total minerals	0.90	0.87 - 0.90	0.90 - 1.20
Calcium (mg)	30.00 - 73.20	20.00 - 37.00	50.00
Magnesium (mg)	-	27.00	54.00
Phosphorus (mg)	20.00 - 57.20	38.00 - 41.00	38.00 - 97.00
Potassium (mg)	287.00 - 323.00	191.00 - 407.00	246.00

Sodium (mg)	3.00 - 35.00	2.00 - 41.00	63.20
Iron (mg)	0.40 - 1.90	0.50 - 1.10	1.50
Vitamins			
Vitamin A (IU)	30.00	175.00 – 540.00	10.00 – 17.00
Thiamine (mg)	0.05 - 0.15	0.03 - 0.09	0.25
Riboflavin (mg)	0.05 - 0.20	0.05 - 0.40	0.11 - 0.30
Vitamin C (mg)	12.00 - 14.00	7.00 - 10.00	11.00
Energy (KJ)	50.00 - 210.00	88.00 - 410.00	133.00 - 139.00

Priya *et al.* (2014) reported that jackfruits have high nutritional and medicinal values. It can strengthen immune system, protect against cancer, aid in healthy digestion, help to maintain a healthy eye and skin, help to boost energy, lowering high blood pressure, controls asthma, help to strengthen the bone, prevent anaemia and maintain a healthy thyroid.

2.1.5 Post harvest utility

A numerous value added products can be prepared from jackfruit from immature stage to well ripened stage, more than 100 items (cutlets, pickle, pulao/ biryani, papad, chips, pakoda, halwa, gulab jamun, sweet vada, jam,custard, wine ,squash, kheer/payasam, mocktail, cake, miniappam etc.) can be prepared from jack fruit.

A suitable preparation technique of quality jackfruit chips and their good packaging was explored by Molla *et al.* (2008). Jackfruit slices were treated with preservative and firming agents, pricked, blanched and then subjected to processing. Three packaging materials namely; metalex foil pouch, high density polyethylene and polypropylene pouch were used for the packaging of fried sample.

Investigation on preservation of tender jackfruit with hurdle technology was done by Nimy *et al.* (2012). This study reported the use of hurdle technology in pre-cut form of tender jackfruit. In - pack sterilisation, use of food additives, mild heat treatment and gamma irradiation were the hurdle technologies used. The treated samples were then stored at ambient and subroom temperature for further analysis. The results suggested that the product developed by the hurdle technology remained excellent for over one year even beyond the next harvest of the tender jackfruit assuring continuous availability of this seasonal fruit.

2.2 Blanching

Blanching is a unit operation prior to freezing, canning, or drying in which fruits or vegetables are heated for the purpose of inactivating enzymes, modifying texture, preserving colour, flavour, and nutritional value and removing trapped air. Hot water blanching and steam blanching are the most commonly used methods, but microwave and hot gas blanching have also been studied. It also helps to cleanse the surface of food, brightens the colour, retard loss of vitamins, soften vegetables and make them easier to pack.

Srivastava and Sanjeev (1994) reported that the vegetables and fruits should be blanched before canning for some time to soften the texture and also enable a greater weight to be pressed into the container without damage to the individual fruit or vegetable.

Negi and Roy (2000) studied the effect of different blanching treatment on β-carotene, ascorbic acid and retention of chlorophyll of leafy vegetables. 95 ± 3°C was the selected blanching temperature in (a) salt solution (b) water followed by potassium meta bi-sulphite (KMS) dip, (c) water, (d) salt solution followed by KMS dip. The second method was found most suitable for blanching.

Ganiyu (2005) investigated the effect of blanching on the antioxidant (AO) properties of some tropical green leafy vegetables. *Structium sparejanophora, Amarantus cruentus, Telfairia occidentalis, Baselia alba, Solanum macrocarpon, Corchorus olitorus, Vernonia amygdalina, and Ocimum gratissimum* were blanched in hot water for five minutes. The results of the study revealed that blanching caused a significant increase in the total phenol content of the green leafy vegetables except in *Amarantus cruentus* and *Vernonia amygdalina.* Conversely, there was a significant decrease in the vitamin C, reducing property and free radical scavenging ability of the blanched green leafy vegetables except in *Structium sparejanophora*. They concluded that blanching of vegetables though making green leafy vegetables more palatable and less toxic, lower their AO properties drastically.

Aguero *et al.* (2005) studied the biochemical and sensory changes in swiss chard (*Beta vulgaris*) during blanching. The effects of steam blanching on chard leaves individually and in three and five leaves deep beds were investigated. Under all conditions tested a reduction of about two orders of magnitude in mesophillic bacterial counts were obtained. They reported that, sensory qualities of chard were best maintained when leaves were blanched individually.

Savas *et al.* (2005) reported that a blanching treatment to inactivate peroxidase (POD) retained the quality attributes in a better level during frozen storage.

Vural *et al.* (2005) suggested a blanching time of two minutes at 80°C to inactivate 90% of initial POD activity for green beans.

Lin *et al.* (2006) found that blanching of stems before squeezing effectively prevented degreening and/or browning, and reduced polyphenol oxidase (PPO) activities and sucrose neutral invertase (SNI) in fresh sugarcane juice.

Akhila *et al.* (2009) evaluated the effects of pretreatments viz., blanching and quick freezing on the quality of dried jackfruit and standardized a suitable packaging material for storing the products. The samples which were blanched for two minutes and freezed at -10°C for three hours followed by drying at 60°C and packed in aluminium laminate were found superior.

Tiong *et al.* (2010) revealed that blanching resulted a significant increase in β - carotene content [fresh (389 - 539 μg/100 g), blanched (510 - 818 μg/100 g)], except in snow pea, for some selected vegetables. Carotene, total phenolic content and AO activities in some of the selected vegetables were increased during the blanching process. The results of the study revealed that consumption of raw vegetables does not have high nutritional benefits and AO activities.

A study on blanching of jalapeno peppers using microwaves was done by Lidia *et al.* (2011). They concluded that microwaves may induce the formation of derivatives of phenolics with enhanced AO activity as the result of blanching.

Pritty and Sudheer (2012) optimized the blanching process for tender 'Varikka' jack fruit. Blanching process at 100°C for one minute using 0.3% citric acid as preservatives was found to be the best in terms of sensory attributes (texture and colour) and enzyme inactivation.

Amit *et al.* (2012) evaluated the kinetics of different physicochemical properties like colour, texture, polyphenols (PPs) and AO capacity of irish york cabbage after blanching process. The blanching treatment was carried out at 80 - 100°C with an increment of 5°C for up to 14 minutes and the kinetics of the different properties (texture, colour, PPs and AO capacity) were studied. Significant reduction in the AO capacity (74.0 – 82.0%), firmness (24.0 – 73.2%) and colour occurred as a result of blanching.

Sidonia *et al.* (2013) made a study of different blanching treatments on turnip. The heat treatment was carried out at 90°C for one to two minutes. Content of TSS (total soluble solid), chlorophyll and total phenolics as well as the AO activity of turnip greens were reduced during water blanching. Most important changes in pH values and titratable acidity were found in the blanching process of water with citric acid. The use of ascorbic acid during the blanching process gave rise to a high AO capacity of turnip greens. The presence of acids in the blanching water reduced the loss of TSS, AO capacity and total phenolic during frozen storage.

2.1 Types of blanching

Nezih (1986) conducted a study on different blanching methods (steam blanching, water blanching, convection oven blanching and microwave blanching) for green beans. Microwave oven blanching was best in terms of blanching with minimum adequate blanching time for complete inactivation of POD enzyme. Sample blanched in convection oven showed significant weight loss due to moisture vapourisation. Convection oven blanched green beans reported lowest chlorophyll content and microwave treated sample was best for retaining higher chlophyll content. Steam blanched sample detected more chlorophyll losses than water blanched sample for equivalent POD inactivation. More intense greenness was found in water blanching and steam blanching during colour measurement.

Conventional water blanching and pulsed microwave (95°C) blanching effect on bell pepper, spinach and carrot were studied by Bognar *et al.* (2002). The study revealed that the absorbed power levels and temperature during microwave blanching was influenced by the type of vegetable, shape, its quality, location in the oven and the power of microwave applied. The study reported the potential application of microwave blanching in minimizing the loss of valuable nutrients.

Shivhare *et al.* (2007) carried out a study on the relation of selected blanching treatments on the quality of carrots over a temperature range of 80 – 100°C. The treatments selected were water blanching, steam blanching, 0.05 N acetic acid solution blanching and blanching with 0.2% calcium chloride solution. The best and most effective blanching treatment was five minutes in hot water at 95°C. At this time – temperature combination, the enzymes (POD and catalase) were found to be completely inactivated and the carrot juice yield, β - carotene and vitamin C contents were estimated to be 55%, 3.18 mg/100 g and 8.192 mg/100 g respectively.

During storage, proper post - harvest management strategy in preserving sugar composition of vegetable soybean by various blanching and storage conditions was investigated by Salvidar *et al.* (2010). Water blanching and cooling treatment of vegetable soybean seeds resulted in decreased leaching of soluble sugar. The presence of pod in correlation with steam blanching helps to retain the soluble sugar during thermal processing.

Guida *et al.* (2013) investigated the effect of conventional hot water (100°C) blanching and ohmic (24 V/cm, 80°C) blanching on artichoke heads during storage by canning, as well as immediately after blanching. The results revealed that the blanching method have effects on the nutritional quality and bioactive compounds in artichoke

es immediately after blanching and during storage by canning. They also reported that reduction in both protein and PPs content in conventionally pre - treated samples was higher than those estimated in samples pre - treated by ohmic blanching method.

2.2.2 Duration of blanching

Activities of POD enzyme in some fresh vegetables (green beans leeks, spinach, celery, squash, carrot, potatoes, cabbage and onions) were determined by Nezih (1986). The vegetables were blanched in hot water at 75, 85 and 95°C for same duration. Inactivation of POD was faster at the higher temperature blanch. This inactivation of enzyme was also affected by the size of vegetable piece and type of vegetable.

Lin and Schyvens (1995) reported that low temperature long time (LTLT) blanching considerably increased the final firmness of sterilized carrot and green beans.

Jae *et al.* (2003) recommended blanching at high temperature and short time for vegetable soyabean.

Nissreen and Helen (2006) reported the effect of low temperature blanching on the texture of whole processed new potatoes. Rate of firmness degradation upon blanching was significantly lower at 60 – 75°C than at 80 – 100°C over the investigated blanching times ($p < 0.05$). The enzyme was rapidly inactivated after 15 minutes at 75°C and after five minutes at both 80 and 90°C. Firmness was significantly higher ($p < 0.05$) for processed potatoes blanched at 65°C than those cooked at 95 or 100°C without blanching. Low temperature blanching results in texture improvement for processed whole new potatoes.

The effects of blanching process on inactivation of peroxidase enzyme, texture, and colour index of pumpkin (*Cucurbita maxima* L.) were studied in the temperature range of 75 – 95°C by Gonc *et al.* (2010). Blanching results in darker and softer pumpkin with processing time.

2.3 Thermal processing

Effect of temperature on firmness of thermally processed fruits and vegetables was studied by Bourne and Comstock (1986). They found out that firmness almost always decreased with increasing temperature and the firmness - temperature plots were rectilinear.

Veronica *et al.* (2002) found that thermal processing enhanced the nutritional value of tomatoes by increasing the bioaccessible lycopene content and total AO activity and were against the notion that processed fruits and vegetables have lower nutritional value than fresh produce.

Effect of high - pressure (HP)/high-temperature processing on chemical pectin conversions in relation to fruit and vegetable texture was investigated by Roeck *et al.* (2009). They found that by combining high temperature with HP, β - eliminations were decreased or even stopped, but there was a stimulation in demethoxylation. These results are very promising in the context of the texture property preservation of HP sterilized fruits and vegetables, as β - elimination is accepted to be one of the main causes of thermal softening and low methoxylated pectin can enhance tissue strength by forming cross - links with calcium ions present.

Maria *et al.* (2010) compared the membrane integrity changes using different analytical methods (HP and thermal processing) and impact on tissue. Texture membrane rupture could clearly be identified at 300 MPa and above in HP treatments and at 60°C and above in the thermal treatments. The texture of onions was influenced by the state of the membranes and was abruptly modified once, the membrane integrity was lost.

Liesbeth *et al.* (2012) demonstrated that the potential benefit of HP over thermal processing of carrots is largely dependent on the processing intensity applied. Mild and severe thermal pasteurization, mild and severe HP pasteurization and HP sterilization resulted in a comparable overall quality than thermal sterilization. Quality of carrot is mostly affected by the thermal sterilization method.

Pritty *et al.* (2013) optimized the thermal process time temperature combination for safe canned tender 'Varikka' jackfruit in context of increasing shelf life by considering microbial and quality aspect of product. The thermal processing at temperature 90°C for 19 minutes (F value 10) and at temperature 121°C for 38 minutes (Fo value one) were chosen as the better time temperature combination for pasteurization and sterilization. Based on the combined result of microbiological quality, characteristic variability and sensory perception; pasteurizing tender jackfruit at 90°C for 19 minutes was chosen as the optimum thermal process treatment for enhancing the shelf life.

2.4 Retort processing

Development of flexible pouch process and pasteurized - refrigerated mango slices evaluation were conducted by Gomez *et al.* (1980). The periodic instrumental and sensory evaluations showed better quality retention at two and 10°C in a 24 week storage study. The storage study reveals that product packed in aluminum laminate pouches or glass jars were better than slices in transparent pouches.

Williams *et al.* (1981) examined the economic suitability of using the retort pouch for processing, packaging and distributing processed fruit and vegetable products during a period of rising energy prices. A retort pouch packaging system was found to be the overall minimum cost packaging system among three packaging systems considered - an existing canning line, a new canning line, and a retort pouch line.

Abou and Miller (1983) studied vitamin retention, colour and texture in thermally processed green beans and royal ann cherries packed in pouches and cans. The thiamin, ascorbic acid and vitamin B - 6 content were significantly more in pouched products than that of canned ones.

Cynthia and Jerald (1989) investigated the retort pouch advantages over conventional metal can. Conduction and convection heating products were selected for this study. i.e pureed pumpkin (conduction heating products), peas in brine and pineapple in juice (products using conduction/convection heating). It was reported that pouches yield greatly less process times for product with conduction heating. Less processing time only was required for agitated cooking of cans than the thinner still - cooked pouches, for particulates in a liquid medium.

Cluter *et al.* (1994) evaluated the shelf life of cling peaches in retort pouches. Fruit source (fresh and frozen) and syrup pH (3.85 and 3.25) were taken as processing variables and 4, 21 and 38°C were selected as the storage temperature. It was reported that sensory colour, texture, acceptability, instrumental colour and sugar composition were greatly affected by pH. Frozen and fresh source peaches at pH 3.85 met shelf life requirements at 21 and 38°C.

Kluter *et al.* (1996) evaluated the shelf life of bartlett pears in pouches (retort). The processing variables were processing temperature (88 and 96°C) and syrup pH (4.0 and 3.5). Periodic sensory evaluation and biochemical/instrumental analyses were conducted during storage at 4, 21 and 38°C. Quality measures are greatly affected by pH. Bivariate correlations from Partial Least Squares (PLS) analysis reported high positive correlation between the first PLS factor and sensory and analytical determinations of colour quality, overall quality, pear flavor intensity, Hunter L, ascorbic acid and sucrose. Pears processed at 88 and 96°C temperature, met minimum military shelf life requirements at 21 or 38°C with a pH of 4.0.

Taiwo *et al.* (1997) studied the production aspects of cow pea in tomato sauce and economic comparison of packaging in retort pouch system and canning. The study reveals that cost of cans be accounted for a larger percentage of the raw material cost than the pouch.

Effect of residual gas volume on quality of retort pouch packed wet - pack pears was evaluated by Olivas *et al.* (2002). A faster darkening and higher ascorbic acid degradation were observed in 30 cc residual gas volume. The maximum residual gas volume that volume that accomplished the desired shelf life was 20 cc (cubic centimeters).

Awuah (2007) pointed that new processing concepts such as the application of variable retort temperature have received attention from processing experts and promises to improve both the economy and quality of thermally processed foods.

2.5 Storage studies

Dragan and Tomaz (2006) performed a comparative study of quality changes in tomato cv. 'Malike' (*Lycopersicon esculentum* Mill.) whilst stored at different temperatures (5 and 10°C). They concluded that temperature had significant effect in weight loss of tomato fruit. Weight loss was minimum for tomato fruit stored at lower temperature and it had more stability and greater storage life. The soluble solids content progressively increased with storage period at both temperatures, but earlier at 10°C.

Othman (2009) found out seasonal effect on PPO activity of fruit. Highest PPO activity was found in early-season fruit and lowest activity for late - season fruits. The PPO activity in the papaya fruit decreased during storage ripening.

Effect of different storage methods on nutritional quality of waterapple fruits (*Syzygium javanica*) were studied by Rajkumar and Mitali (2009). Study revealed that the sealed polythene and two per cent wax emulsion coating in refrigerator were more effective in extending shelf life of waterapple fruits. The fruits showed comparatively less weight loss and shrinkage during storage and remained quite fresh and turgid at the end of storage period.

Postharvest mechanical and physico - chemical changes in jambu air (*Syzygium aqueum* Alston) fruit was studied by Tehrani *et al.* (2011). It was observed that weight loss, TSS and pH of the jambu airfruits increased with storage whilst colour index and firmness of pulp of the fruits decreased.

Effect of salicylic acid (SA) treatments on storage life of peach fruits was found out by Muhammad *et al.* (2012). SA at 2.0 mmol/L concentration significantly exhibited minimum weight loss, higher flesh firmness, higher titrable acidity contents, increased soluble solid content (SSC), higher skin luminosity and decreased a^* values compared with other treatments including control. Present results suggested that SA at 2.0 mmol /L concentration could be used for the commercial preservation of peach fruits for up to five weeks without any spoilage.

Effects of atmosphere composition and temperature on quality of stored Jujube fruit was done by Lin *et al.* (2004). The results indicated that the contents of ethyl acetate and ethanol, degradation of anthocyanin, and chlorophyll were significantly lower in the fruits stored in controlled atmospheric (CA) at -1°C than those in air at -1°C. Short term high O_2 (70%) treatment was the most effective in maintaining peel colour, anthocyanin and chlorophyll contents and preventing peel browning compared to other treatments.

Nomeda *et al.* (2006) found out the correlation of fruit quality parameters and losses during storage. Apples picked at the optimal harvest time lost the least mass during storage period. Apples that were picked very late were the least firm after storage. There was a particularly strong positive correlation between post - storage acidity and firmness at harvest, and a particularly strong negative correlation between post-storage sugar/acid ratio and firmness at harvest. Post - storage soluble solids content and post-storage sugar/acid ratio were strongly correlated with soluble solids content at harvest.

Jan and Rab (2012) investigated the influence of storage duration on physico - chemical properties of apple fruits. The per cent weight loss, TSS, pH, total sugar, TSS/Acid ratio, bitter pit incidence and soft rot increased with increase in storage duration while starch score, juice content, titratable acidity, vitamin C, density and firmness of fruit decreased with increase in storage duration.

Effect of storage temperature on physico - chemical and microbiological properties of pasteurized milk was investigated by Samia *et al.* (2013). Highly significant changes were found for coliform bacterial count and log/cfu/ml for TBC of pasteurized milk due to variation of temperature and storage duration.

Shelf life study and quality evaluation of retort pouch packed tender jackfruit curry was done by Nadanasabapathi *et al.* (2013). The curry was acceptable and stable with good texture and sensory qualities upto 12 months of storage.

2.6 Quality parameters

2.6.1 Ascorbic acid

Hossian and Haque (1979) reported that jackfruit contains 2.64 - 11.77 mg/100g of ascorbic acid.

Nezih (1986) reported that ascorbic acid was found to be significantly ($p < 0.05$) higher in the microwave blanched sample. Ascorbic acid contents of water blanched green beans were higher than those of steam blanched ones. Lowest ascorbic acid was found to be in convection oven blanched green beans.

Preharvest factors and postharvest factors influencing vitamin C content of horticultural crops were studied by Seung and Adel (2000). Storing fruits and vegetables in reduced O_2 and or up to 10% CO_2 atmospheres can reduce the loss of vitamin C after harvest; higher CO_2 levels can accelerate vitamins C loss. Vitamin C degradation of produce was observed during processing and cooking. However, further loss of vitamin C was limited during the frozen-storage of horticultural products.

Aguero *et al.* (2005) studied about the thermal inactivation of POD during blanching of butternut squash. Decreases in ascorbic acid contents due to blanching were analyzed. Blanching processes at high temperature and short time resulted in higher ascorbic acid retention. They observed a linear relationship between ascorbic acid retention and processing temperature.

Savas *et al.* (2005) reported that half - life of ascorbic acid in unblanched green beans was estimated to be 1.89 months. It increased to 2.15 and 3.48 months by blanching at 70°C for 2 minutes (for >90% lipoxyganase (LOX) inactivation) and 90°C for 3 minutes (for >90% POD inactivation), respectively.

Lin *et al.* (2006) reported that addition of 0.1% vitamin C seemed to be more effective than blanching of sugarcane stems, and helped to maintain the quality of fresh sugarcane juice for up to five days at 10°C. Added vitamin C delayed the increase of reducing *sugar*, viscosity, titratable acidity and total microbial count, reduced PPO and SNI activities, and prevention of degreening and/ or browning in fresh sugarcane juice during storage.

Influence of home freezing and storage on vitamin C contents of some vegetables was studied by Nursal and Yucecan (2007). Okra, potatoes, green beans, broccoli, spinach and peas were included to estimate the vitamin C levels of home freezing with the impact of processing and storage. Depending on the vegetable type, pre-freezing operations caused 30.9 - 48.0% decrease in the initial vitamin contents. Home freezing alone did not make any significant difference, but six months storage period resulted in a total of 42.4% (green beans) and 66.5% (broccoli) decrease in vitamin C content.

Berat and Sevinc (2008) investigated the influence of commercial freezing and storage on vitamin C content of some vegetables. The freezing process alone did not influence the vitamin levels except in the cases of green beans and spinach. Total losses were between 27.6% and 57.9% for the vegetables at the end of six month commercial frozen storage period. It was observed that irrespective of the vegetable type, prefreezing treatment and their subsequent frozen storage had a major impact on the vitamin C content.

Biljana and Marija (2009) investigated the effect of preservation method and storage condition on vitamin C loss in beverages. Depending on the storage condition, Vitamin C is readily oxidized and lost during storage of the beverages. After 30 days of storage at 4 - 8°C, the overall loss of ascorbic acid was from 81.01% to 90.27% in thermally pasteurized samples and from 97.83% to almost complete loss in samples preserved with sodium benzoate.

Effect of processing on the vitamin C content of seven Nigerian green leafy vegetables (*Telfaria occidentalis* (ugu), *Talinum triangulare* (waterleaf), *Basella albab* (indian spinach), *Celosia argentea* (soko), *Vernonia amygdalina* (bitter leaf), *Amaranthus hybridus* (tete) and *Crassephalum crepidioees* (rorowo)) was studied by Babalola *et al.* (2010). Blanching and boiling reduced the vitamin C content of soko and tete tremendously, with a value of 91.50% reduction for boiled tete. The percentage loss for sundried vegetables was the lowest when compared with other processing methods with a reduction of 6.50 and 12.40% in Indian spinach and rorowo, respectively. Squeeze washing reduced the vitamin C content of ugu from 62.50 mg/100 g to 6.47 mg/100 g (89.65%) and bitter leaf from 42.40 mg/100 g to 4.28 mg/100 g (89.90%). Squeeze washing followed by boiling of bitter leaf reduced the vitamin C content from 42.40 mg/100 g to 2.18 mg/100 g recording the highest loss of 94.90% when compared with other processing methods.

Tiong *et al.* (2010) reported that blanching caused a significant decrease in ascorbic acid content [fresh (1.2–7.8 mg/100 g), blanched (0.67–3.8 mg/100 g)] in four - angled bean, french bean and long bean.

Jacek (2011) found out the effect of canning and freezing on the vitamin C content in immature seeds of five cultivars of common bean (*Phaseolus vulgaris* L.). The result showed that canned seeds retained significantly less vitamin C content than that of frozen products.

Oyetade *et al.* (2012) studied stability studies on ascorbic acid (vitamin C) from different sources such as grape juice, ascorbic acid (laboratory grade), and vitamin C tablet (a pharmaceutical product). Results of analysis showed that stability of the vitamin was significantly affected by packaging materials, storage temperature condition and exposure to air. A significant negative correlation exists between ascorbic acid decline and time of storage and exposure to air. Ascorbic acid content was more stable in the three sources when stored under refrigeration condition (4 - 5°C) as obtained in the investigation.

Effect of Nigerian market storage conditions on ascorbic acid contents of selected tetrapak packaged citrus fruit juice was investigated by Ojo *et al.* (2013). Six different brands of tetrapak packaged citrus fruit juice were selected for the study. The results showed that there was gradual decrease in ascorbic acid contents and pH values with increase in storage period irrespective of the brands but at different rates depending on the brand while there was increase in total titratable acidity after storage for 10 months at ambient room temperature.

Pritty *et al.* (2014) reported that the mean values of ascorbic acid content significantly decreased from 6.09 ± 0.78 to 5.92 ± 0.87 mg/100 g and 6.13 ± 0.75 to 5.97 ± 0.83 mg/100 g for sterilized and pasteurized tender jackfruit in cans during storage. The losses in ascorbic acid may be due to high temperature and light during storage. The losses were reduced in samples having KMS due to better AO property of KMS.

2.6.2 Total soluble solid (TSS)

Fruit quality changes in pears during CA storage was investigated by Anna *et al.* (2006) TSS content, flesh firmness, titrable acidity and the TSS/titrable acidity ratio varied greatly among the cultivars tested at harvest time, after CA storage, and after shelf life. There were no significant changes in soluble solids at the time of harvest and after storage.

Changes in acids, pH, sugars and other quality parameters during extended vine holding of ripe processing of tomatoes were studied by Gordon *et al.* (2011). An increase in fruit pH was observed during ripening. The increase in pH was paralleled by a decrease in titratable acidity, due to a loss of citric acid. Glucose and fructose concentrations also decreased with increasing maturity after ripening. However other quality parameters (lycopene, colour, total pectin, pectin solubility, and Bostwick consistency) were insignificant.

Majid and Gholami (2011) predicted the firmness of carrot as a function of its TSS. A typical linear regression model was developed for predicting carrot firmness (FIR) of nantes carrot based on its TSS.

Sidonia *et al.* (2013) reported that the use of acids in the blanching water minimized the loss of TSS, antioxidant capacity and total phenolic during frozen storage of turnip.

Pritty *et al.* (2014) studied the effect of TSS on storage of tender jackfruit in cans. They reported that 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 pasteurized in citric acid solution and maximum, for samples sterilized in brine solution.

Dinesh *et al.* (2014) studied the effect of TSS during storage of litchi fruits under different temperatures. It was observed that the TSS (^{0}Brix) of litchi fruits increased with the storage period. TSS, reducing sugar, non-reducing sugar and total sugar increased up to first 10 days of storage and there after declined.

2.6.3 pH

CA - induced changes in pH and organic acid metabolism of stored strawberry fruit was investigated by Deirdre *et al.* (1999). An increase pH and decrease in titratable acidity was observed in internal tissues of CA stored strawberry fruit. Since pH affects colour expression of the anthocyanin pigment, these changes contributed to the observed changes in colour.

The pH plays an important role in the canning process of jackfruit. Addition of 0.75 to one per cent citric acid to the canning syrup was found effective for safe canning process. Canning of jackfruit in combination with more acidic fruits like Bangalora mango and pineapple achieves the same purpose and provides acceptable products (Bhatia *et al.*, 2006).

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 to 121°C under a pressure of 0.7 to 1.05 kg/cm^2 till the centre of can attains these high temperatures.

2.6.4 Colour

Amit *et al.* (2012) observed that blanching of irish york cabbage caused a significant reduction in firmness and colour.

Jun *et al.* (2013) reported that colour parameters of seedless grape can be improved by novel high - humidity hot air impingement blanching (HHAIB) pretreatment.

Chaikham *et al.* (2014) investigated the effects of thermal processing (90°C for one to three minutes) and HP (400 or 500 MPa at 25°C for 15 or 30 minutes) on colour, phytochemical and microbiological properties of herbal - plant infusion. It was found that pressurized infusions comprised of high concentrations of ellagic acid, gallic acid, ascorbic acid, acetic acid, total PPs, and gamma oryzanol compared to the pasteurized samples. Colour parameters indicated that pressurization could preserve the natural colour of the products better than pasteurization.

Guillermo *et al.* (2014) evaluated the effects of freezing, blanching and frozen storage (five months at 18°C) on the physico - chemical qualities of broad beans at milk maturity stage. Five months frozen storage caused 34% and 31% degradation in total chlorophyll in, over blanched beans and minimally blanched beans respectively. Maximum colour values variation was observed for fresh beans followed by blanched beans and frozen beans.

Pritty *et al.* (2014) investigated the hunter parameters (‘L’, ‘a’, ‘b’) of canned ‘Varikka’ jackfruit. The ‘L’, ‘a’, ‘b’ values of fresh sample were 70.62, -1.15, 15.185 and that of sterilized and pasteurized samples were 54.16, 9.95, 13.06 and 74.93, 0.95, 14.83 respectively after two month of storage.

2.6.5 Texture

Practice of testing physical properties of food products, usually by compression is called texture analysis.

Guzman and Barrett (2000) reported that calcium chloride or calcium lactate dips (2.5%, one minute) either alone or in combination with heat treatment maintained or improved the firmness of fruits and vegetables at 5°C.

Indrawati *et al.* (2008) reviewed that HP processing is an efficient alternative to traditional preservation and food processing methods due to its minimum effects on covalent bonds resulting in limited modifications in sensory and nutritional quality.

Guillermo *et al.* (2014) evaluated the effects of freezing, blanching and frozen storage (five months at 18°C) on the physico - chemical qualities of broad beans at milk maturity stage. In sensory evaluation of cooked beans, a significant increase in texture was found in unblanched beans compared with overblanched beans.

Pritty *et al.* (2014) reported that firmness and toughness of canned tender jackfruit were low in sterilized samples as compared with pasteurized 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 sterilized and pasteurized tender jackfruit respectively after two months of storage.

2.6.6 Microbial quality

Commercial sterility for low acid foods may be defined as that condition in which all *clostridium botulinum* spores and all other pathogenic bacteria have been destroyed as well as more heat resistant organisms if present, could produce spoilage under normal conditions of storage and distribution (Denny, 1970).

Abdulsudi *et al.* (2010) concluded that electrolized water can be used as alternative to sodium hypochlorite solution for the microbial control in agricultural produces and food.

Aruna and Poonam (2013) conducted microbiological studies and found out negligible plate count (cfu/g) of mould, bacteria and yeast in processed tomato salsa packed in glass jars, cans and retort pouches during four months of storage analysis.

Pritty *et al.* (2014) reported that tender jackfruit pasteurized at 90°C with F value 10 and sterilization at 121°C with F_0 value one in canning process were microbiologically safe.

2.6.7 Sensory quality of food

According to ISO (5492) 1992, sensory evaluation is the examination of organoleptic attribute of a product by the sense organ.

Chandrasekar *et al.* (2004) had conducted research on heat penetration characteristics and shelf - life studies of brine processed mushrooms in retort pouches. Sensory evaluation of mushroom curry prepared from the stored mushrooms showed that the product had high acceptability (7.9 on a scale of 10) which reduced very slightly (to 7.5) during storage for 12 months. No deformity, leakage or spoilage was noticed and the product remained sterile and acceptable even after 12 months of storage at the ambient conditions (20 - 30°C).

Deogade *et al.* (2008) studied the sensory quality of ready to eat chicken curry added with hot spice mixture containing salt and chicken masala. The study revealed that the flavour, juiciness, texture and overall palatability scores of chicken curry improved significantly with addition of 3.0% salt level as compared to that of 2.5, 3.5 and 4.0%. Spice mixture containing 1.0% commercial chicken masala exhibited significantly higher scores for all the sensory attributes over 0.5 and 1.5%. It is thus concluded added that spice mixture added 3.0% salt and 1.0% commercial chicken masala was more suitable to enhance the sensory quality of ready to eat chicken curry.

Costell and Dursan (2012) explained that texture is a primary attribute that, together with taste, visual appearance and aroma comprises the sensory quality of food. The only way to evaluate sensory quality or some of its attributes (i.e., result of sensation experienced by human when consuming food) is to ask the opinion of the consumer, since sensory quality is not an intrinsic food characteristic, but the result of interaction between human kind and food.

Aruna and Poonam (2013) reported sensory score for processed tomato salsa packed in glass jars, cans and retort pouches during four months of storage analysis. The score was in the order of glass jars (refrigeration temperature) > cans > glass jar (room temperature) > retort pouch (refrigeration temperature) > retort pouch (room temperature).

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The materials used and research methodologies employed to achieve the specified objectives of the study are detailed in this chapter.

3.1 Sample Collection

Tender 'Koozha' jackfruits (*Artocarpus heterophyllus* L.) at a harvest maturity of 50 - 70 days after fruit formation were collected from fruit research station, Vellanikkara, Thrissur. The jackfruits were washed properly in tap water for the removal of external impurities and peeled manually using a stainless steel knife. They were then uniformly cut into pieces. These uniform sized pieces were dipped in 0.1% KMS solution for 15 minutes for preventing the browning action in a stainless steel container.

3.2 Estimation of Physico- Chemical Characteristics

3.2.1 Ascorbic acid

Ascorbic acid is a water-soluble vitamin and it also known as vitamin C. It was determined by dye method (Sadasivam and Manickam, 1992). Four per cent oxalic acid, standard ascorbic acid solution in four per cent 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) were the reagents used for the analysis. Hundred milli gram of pure dry crystalline ascorbic acid was taken and made upto 100 ml using four per cent oxalic acid to get the stock solution. The working standard solution (100 ml) was prepared by diluting 10 ml stock solution using four per cent oxalic acid. Five milli litre each of working standard solution and four per cent oxalic acid were pipetted into a conical flask and titrated against the dye solution. The end point was delineated as the appearance of pale pink colour which persisted for a few minutes. The titration was repeated three times to get the concordant value. The amount of dye (V1) used was determined and such an amount was regarded as 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 (VS) was taken and made up to 100 ml with four per cent oxalic acid solution. Five milli litre of the made up solution was pipetted out into a conical flask and titrated against the dye and the amount used was labeled as V2. The quantity of ascorbic acid (mg) present in 100 gm of sample was calculated as follows.

$$\text{Ascorbic acid (mg/100g)} = \frac{0.5}{V1} * \frac{V2}{5} * \frac{100}{VS} * 100 \qquad 3.1$$

3.2.2 Crude fibre

Two gram 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 two - three times to remove the acid. 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. The residue was transfered to ashing dish (weight of residue + ashing dish = W1) and dried for two hour at 130 ± 2°C. Weight of the dish and the residue (W2) was taken after cooling in the desiccator. The dish was further ignited for 30 minutes at 600 ± 15°C and weighed after cooling (W3).

$$\text{Crude fibre content (\%)} = \frac{(W2-W1)-(W3-W1)}{W} \qquad 3.2$$

3.2.3 Colour

Colour analysis of jackfruit was done with the help of ColourFlex EZ spectrophotometer (Plate 3.1). It is a versatile colour measurement instrument that can be used on products of virtually any size, and industry. The spectrometer uses a xenon flash lamp to illuminate the sample. A dispersion grating was used to separate the reflected light (from the sample) into components. Numerical result of colour was obtained by analyzing the relative intensities of the light at different wave lengths along with visible spectrum (400 - 700 mm).

Calibration was done with a NIST (National Institute of Science and Technology) traceable white calibrated tile that was placed at the sample port during standardization to set the top of scale, the black glass being placed at the sample port during standardization to set the zero. The colour of the sample was measured by filling the cut samples of tender jackfruit in the sample port without any void space. The deviations of the colours 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.

3.2.4 pH

The negative log of the activity of the hydrogen ion in an aqueous solution is referred as pH. Solutions with a pH greater than seven are basic solutions and a solution with pH less than seven are said to be acidic, pH equal to seven being pure water. Foods are classified into different groups based on their pH. pH of the tender jackfruit was measured using Systronic digital pH meter (Plate 3.2). Instrument was calibrated with distilled water and then samples were tested (average value calculated from the three replications). Samples were prepared by homogenizing 10 g of the sample with 10 ml distilled water.

3.2.5 Texture analysis

Hardness, brittleness, spreadability, adhesiveness, tensile strength, extensibility etc. of vast range of product can be measured using texture analyser. Texture of tender jackfruit (firmness and toughness) was measured using stable micro systems texture analyser (UK) (Plate 3.3). It gave a three-dimensional product analysis by measuring distance, force and time. Five milli meter diameter cylindrical probe compressed the sample which was kept on the platform of the instrument. The test was conducted at a speed of 10 mms^{-1}. The firmness or hardness (peak force), and toughness (area under the curve) were determined from the force deformation curve.

3.2.6 Titrable acidity

The crushed jackfruit slices were filtered through a muslin cloth. Fresh filtered homogenized pulp (10 g) was made up to 100 ml with distilled water. Ten milli litre of the prepared solution was titrated against 0.1N NaOH solution using phenolphthalein as indicator. The appearance of a light pink colour indicated the end-point. This 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 (Ns) present in 100 g of sample was calculated as follows;

$$\text{Ns}\ (\%) = \frac{(\text{Normality of alkali} \times \text{titrate value} \times \text{equivalent weight of acid})}{\text{volume of the sample taken}} \qquad 3.3$$

3.2.7 Total soluble solid

TSS is considered as one of the important quality parameter of fruit. It is highly positively correlated with sugar content and measured as °Brix. Sugar content includes carbohydrates, organic acids, proteins, fats and minerals of fruit. Samples were crushed and made into juice. TSS was measured using refractometer (ERMA INC Tokyo Japan) by standard method.

Plate 3.1 Colourimeter

plate 3.3 Texture analyser

Plate 3.2 pH meter

3.3 Standardization of Blanching Treatment

3.3.1 Optimization of blanching time

Approximately 250 g prepared tender jackfruit samples were taken and blanched using hot water blancher (Plate 3.4). The blancher was filled to two - third of its capacity with hot water. The blanching temperature selected was 100°C (Pritty and Sudheer, 2012). The different time - temperature combinations selected for standardization of blanching time of 'Koozha' variety tender jackfruit were;

B_1: Blanching in 100°C for one minute.

B_2: Blanching in 100°C for two minutes.

B_3: Blanching in 100°C for three minutes.

B_4: Blanching in 100°C for four minutes.

B_5: Blanching in 100°C for five minutes.

B_6: Blanching in 100°C for six minutes.

B_7: Blanching in 100°C for seven minutes.

Blanched samples were immediately subjected to cooling by dipping in cold water. Inactivation of POD enzyme is considered as the blanching adequacy because it is considered as the most heat-resistant among plant constitutive enzymes. All the blanched samples were tested for enzyme inactivation and initial standardization was done by enzyme inactivation test. The experiments were done in triplicate immediately after blanching.

3.3.1 Qualitative test for POD.

The blanched tender jackfruit pieces were crushed in a porcelain bowl immediately after blanching. Twenty milli litre distilled water was added to crushed sample (10 to 20 g) which was taken in a test tube. Guaiacol (one per cent) and hydrogen peroxide (0.3%) solutions were then prepared as prescribed by Ranganna (1991). One milli litre guaiacol solution and 1.6 ml hydrogen peroxide solution were poured into the test tube and the contents were thoroughly mixed. A rapid and intensive reddish-brown tissue colouring within five minutes indicated a high POD enzyme activity. The gradual appearance of a weak pink colour indicated an incomplete POD inactivation or low POD activity. If there was no colour development after five minutes, the reaction was negative and the enzymes were considered inactivated (Shivhare *et al.*, 2007.).

3.3.2 Qualitative test for catalase

Approximately two gram blanched tender jackfruit was crushed immediately after blanching and mixed with 20 ml distilled water in a test tube. One per cent hydrogen peroxide solution (0.5 ml) was added after 15 minutes. A strong gas (oxygen) generation for about two – three minutes indicated the presence of catalase, and no release of gas showed the complete inactivation of catalase. (Shivhare *et al.*, 2007.)

Blanched sample was immediately subjected to cooling by dipping in cold water. Based on the enzyme inactivation, most appropriate time - temperature combinations were selected and these combinations were used to standardize the blanching treatment with different blanching preservatives.

3.3.3 Optimization of blanching preservatives

BS_1: Blanching in hot water.

BS_2: Blanching processes in boiling water containing 0.1% KMS.

BS_3: Blanching processes in boiling water containing 0.3% citric acid

BS_4: Blanching processes in boiling water containing 0.3% citric acid + 0.1% KMS

Standardization of blanching of tender 'Koozha' jackfruit was done by considering the factors like enzyme inactivation, colour, texture and crude fiber.

Plate 3.4 Hot water blancher

3.4 Thermal Process Optimization

Thermal processing was done in retort pouches (15 cm × 20 cm). It is a flexible laminated package that can withstand thermal processing temperature. It combines the advantages of both metal cans and plastic packages. This three ply laminate consist of exterior polyester (12.5 μm), middle aluminum foil (12.5 μm) and interior cast polypropylene (75 μm) layer. Physical properties of retort pouch are listed in table 3.1.

Table 3.1 Physical properties of retort pouch

Properties		Values
Thickness (μm)	Total	100
	Polyester	12.5
	Al Foil	12.5
	Cast PP	75
Tensile strength (kg/cm^2)	Machine direction	460
	Cross direction	430
Elongation at break (%)	Machine direction	45
	Cross direction	35
Heat seal strength (kg/cm^2)	Machine direction	390
	Cross direction	380
Bond strength (g /10 mm)		180
Pouch burst strength (psig)		30
OTR (ml/m^2/ 24 h at 1 atm. & at 25°C)		0.35
WVTR (g/m^2/24 h at 37^0C & 90%RH)		0.02
Global migration residue (mg/dm^2) (maximum limit value :10 mg/dm^2)	Water extractives at 121°C for 2h	0.60
	3% Acetic acid extractives at 121°C for 2h	0.25
	n-heptane extractives at 66°C for 2h	1.7

3.4.1 Pouch filling, exhausting and sealing

One hundred and forty gram blanched tender jackfruit pieces and 140 ml brine solution (2%) were filled manually in the retort pouch. After filling the retort pouch with tender jackfruit and syrup solution, the entrapped air was removed by steam flushing method (Plate 3.6). Exhausting steam temperature was around 100°C. Then the pouches were sealed immediately after exhausting. Sealing (125- 135°C) was done by hydraulic sealer (Plate 3.7).

3.4.2 Positioning of thermocouple in retort pouch

One of the pouches was fixed with a thermocouple sensor. The sensor tip was inserted into the tender jackfruit piece for recording core temperatures. Then the remaining pouches were arranged in perforated aluminium trays and loaded into an over - pressure autoclave.

3.4.3 Thermal processing

F value is defined as the time needed to reduce microbial numbers by a multiple of D value and F_0 value is used to describe process that operate at 121.1°C which are based on the micro organism with Z value of 10°C. (Donald and Ricardo, 2007). Pritty *et al.* (2014) optimized the thermal processing for canned 'Varikka' tender jackfruit for both pasteurization and sterilization (Sterilization was done at F_0 = 1 and pasteurization at F = 10). The same F_0 and F values were co opted for this research. Thermal processing was done at boiling water temperature since the pH of jack fruit is below 4.5. Thermal processing was done over - pressure autoclave (John Fraser and Son Ltd, UK) available at the CIFT(Central Institute of Fisheries Technology), Cochin, which possessed a steam generation type operation mode (Plate 3.5). Process times were determined using the cold point method with the help of valsuite software that optimize a suitable combination of time and temperature. The processed pouches (Plate 3.4) were cooled by dipping in cold water to a core temperature of 40°C to prevent the product from being overcooked.

3.4.4 Microbial analysis

Microbial analysis was performed for the quantification and identification of micro organisms. Detection of bacteria, fungus and yeast were done using total plate count method. Enumeration of bacteria, yeast and fungus were done by serial dilution and plating method outlined by Anon. (1967). Nutrient agar was used for bacteria culture and potato dextrose medium was used for fungal and yeast culture. Specific amounts of nutrients were dissolved in 100 ml distilled water for the preparation of culture medium with respect to different micro organisms. pH of the medium was adjusted using 0.1N NaOH and 0.1N HCl.

3.4.4.1 Standard plate count method

This method allowed the growth of microorganism in nutrient culture petri plate and the colonies developed were counted. Ten milli litre (W_S) of tender jackfruit juice was extracted by crushing using sterile pestle and mortar. It was then added to 90 ml of sterile water (10^{-1} dilution) and shaken well for 10 - 15 minutes to assure uniform distribution of microorganisms. One milli litre of this diluted sample was transferred to sterile petri plate with a sterile micro pipette. For the spore count determination in sterilized product, diluted sample was kept in a water bath at 80°C for 10 minutes before transferring to petri plate. Molten and cooled nutrient medium (15 – 20 ml) at 45°C conducive for the growth of the specific organism were added to respective petri plates. The plates were rotated clockwise and anticlock wise for the thorough mixing of dilutent and the medium. Then the petri plates were incubated at 37°C and 55°C for one to two days, for the bacterial growth and spore formation respectively and for three 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 (Ns) for dilution factor (DF) was calculated as given below.

$$Ns = \frac{(Ncfu \times DF)}{Ws} \qquad 3.4$$

3.4.4.2 Commercial sterility test

The thermally processed samples (sterilized samples) were incubated at 37°C for 15 days. One to two gram of the sample was taken aseptically by a sterilized forceps from the incubated cans. It was inoculated into the sterilized fluid thioglycolate broth in test tubes. A layer of sterilized liquid paraffin was applied on to the top of the broth and incubated at 37°C for 48 hours and at 55°C for four days (IS: 2168-1971) for the growth of mesophilic and thermophilic bacterium respectively.

3.4.5 Standardization of time - temperature combination for thermal processing

Microbiologically safe samples (total plate count, bacteria, yeast and mould) were selected for further treatment. Selected samples were used to standardize the thermal processing with different solutions. One hundred and forty pouches with different solutions were processed under two categories: 70 pasteurized pouches and 70 sterilized pouches.

TP1: thermal processing at T_1°C with 0.3% citric acid

TP2: thermal processing at T_1°C with 0.1% KMS

TP3: thermal processing at T_1°C with 2% Brine

TP4: thermal processing at T_1°C with 0.1% KMS + 0.3% citric acid

TP5: thermal processing at T_1°C with 0.1% KMS + 2% Brine

TP6: thermal processing at T_1°C with 0.3% citric + 2% Brine

TP7: thermal processing at T_1°C with 0.1% KMS + 0.3% citric acid+ 2% Brine

TS1: thermal processing at T_2°C with 0.3% citric acid

TS2: thermal processing at T_2°C with 0.1% KMS

TS3: thermal processing at T_2°C with 2% Brine

TS4: thermal processing at T_2°C with 0.1% KMS + 0.3% citric acid

TS5: thermal processing at T_2°C with 0.1% KMS + 2% Brine

TS6: thermal processing at T_2°C with 0.3% citric + 2% Brine

TS7: thermal processing at T_2°C with 0.1% KMS + 2% Brine + 0.3% citric acid

T_1 and T_2 are the temperatures used for pasteurization and sterilization respectively.

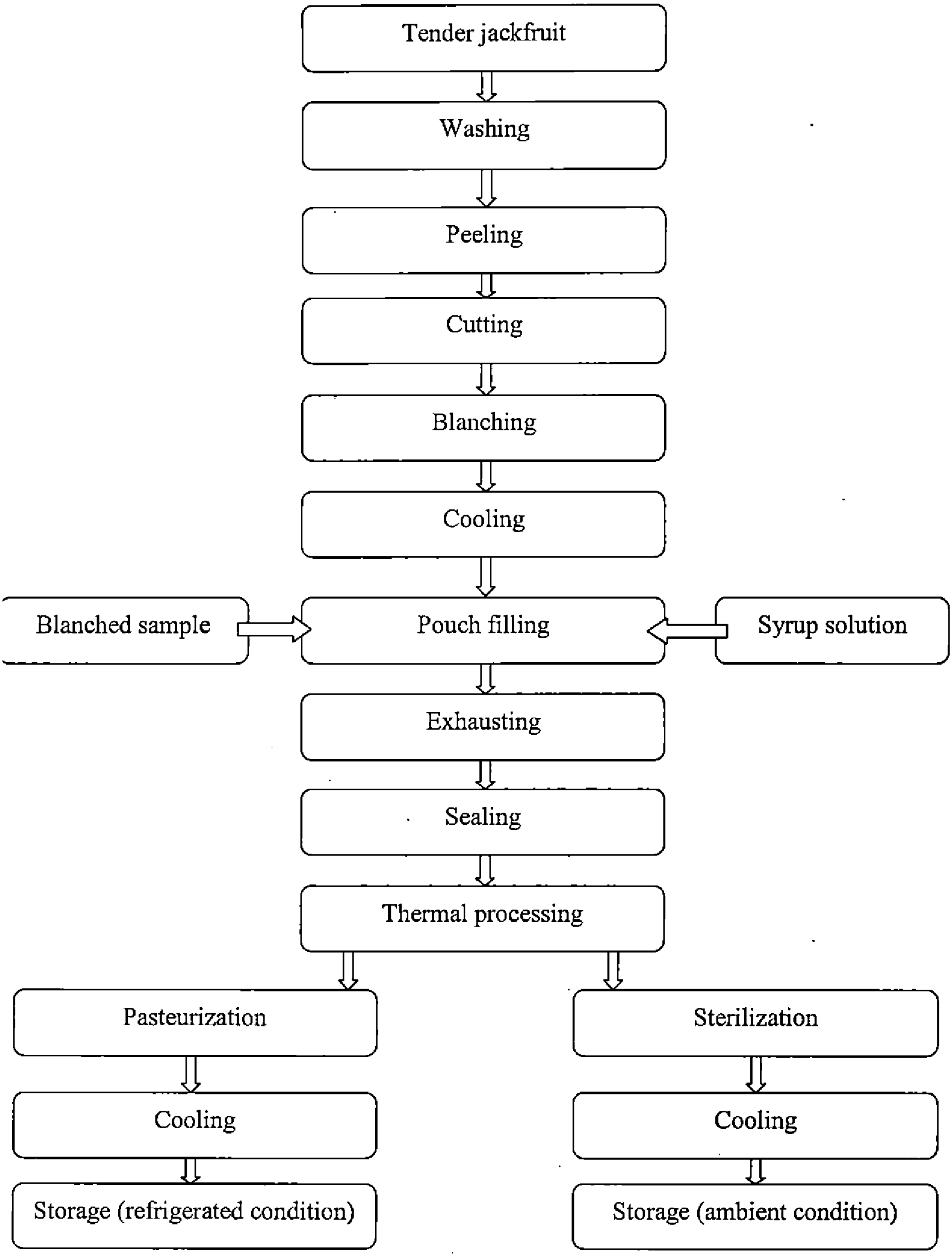


Fig 3.1 Flow chart for thermal processing of retort pouch packaging

3.4.6 Storage studies

The sterilized and pasteurized pouches were stored for three months for the shelf life study. The tender jackfruit samples in sterilized pouches were stored in ambient condition (temperature at 20 - 25°C and relative humidity (RH) at 50-60%) and those samples in pasteurized pouches were stored in refrigerated condition (10°C). The following parameters were tested in every 15 days interval upto two month and final analysis was done after three months of storage.

(1) TSS (2) pH (3) Titrable acidity (4) Vitamin C (5) Crude fibre (6) Colour (7) Texture (8) Microbial analysis (9) Sensory qualities.

3.4.7 Statistical analysis

Standardization of thermal process and optimum preservative concentration for maximum shelf life was determined by post hock tests [(1) TSS (2) pH (3) Titrable acidity (4) Vitamin C (5) Crude fibre (6) Colour (7) Texture (8) Microbial analysis were tested in every 15 days interval upto two month and final analysis was done after three months of storage] following one way analysis of variance (ANOVA). Kendall's coefficient of concordance test was used for assessing the significant agreement among the judges during sensory evaluation using SPSS (Statistical package of social sciences) software. The mean rank scores were taken as the criterion to differentiate the different product as regards their acceptability with regard to four parameters namely colour, flavour, texture and overall acceptability.

3.4.8 Ranking of treatments

To identify the best preservative, the treatments were ranked according the different quality parameters. Treatments with high order ranking were selected to sensory evaluation.

3.4.9 Sensory analysis

Sensory analysis is a scientific approach that analyses and measures human responses to the composition of food, comprising colour, flavour, texture and overall acceptability. It is combination of experimental design and statistical analysis to use the human senses for the purpose of evaluation. Sensory evaluation of tender jack fruit was done by 9 point headonic scale (Ranganna, 1986) by preparing 'jackfruit thoran' out of three month stored tender jackfruit. The 9 points in the headonic scale are

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.

3.4.10 Cost economics

Suitable assumptions and standard procedure was used for the analysis of cost economics. Cost analysis is given in appendix D.

Plate 3.4 Processed tender jackfruit in retort pouches

Plate 3.5 Retort autoclave

Plate 3.6 Exhausting

Plate 3.7 Sealing

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The results of the present study on 'Development and quality evaluation of retort pouch packed tender jackfruit' are presented in this chapter. The results are critically analyzed in comparison with published literature and are discussed briefly.

4.1 Physico - Chemical Characterstics of fresh 'Koozha' tender jackfruit.

The physico – chemical characteristics of fresh 'Koozha' tender jackfruit are presented in Table 4.1. The average values of the chemical components viz., ascorbic acid, crude fibre, pH, titrable acidity and TSS were estimated to be 11.75 mg/100 g, 2.074%, 4.150, 0.200% and 6.010 respectively.

Table 4.1 Physico – chemical characteristics of 'Koozha' tender jackfruit.

Chemical characteristic		
Ascorbic acid (mg/100g)		11.75
Crude fibre (%)		2.074
pH		4.150
Titrable acidity (%)		0.200
TSS(°B)		6.010
Physical characteristics		
Texture	Firmness (N)	74.658
	Toughness (N.sec)	199.388
Colour values	L*	70.313
	a*	0.310
	b*	15.780

The average values of the physical parameters viz., firmness, toughness, L* value, a* value and b* value were found to be 74.658 N, 199.388 N.sec, 70.313, 0.310 and 15.780 respectively.

4.2 Standardization of Blanching Treatment

Optimization of blanching treatment has been carried out in two stages. In the first stage the blanching time was optimized and subsequently based on the optimum blanching time the best blanching preservative was identified.

4.2.1 Optimization of blanching time

The enzymes namely POD and catalase are very crucial with regard to the shelf life is concerned. The presence of these enzymes will reduce the shelf life of processed products. So the initial task was to ensure the absence of these two enzymes after blanching process. During the initial screening process with a trial run of the blanching treatment each replicated thrice at a standardized temperature of 100°C, presence of the above mentioned enzymes were detected during the one minute and two minutes process (B_1 and B_2 respectively). It was not detected during further treatments. So it was concluded that at least three minutes blanching was necessary. The status of enzyme inactivation for each treatment is listed in Table 4.2.

Table 4.2 Status of enzyme inactivation

Treatment	Time of processing at 100°C	Status of enzyme inactivation
B_1	1 min	✓
B_2	2 min	✓
B_3	3 min	×
B_4	4 min	×
B_5	5 min	×
B_6	6 min	×
B_7	7 min	×

✓ : Presence of enzyme identified, × : Absence of enzyme identified

Thus the experiment was further carried out with blanching timing starting from three minutes and extending up to seven minutes, each blanching time at a one minute interval being regarded as treatments. Thus a three replication trial with five blanching timings along with an absolute control was carried out in the department lab. The results of the trial based on the six parameters of observation firmness, toughness, L* value, a* value, b* value and crude fibre are presented in Table 4.3.

Table 4.3 Effect of blanching time on texture, colour and crude fibre of samples

Treatment	Firmness (N)	Toughness (N.sec)	L*	a*	b*	Crude fibre (%)
Control	74.658^{a}	199.388^{a}	70.313^{a}	0.310^{a}	15.780^{a}	2.074^{b}
B_3	61.330^{b}	174.722^{b}	66.520^{b}	0.520^{b}	14.720^{b}	2.217^{a}
B_4	53.330^{c}	166.722^{c}	65.800^{c}	0.630^{c}	13.320^{c}	2.217^{a}
B_5	48.500^{d}	162.388^{d}	63.740^{d}	0.730^{d}	11.250^{d}	2.217^{a}
B_6	45.437^{e}	153.388^{e}	61.740^{e}	1.250^{e}	10.220^{e}	2.214^{a}
B_7	42.770^{e}	136.722^{f}	60.330^{f}	1.280^{f}	8.850^{f}	2.214^{a}

The texture of the samples were analyzed by two factors (firmness (N) and toughness (N.sec)) using texture analyzer. It could be observed that firmness and toughness decreased with increasing processing time. Similar observations were made by Pritty and Sudheer, (2012) with the experiment using 'Varikka' variety of tender jackfruit. A minimum reduction in firmness (18%) and toughness (13%) was observed in three minutes blanching process. However the maximum reduction in firmness (43%) and toughness (32%) was found in seven minutes blanched samples. The initial loss of firmness may due to loss of turgor due to membrane disruption (Greve *et al.,* 1994). Important additional softening occurs partly as a result of solubilization and depolymerization of pectic polymers that are involved in cell - cell adhesion (Van, 1979; Greve *et al.,* 1994; Waldron *et al.,* 1997). All the treatments were significantly different at one per cent significant level. The effect of blanching time on firmness and toughness are depicted in Fig 4.1 and 4.2 respectively.

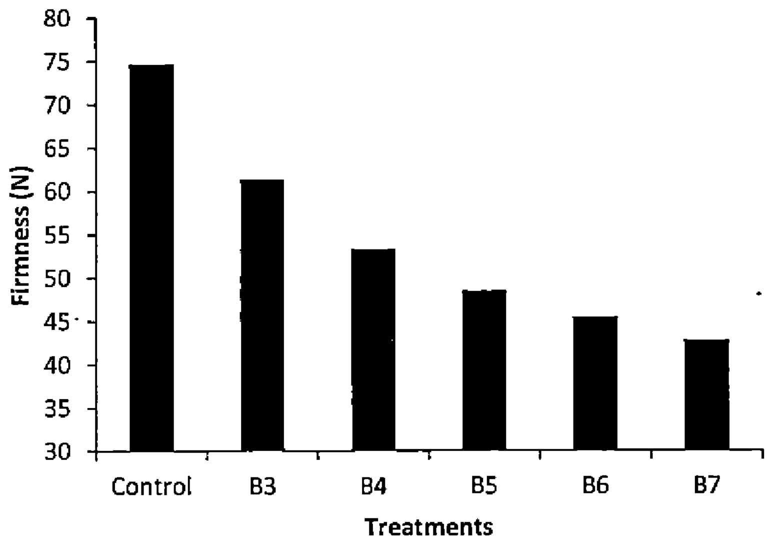


Fig. 4.1 Effect of blanching time on firmness of blanched tender jackfruit

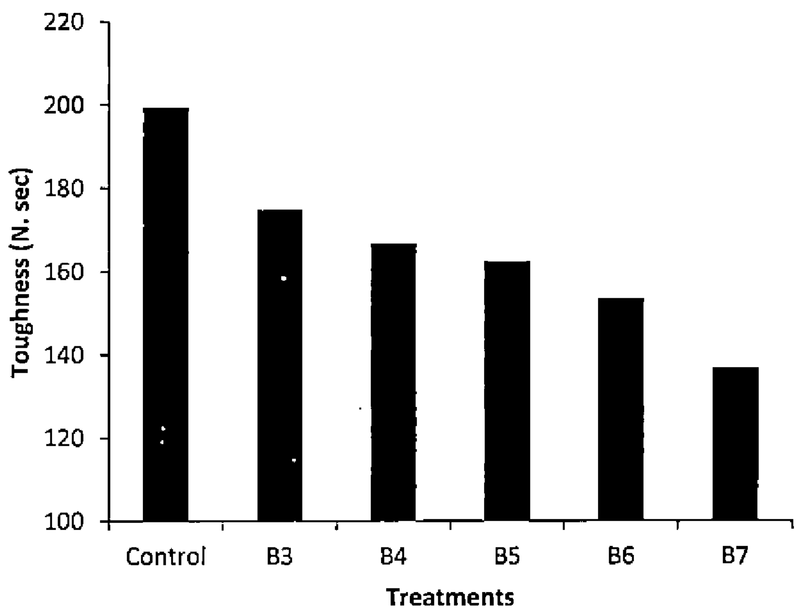


Fig.4.2 Effect of blanching time on toughness of blanched tender jackfruit

Colour analysis was done by analyzing the L*, a*and b* values. The average values of L*, a*and b* of control sample were 70.31, 0.31 and 15.78 respectively. L* and b* values were showed decreasing trend with increasing process time (Fig. 4.3). But a* values showed increasing trend with process time. The three minutes blanched sample retained more colour compared with seven minutes blanched sample. This agrees well with the earlier study on optimization of blanching treatment for 'Varikka' variety tender jackfruit by Pritty and Sudheer, (2012). Amit *et al.* (2012) also observed that blanching of irish york cabbage caused a significant reduction in colour values. Change in colour values may due to the breakdown of starch into dextrin and reducing sugar by heating (Su *et al.*, 2013).

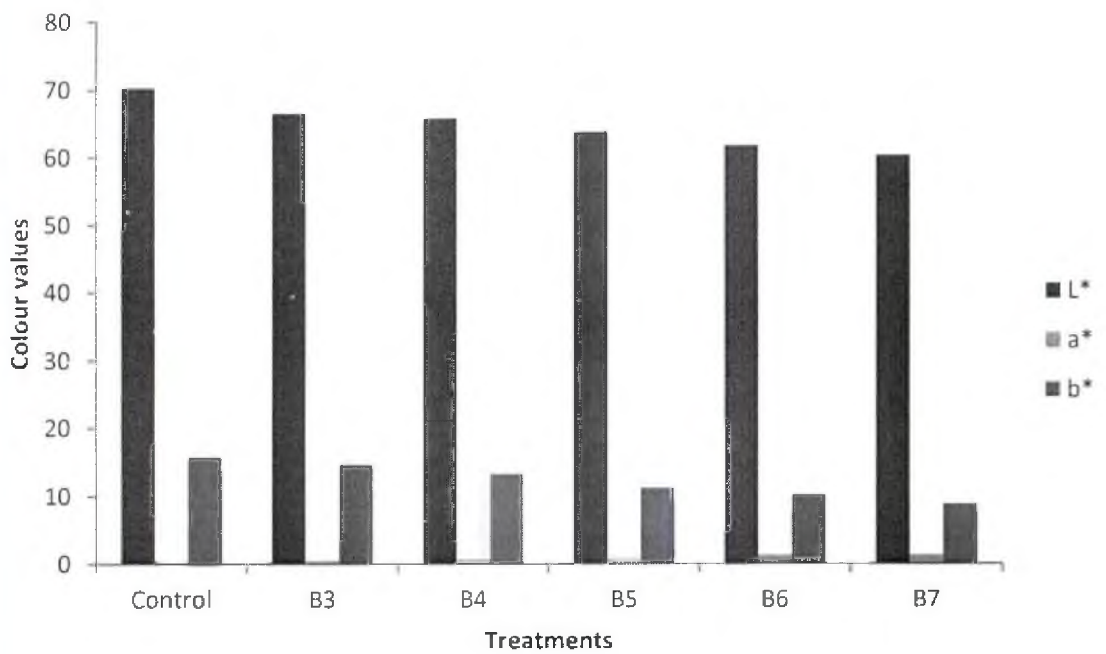


Fig. 4.3 Effect of blanching time on colour of blanched tender jackfruit

Crude fibre content of control sample was 2.074%. The results revealed that there is no significant effect on crude fibre content with the increase in blanching process (Table 4.3). Similar findings were reported by Joy *et al.*, (2007) on fibre content during the processing, storage and cooking of fruits and vegetables.

Table 4.4 ANOVA table for blanching time optimization

Quality attributes	Source of variation	SS	df	MS	F- value	Prob.
Firmness	Between groups	2130.747	5	426.149	463.187	0.0001
	With in groups	11.040	12	0.920		
	total	2141.787	17			
Toughness	Between groups	6655.398	5	1331.080	1989.476	0.0001
	With in groups	8.029	12	0.669		
	total	6663.427	17			
L* (black - white)	Between groups	194.362	5	38.872	699644.32	0.0001
	With in groups	0.001	12	0.000		
	total	194.363	17			
a* (green - red)	Between groups	2.344	5	0.469	12056.594	0.0001
	With in groups	0.000	12	0.000		
	total	2.345	17			
b*(blue - yellow)	Between groups	109.207	5	21.841	982815.77	0.0001
	With in groups	0.000	12	0.000		
	total	109.207	17			
Crude fibre	Between groups	0.050	5	0.010	3550.738	0.0001
	With in groups	0.000	12	0.000		
	total	0.050				

To identify the best treatment a scoring of the treatments for each parameter was done based on the subgroups that were identified using DMRT (Duncan's multiple range test) (Table 4.4). The scores for each treatment parameter wise and the total score are presented in table 4.5. The sum total of score for each treatment was calculated for identification of the most suitable treatment that retained all the characteristics of the product as close as the untreated tender jackfruit (control). The three minutes blanching time was identified as the most optimal time, based on the total rank score and the same was selected for further experiment.

Table 4.5 Ranking of the treatments for blanching time optimization

Treatment	Firmness	Toughness	L*	a*	b*	Crude fibre	Total rank
Control	1	1	1	1	1	6	11
T_1 (3 min)	2	2	2	2	2	3	13
T_2 (4 min)	3	3	3	3	3	3	18
T_3 (5 min)	4	4	4	4	4	3	23
T_4 (6 min)	5.5	5	5	5	5	3	28.5
T_5 (7 min)	5.5	6	6	6	6	3	32.5

4.2.2 Optimization of blanching treatment

At a default of three minutes blanching time at 100°C four blanching treatments namely blanching in boiling water (BS_1), blanching in boiling water containing 0.3% citric acid (BS_2), blanching in boiling water containing 0.1% KMS (BS_3) and blanching in boiling water containing 0.3% citric acid + 0.1% KMS (BS_4) with the untreated tender jack fruit control was carried out in the department lab. The parameters of observation were texture (firmness, toughness), colour (L*, a*, b*) and crude fibre in a CRD with three replication. The results of the statistical analysis are presented in Table 4.6.

Table 4.6 Effect of blanching treatment on texture, colour and crude fibre content

Treatment	Firmness	Toughness	L*	a*	b*	Crude fibre
control	64.790[a]	182.100[a]	69.450[d]	-0.560[b]	13.930[b]	2.040[b]
BS_1	51.650[b]	142.870[b]	65.440[e]	-0.310[a]	10.456[e]	2.210[a]
BS_2	53.590[b]	142.310[b]	70.530[c]	-0.630[c]	14.720[a]	2.220[a]
BS_3	52.860[b]	143.070[b]	71.650[b]	-0.730[d]	11.240[c]	2.220[a]
BS_4	52.020[b]	143.950[b]	71.960[a]	-1.230[e]	10.850[d]	2.210[a]

The effect of different preservatives used in blanching on texture in terms of firmness and toughness of the blanched samples are shown in Fig. 4.4 and Fig 4.5 respectively. The firmness values for the treatment BS_1, BS_2, BS_3 and BS_4 were 51.650, 53.590, 52.860 and 52.020 N. The results of ANOVA analysis (Table 4.5) revealed that there is no significant effect on firmness and toughness with the different preservatives. Similar observation in tender 'Varikka' jackfruit was reported by Pritty and Sudheer, (2012) during standardization of blanching process.

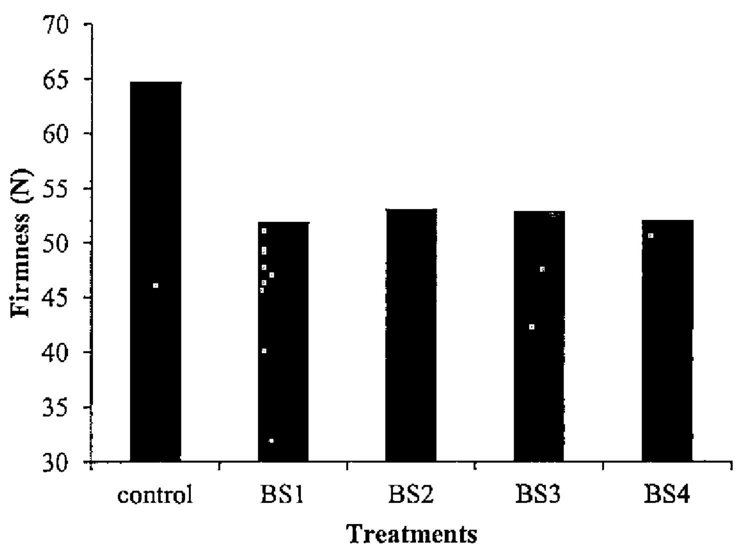


Fig. 4.4 Effect of preservatives on firmness of blanched tender jackfruit.

Crude fibre content of control sample was 2.040%. The results revealed that there is no significant effect on crude fibre content with the different blanching preservatives. Similar observation was noted by Pritty *et al.*, (2014) during canning of tender 'Varikka' jackfruit with different preservatives as filling solution.

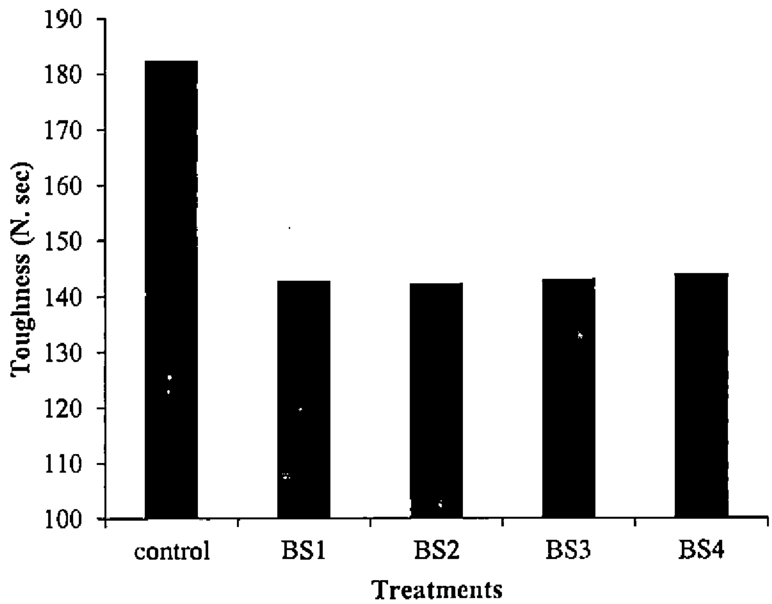


Fig. 4.5 Effect of preservatives on toughness of blanched tender jackfruit.

Effects of preservatives on colour of blanched samples are presented in Fig.4.6. There was significant variations in colour values. L* value showed increasing trend with preservatives whereas a* value showed decreasing trend. The gain in green colour (decrease in 'a' value) 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. This agrees well with the earlier study on optimization of blanching preservatives for 'Varikka' tender jackfruit by Pritty and Sudheer, (2012). Colour values of BS_2 came close with the colour values of control sample.

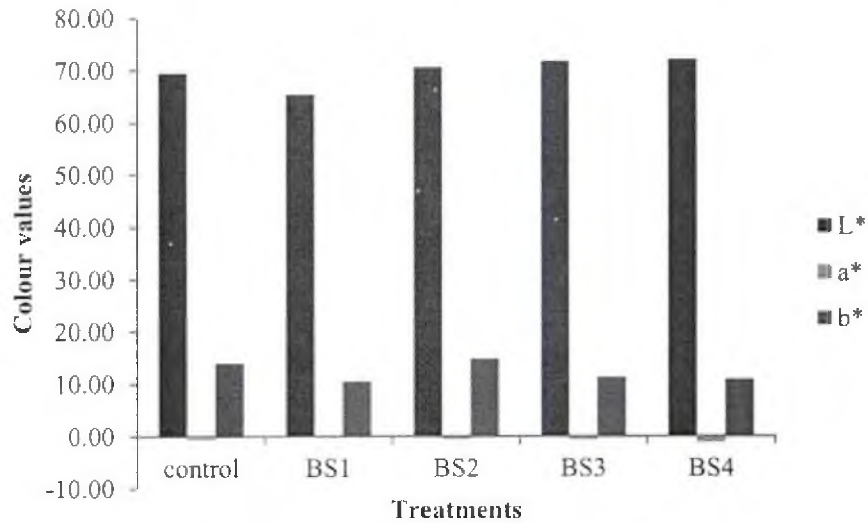


Fig. 4.6 Effect of preservatives on colour values of blanched tender jackfruit.

Table 4.5 ANOVA table for blanching treatment

Quality attributes	Source of variation	SS	df	MS	F- value	Prob.
Firmness	Between groups	367.567	4	91.892	138.381	0.0001
	With in groups	6.640	10	0.664		
	total	374.208	14			
Toughness	Between groups	3658.609	4	914.652	168.968	0.0001
	With in groups	54.132	10	5.413		
	total	3712.741	14			
Crude fibre	Between groups	0.077	4	0.019	699644.32	0.0001
	With in groups	0.000	10	0.000		
	total	194.363	14			
L* (black - white)	Between groups	83.179	4	20.795	259955.18	0.0001
	With in groups	0.001	10	0.000		

	total	83.180	14			
a* (green - red)	Between groups	1.376	4	0.344	25794.550	0.0001
	With in groups	0.000	10	0.000		
	total	1.376	14			
b*(blue - yellow)	Between groups	45.438	4	11.359	189332.09	0.0001
	With in groups	0.001	10	0.000		
	total	45.439	14			

The sum of total score of each treatment was calculated for the identification of most suitable treatment that retained all the characteristics of the product as similar to the untreated tender jackfruit. Ranking of different treatments are given in Table 4.7.

Table 4.7 Ranking of the treatment for blanching preservative optimization

Treatment	Firmness	Toughness	L*	a*	b*	Crude fibre	Total rank
Control	1	1	1	1	1	5	10
BS1	3.5	3.5	5	3.5	4.5	2.5	22.5
BS2	3.5	3.5	2	2	2	2.5	15.5
BS3	3.5	3.5	3.5	3.5	3	2.5	19.5
BS4	3.5	3.5	3.5	5	4.5	2.5	22.5

From the table, blanching in boiling water containing 0.3% citric acid treatment had a total rank score of 15.5 and was identified as the best blanching treatment in terms of textural properties, colour attributes and crude fibre content. Citric acid is a natural preservative. By the usage of this natural preservative, it is possible to avoid the harmful effect of KMS (Nair and Elmore, 2003).

4.2 Optimization of Thermal Processing

4.2.1 Optimization of thermal processing time temperature combination

In the present investigation, the pasteurization and sterilization temperature were 90°C and 121°C respectively (Pritty *et al.*, 2013). Time required to reach F = 10 and F_0 = 1 for pasteurization and sterilization respectively were calculated as mentioned in section 3.4.4 relates with microbial analysis. From the heat penetration curves given in Fig. 4.7 and 4.8 it was found that time taken by pasteurization at 90°C, to reach the F value 10 was 24 minutes and by sterilization at 121°C for attaining F_0 value one was 15 minutes. The microbial load of any processed substance is of utmost importance as it is the most decisive parameter for co opting a technology towards processing. Pasteurization and sterilization were further assessed for the presence of any micro organism. Table 4.8 revealed no contamination with any form of microorganism when processed as detailed above and were ajudged as the best treatments respectively in both the cases.

Table 4.8 Microbial analysis of thermally processed tender jackfruit.

Treatment	Microbial load (10^1 cfu g^{-1})					
	Bacteria		Fungus	Yeast	Spore count	
	55°C	37°C			55°C	37°C
Pasteurized sample (90°C)	0	0	0	0	......	.....
Sterilized sample (121.1°C)	0	0	0	0	0	0

To identify the best filling solution, further experimentation was carried out with default standardized blanching temperatures using seven filling solutions namely

0.3% citric acid, 0.1% KMS, 2% Brine, 0.1% KMS + 0.3% citric acid, 0.1% KMS + 2% Brine, 0.3% citric + 2% Brine and 0.1% KMS+ 2% Brine+ 0.3% citric acid.

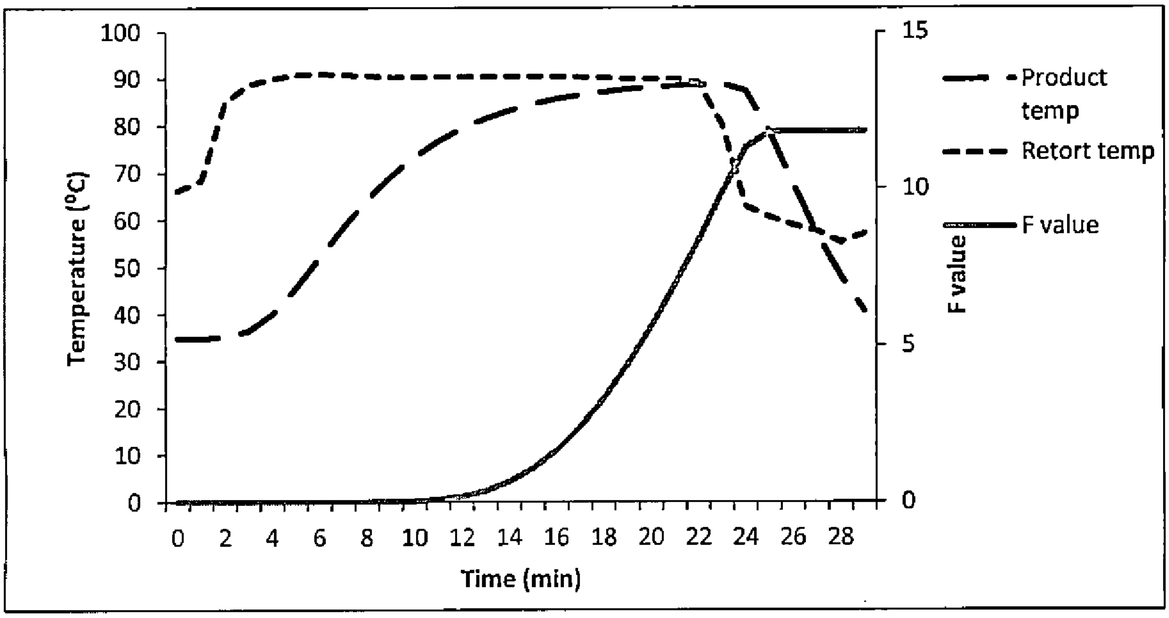


Fig 4.7 Heat penetration characteristic for pasteurization

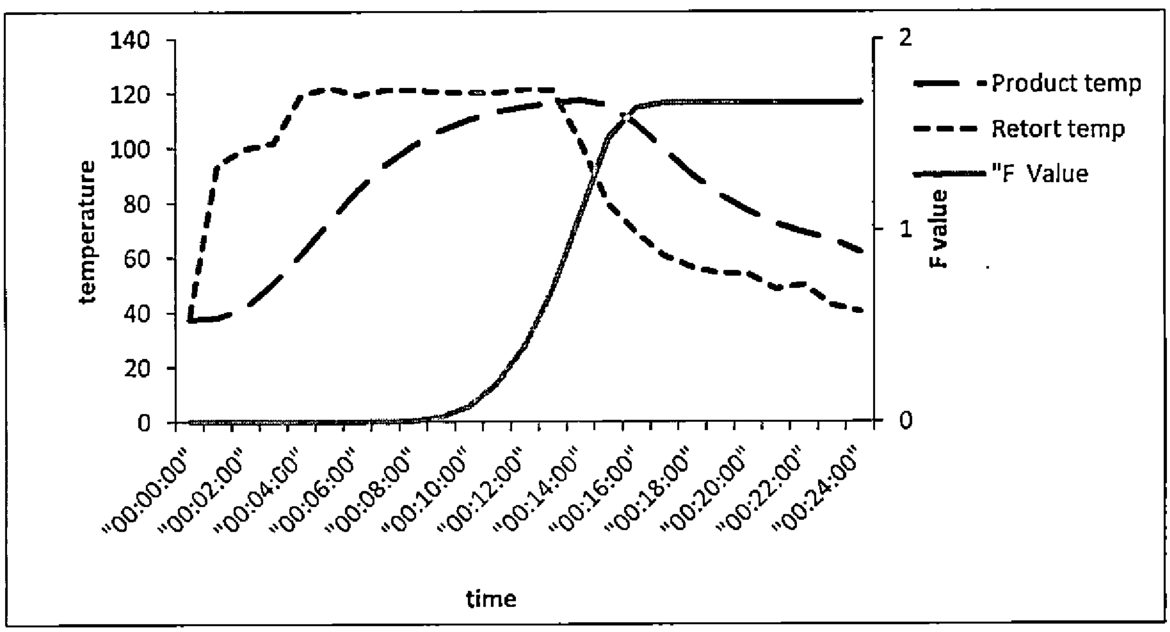


Fig 4.8 Heat penetration characteristics of sterilization

The experiment was carried out in the laboratory attached to the processing department with seven filling solutions as CRD with three replications. The results of the experiment are presented and discussed in the order of the pasteurization processes followed by sterilization. The study will be complete only if variations in the parameters observed on storage of the processed product for three months with the major parameters under observation as TSS, titrable acidity, pH, firmness, toughness, crude fibre and colour parameters such as L* value, a* value and b* value. Pasteurized and sterilized tender jackfruit after three months of storage shown in Plate 4.1 and Plate 4.2.

4.2.2 Optimization of preservatives (filling solution) in thermal processing

4.2.2.1 Effect of preservatives and storage period on TSS content

a) Effect of preservatives and storage period on TSS content of pasteurized sample.

TSS was found to be maximum in TP3 (4.64°B) and was found to be significantly the highest in all stages of observation starting from the first day of processing and continuing the observations at 15 days, 30 days , 45 days, 60 days and 90 days . The results of TSS obtained were statistically analyzed and listed in Table C1 of Appendix C. The minimum TSS was noticed in the case of TP5 (3.81°B) at all stages of observation. The chronology of the treatments with respect to the TSS content in a decreasing order was T3, T6, T1, T2, T4, T7 and T5. This pattern was conspicuous at all stages of observation. With regard to the variations in TSS content over the days of storage, only marginal changes were noticed, and this can be readily read from Fig. 4.9. The maximum percentage increase in total soluble solid was noted in TP1 (1.43%) and minimum in TP4 (0.71%) during the three months storage. Similar gradual increase in TSS noticed during the storage of canned tender 'Varikka' jackfruit by Pritty *et al.* (2014). Dinesh *et al.* (2014) also observed the TSS (°B) of litchi fruits increased with the storage period. According Salunkha *et al.* (1974), the increment of total soluble solids is caused by the biosynthesis processes or degradation of polysaccharides during storage.

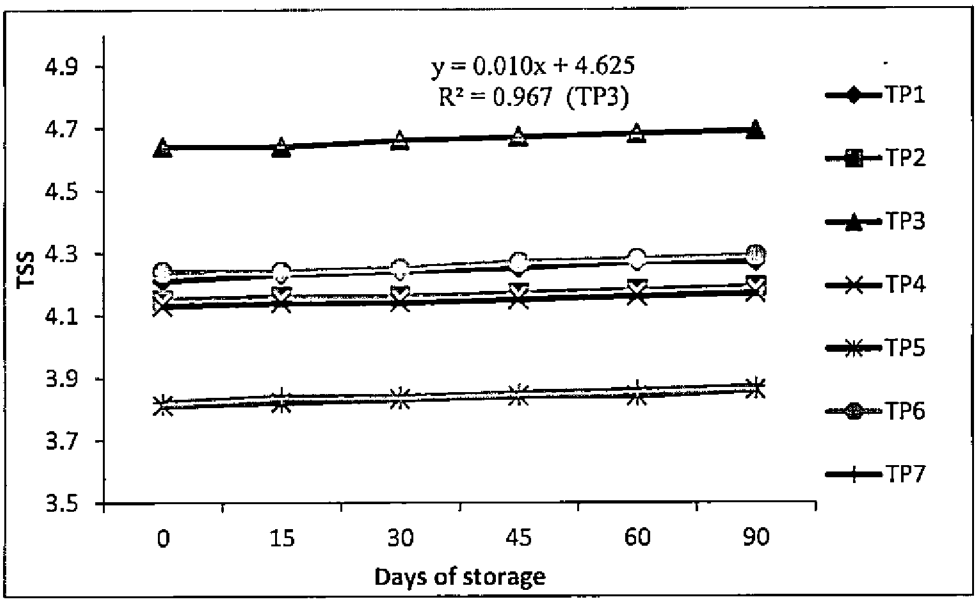


Fig 4.9 Effect of storage period and preservative on TSS of pasteurized samples

b) Effect of preservatives and storage period on TSS content of sterilized samples.

The TSS was found to be maximum for TS2 (4.55°B) and minimum for TS1 (4.14°B). With respect to TS2, the effect of TS2 was significantly superior to the effect of all other treatments though a slight increase in TSS was noticed over the subsequent period of storage. Similar gradual increment was noted during storage of canned and sterilized tender 'Varikka' jackfruit by Pritty *et al.,* (2014). Biosynthesis processes or degradation of polysaccharides during storage could be the reason for increment of total soluble solid. The rank order of the treatments in terms of their effects was TS2, TS3, TS4, TS6, TS7, TS5 and TS1. The mean values of TSS increased from 4.26 to 4.31°B and the minimum percentage increase was noticed in TS2. The nature of variation in TSS of retort packed tender jackfruit during the three months of storage is shown in the Fig.4.10 and Table C2 of Appendix C.

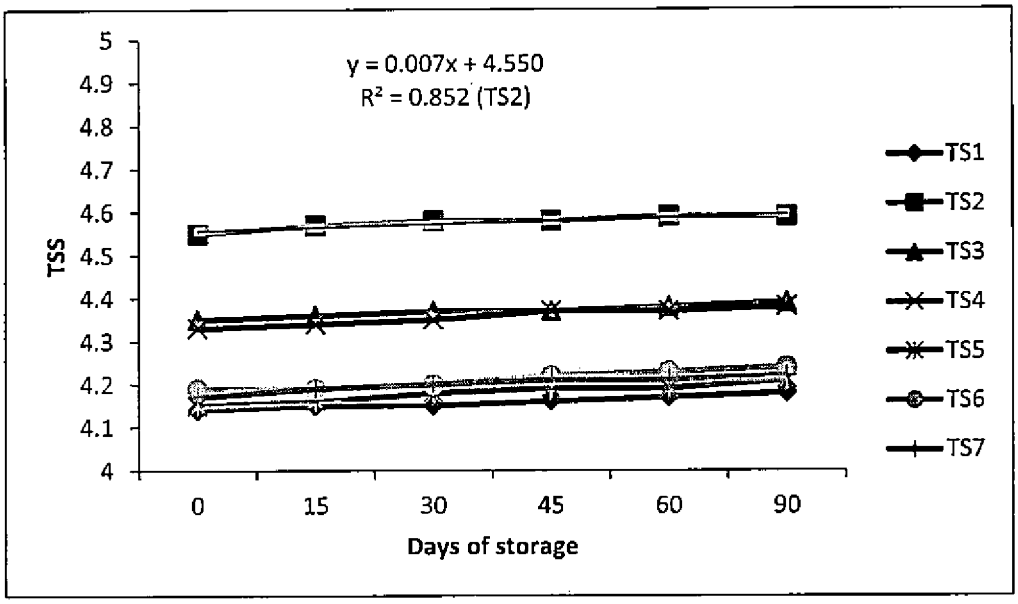


Fig.4.10. Effect of storage period and preservatives on TSS of sterilized samples

4.2.2.2 Effect of preservatives and storage period on firmness

a) Effect of preservatives and storage period on firmness of pasteurized and retort packed tender jackfruit.

Firmness of fresh sample was 76.21 N. Citric acid treatment (TP1) was found to be the best and significantly superior at all stages of observation. A gradual decrease in firmness was noticed over the periods of storage with more or less the same quantum of decrease for all the treatments, the decreased order of treatments being T1, T2, T4, T7, T6, T5 and T3. The gradual decrease in firmness of all the treatments in depicted in Fig. 4.11. The results obtained were statistically analyzed and listed in Table C3 of Appendix C. A similar gradual decrease in firmness during storage of pasteurized and canned tender 'Varikka' jackfruit was reported by Pritty *et al.* (2013). Minimum percentage reduction in texture was found in treatment with citric acid preservative and maximum variation was observed in brine processed treatment (TP3). The mean firmness value decreased from 37.68 to 33.044 N during three months of storage. Thermal processes result in softening of vegetables. The initial loss of firmness is related with loss of turgor due to membrane disruption (Greve *et al.*, 1994). Important additional softening occurs partly as a result of solubilization and depolymerization of pectic polymers that are involved in cell - cell adhesion (Van, 1979; Greve *et al.*, 1994; Waldron *et al.*, 1997).

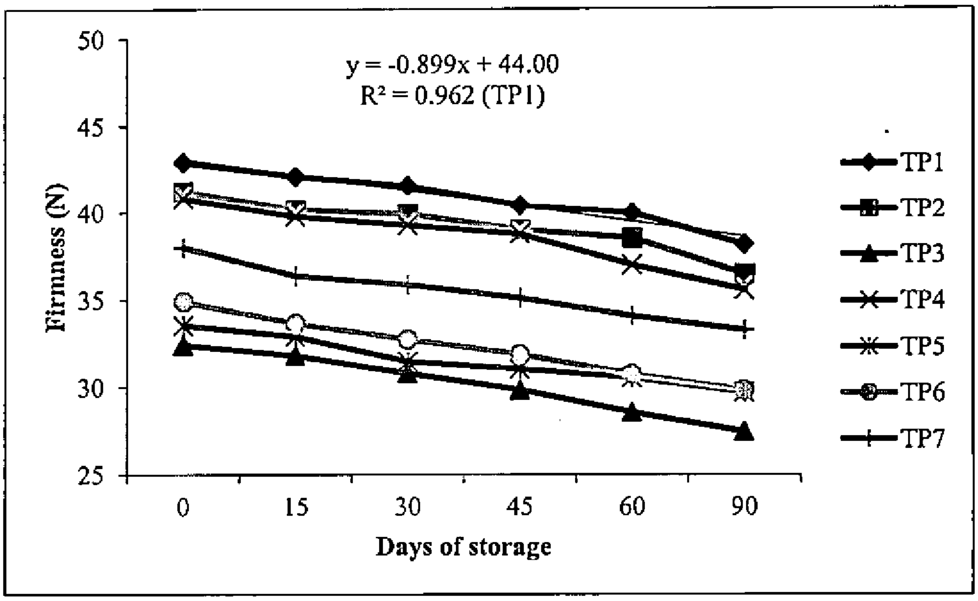


Fig.4.11 Effect of storage period and preservatives on firmness of pasteurized samples

b) Effect of preservatives and storage period on firmness of sterilized and retort packed tender jackfruit.

The firmness of retort packed tender jackfruit was found to be decreasing during the storage period and is presented in Fig.4.12 and Table C4 of Appendix C. The firmness was found to be maximum with respect to TS1 and the effect of the treatment TS2 and TS4 were on par with TS1 initially. The effect of TS3 on firmness was found to be minimum. The gradual ordering of the treatments was TS1, TS2, TS7, TS4, TS6, TS5 and TS3. Minimum percentage reduction in firmness was found in citric acid treatment and maximum variation was observed in brine processed treatment. Mean firmness value decreased from 6.02 to 2.11 N during the three months storage period. Thermal processes result in softening of vegetables. This agrees well with finding of firmness during the storage of canned and sterilized tender 'Varikka' jackfruit by Pritty *et al.* (2014).

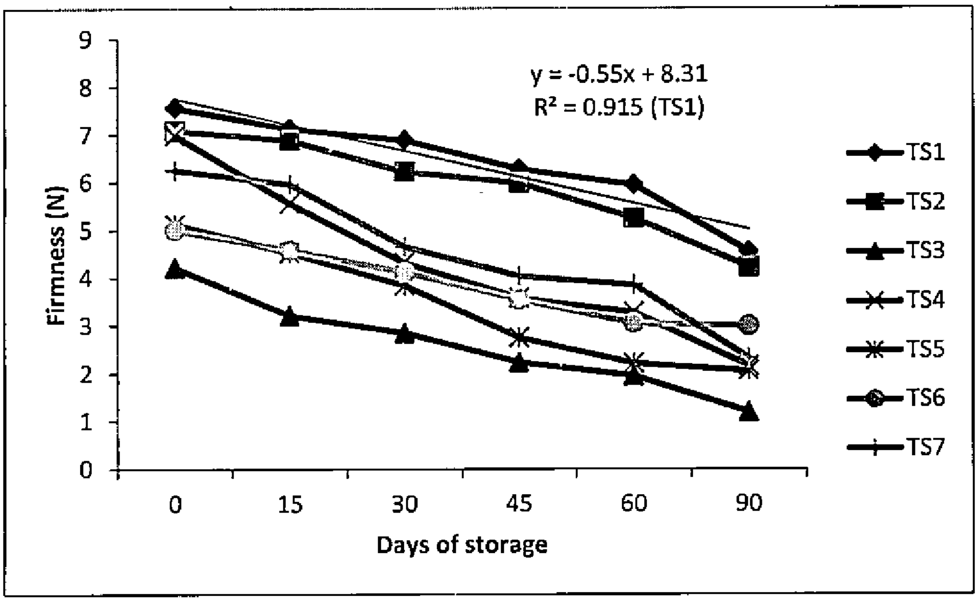


Fig.4.12 Effect of storage period and preservatives on firmness of sterilized sample

4.2.2.3 Effect of preservatives and storage period on toughness

a) Effect of preservatives and storage period on toughness of pasteurized and retort packed tender jackfruit.

A gradual decrease in toughness of tender jackfruit under all the treatments was noticed for all the days of storage. The pattern of toughness of jackfruit under the seven treatments was in the order TP1 > TP4 > TP2 > TP7 > TP6 > TP5 > TP3. The decrease as also the relational positioning of all treatments is explicitly noticeable in Fig. 4.12 and Table C5 of Appendix C. Significant variation due to the effect of different preservative treatments was observed. The maximum percentage.reduction in toughness was noticed in TP3 (14.58%) and minimum in TP2 (9.45%) treatment. The mean value of toughness decreased from 129.87 to 115.51 N.sec. i.e. 11% reduction in mean value of toughness was noticed. Thermal processing may cause textural degradation. This agrees well with the result of earlier study on optimization of canning process for tender 'Varikka' jackfruit by Pritty *et al.* (2014).

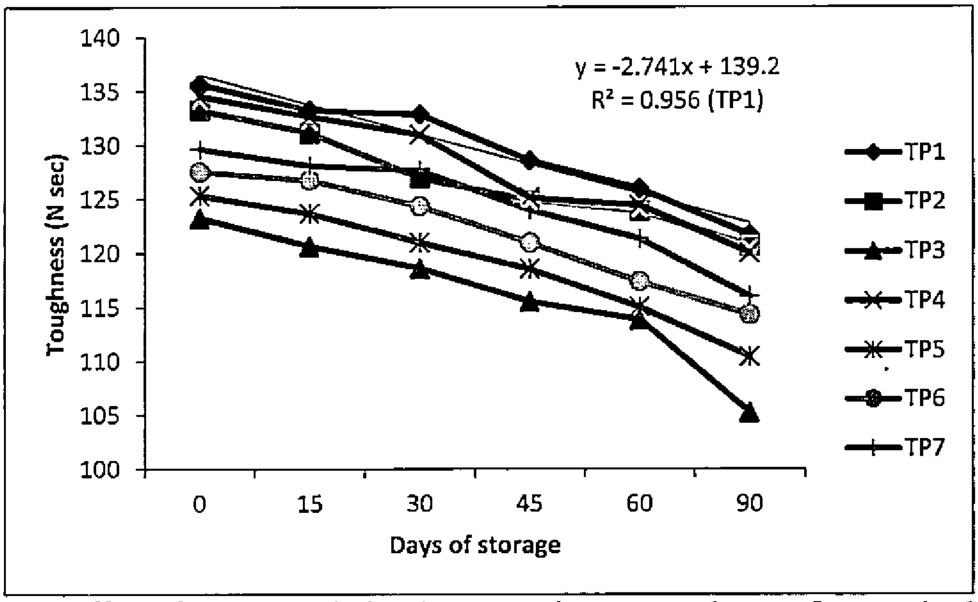


Fig. 4.12 Effect of storage period and preservatives on toughness of pasteurized samples

b) Effect of preservatives and storage period on toughness of sterilized and retort packed tender jackfruit.

The toughness of thermally processed retort packed tender jackfruit obtained using different preservatives is given in Fig. 4.13. Toughness was found to be decreasing as the storage period increased and the mean value reduced from 11.46 N.sec to 5.33 N. sec during the three months storage period. The results obtained were statistically analyzed and listed in Table C6 of Appendix C. Significant variation due to the effect of different preservative treatments was observed. The maximum percentage reduction in toughness was noticed in TS3 and minimum in TS1. Similar observation was noticed in earlier study on storage of canned and sterilized tender 'Varikka' jackfruit by Pritty *et al.* (2014).

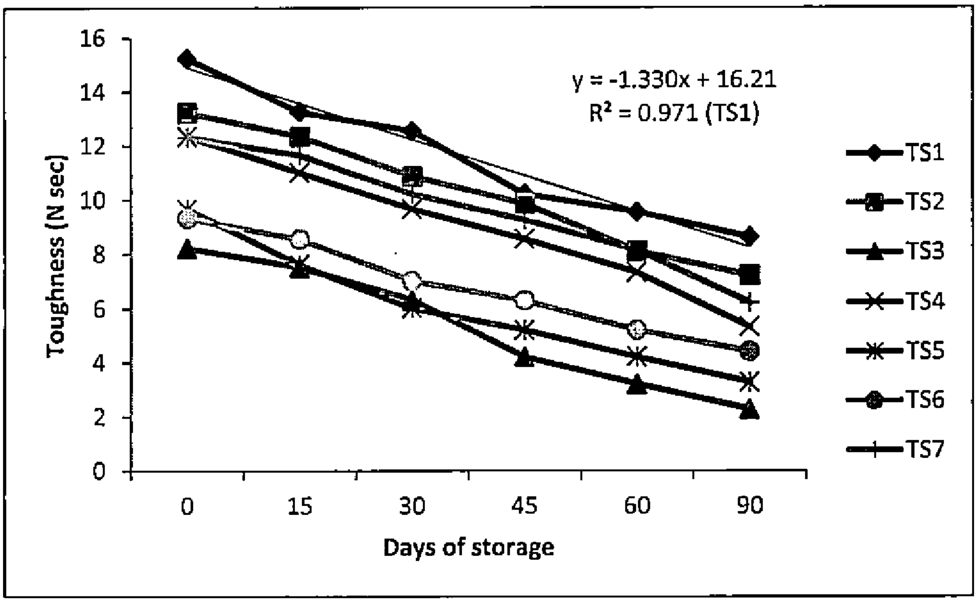


Fig.4.13 Effect of storage period and preservatives on toughness of sterilized samples

4.2.2.4 Effect of preservatives and storage period on titrable acidity

a) Effect of preservatives and storage period on titrable acidity of pasteurized and retort packed tender jackfruit.

Titrable acidity was found to be maximum in TP1 (0.96) and was significantly superior and the best. The minimum titrable acidity was noticed in TP2, TP3 and TP5. The treatments TP2, TP3 and TP5 as also TP4, TP6 and TP7 formed the subgroups and sub grouping was non overlapping except that in 30 and 45 days of storage. With regard to titrable acidity the turning point for a decreased change was only at the 30 th day after storage except for TP5 which did not show any change in titrable acidity throughout the period of observation. When titrable acidity is relatively higher the decreased variations are noticed at the 30th day of storage. The graphical representation of such a turning point is plateau (Fig.4.14). Minimum percentage reduction in titrable acidity was noticed in TP1 and maximum reductions were observed in TP2, TP3 and TP5. The results of statistical analysis are given in Table C7 of Appendix C. In case of pasteurized jackfruit samples which were preserved in citric acid or combination of citric acid with other preservatives, initial values of titrable acidity was comparatively higher than that of treatments without citric acid. The decay in the titrable acidity values may be due to hydrolysis of polysaccharides and non-reducing sugars to hexose sugars as reported by Dev *et al.* (2006) in storage study of onion rings.

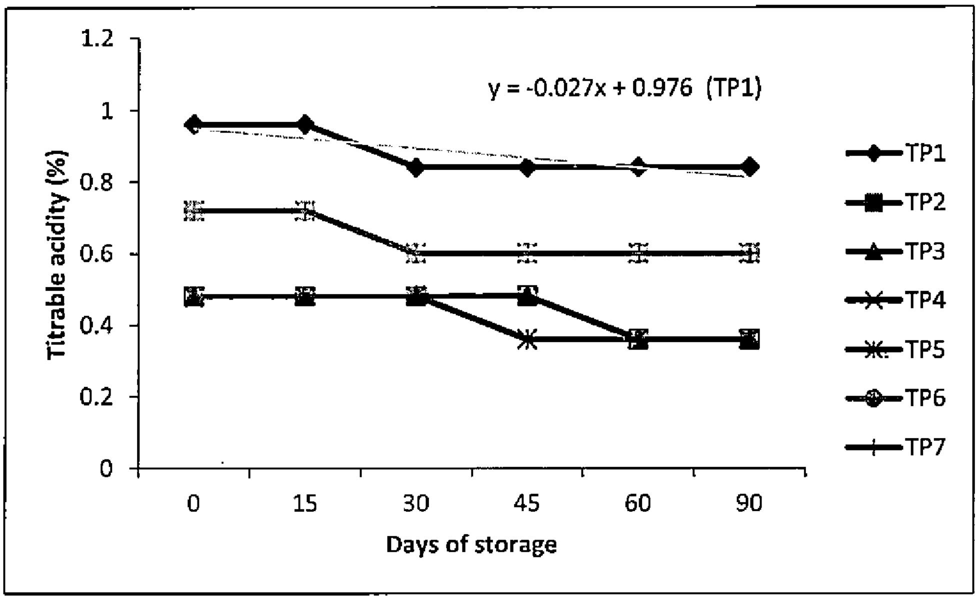


Fig.4.14 Effect of storage period and preservatives on titrable acidity of pasteurized samples

b) Effect of preservatives and storage period on titrable acidity of sterilized and retort packed tender jackfruit.

The titrable acidity ranged among three values only as 0.48, 0.72 and 0.84 upto the 30th day of storage with the maximum noticeable in TS1, TS4, TS6 and TS7 and minimum noticeable in TS2, TS3 and TS5. Subsequently there was a slight fall in titrable acidity. More or less the same subsets of treatment were noticeable through the period of study. The reason for this decay of titrable acidity could be same as that of pasteurization. The titrable acidity of thermally processed retort packed tender jackfruit obtained for different treatments is shown in Fig.4.15 and Table C8 of Appendix C.

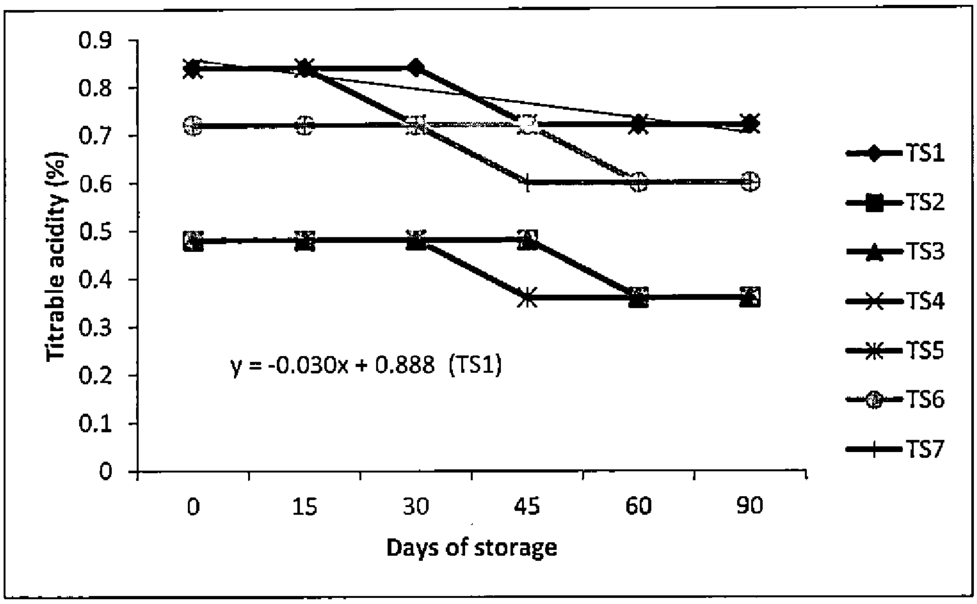


Fig.4.15 Effect of storage period and preservatives on titrable acidity of sterilized samples.

4.2.2.5 Effect of preservatives and storage period on vitamin C

a) Effect of preservatives and storage period on vitamin C of pasteurized and retort packed tender jackfruit.

The maximum vitamin C was noticeable in the case of TP2 (10.87 mg/100 g) and the vitamin C of tender jackfruit under the treatments TP4 and TP7 were on par with that of TP2 Subsequently on storage the decreased order of vitamin C content was read with respect to the treatments TP2, TP4, TP7, TP6, TP1, TP5 and TP3. Though there is an ordering the decrease in vitamin C content was only with respect to the decimal places. The nature of variation in ascorbic acid of retort packed tender jackfruit during three months of storage is shown in the Fig. 4.16 and Table C9 of Appendix C. The mean value of ascorbic acid slightly decreased from 9.98 to 9.79. Minimum percentage reduction in vitamin C during storage period was found in treatment with KMS, because of its better anti - oxidant capacity (Dev *et al.*, 2006) and maximum percentage reduction in vitamin C was found in brine processed treatment. Loss of vitamin C increases with time and temperature of processing. This agrees well with the earlier study on effect of thermal treatment on ascorbic acid content of pomegranate juice by Ranu and Uma (2011). According to Lee and Kader (2000), degradation of ascorbic acid primarily involves oxidation to dehydroascorbic acid, followed by hydrolysis to 2,3 - diketogulonic acid and further oxidation, dehydration and polymerization, forming a wide array of nutritionally inactive products.

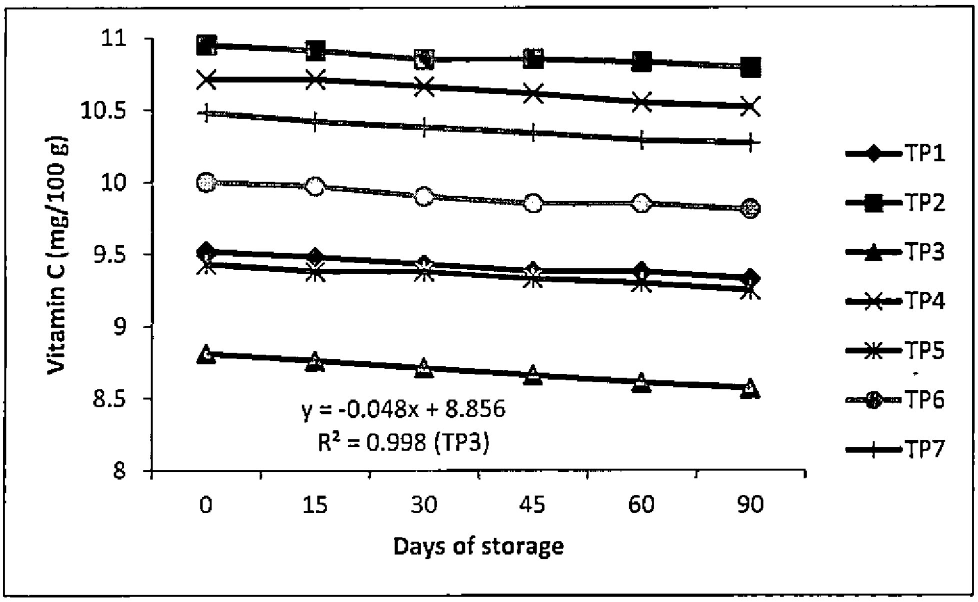


Fig.4.16 Effect of storage period and preservatives on vitamin C for pasteurized samples

b) Effect of preservatives and storage period on vitamin C of sterilized and retort packed tender jackfruit.

The vitamin C was found to be maximum due to the effect of treatment TS2 and minimum with respect to the effect of TS3. The observations were statistically analyzed and result of statistical analysis is shown in Table C10 of Appendix C. The changes in vitamin C content were only marginal over the days of storage with a significantly different ordering of the treatment as TS2, TS4, TS7, TS6, TS1, TS5 and TS3. The nature of variation in ascorbic acid of sterilized tender jackfruit during three months of storage is shown in the Fig. 4.17. The mean value of ascorbic acid decreased from 8.02 to 8.00 during the three month storage period. In sterilization also minimum reduction in ascorbic acid during storage period was found in treatment with KMS and maximum reduction in absorbic acid was found in brine processed treatment. Sunil *et al.* (2015) also agreed that addition of 0.1% KMS significantly increased ascorbic acid content in mandarin juice. He also found out that the reduction in ascorbic acid content of the juice during storage is due to the oxidation process. Beltran *et al.* (2009) also reported the loss of ascorbic acid in stored orange juices with the storage period.

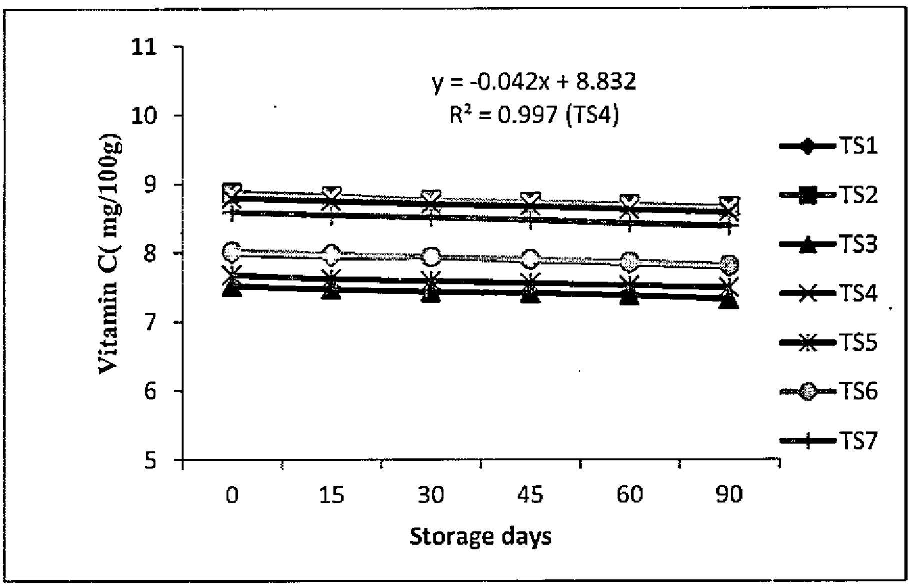


Fig.4.17 Effect of storage period and preservatives on vitamin C for sterilized samples

4.2.2.6 Effect of preservatives and storage period on pH

a) Effect of preservatives and storage period on pH of pasteurized and retort packed tender jackfruit.

The pH of tender jackfruit treated with TP3 was relatively maximum and significantly highest with respect to all of the treatments throughout the period of observation with a change noticed only with respect to the second decimal position.

The minimum pH was noticed in the case of TP1 with pH under the effect of all other treatment aligned as TP3 > TP5 > TP2 > TP4 > TP6 > TP7 > TP1. The comparative reading on pH with respect to the different treatments is depicted in Fig. 4.18 and result of statistical analysis is shown in Table C11 of Appendix C.

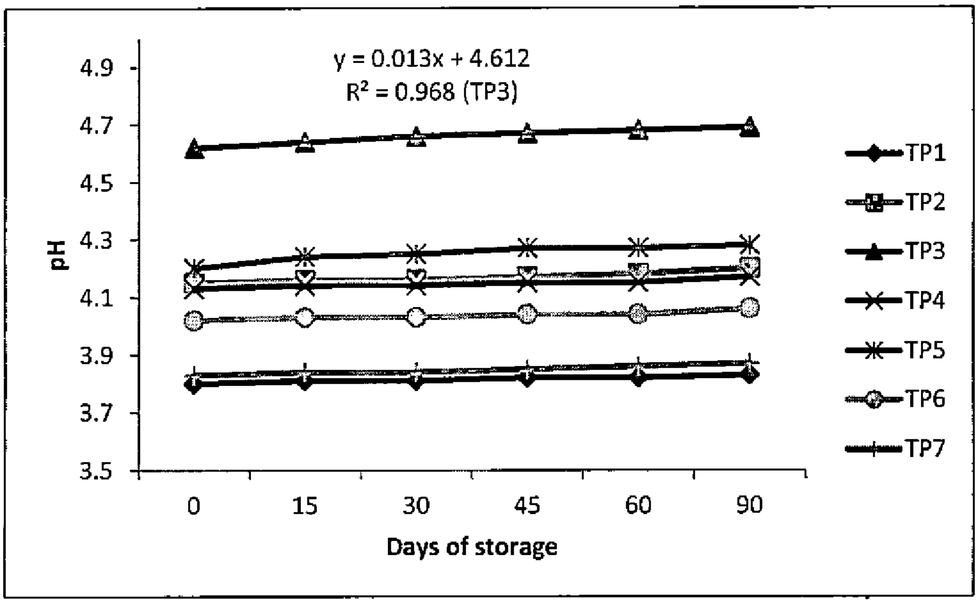


Fig.4.18 Effect of storage period and preservatives on pH for pasteurized samples

The pH of retort packed tender jackfruit exhibited an increasing trend in 90 days of storage. Mean value of pH increased from 4.11 to 4.16. Minimum percentage increase was observed in TP1 (0.79%) treatment and maximum percentage increase in pH was noted in TP5 (1.90%) followed by TP3 (1.52%). In case of retort packed tender jackfruit samples which were preserved in citric acid or combination of citric acid with KMS and brine, increment in pH was comparatively lower than that of treatments without citric acid. It was observed that there is a significant variation in pH of thermally processed jackfruit having citric acid as preservative, since acidity lowers the pH value. Similar observations were reported by Pritty *et al.* (2014).

b) Effect of preservatives and storage period on pH of sterilized and retort packed tender jackfruit.

The pH resulting from the effect of preservatives treatment ranged from 4.14 to 4.55 with a significantly noticeable maximum with respect to TS2 and the ordering of treatments were TS2, TS3, TS4, TS6, TS7, TS5 and TS1. The pH of retort packed tender jackfruit during three months of storage is detailed in Fig.4.19 and result of statistical analysis detailed in Table C12 of Appendix C. The pH of retort packed tender jackfruit exhibited an increasing trend in 90 days of storage and the mean value of pH increased from 4.26 to 4.31 during the storage. Comparatively lower increment in pH for samples which were preserved in citric acid and combination of citric acid with KMS or brine may due to acidity lowers pH (Pritty *et al.*, 2014).

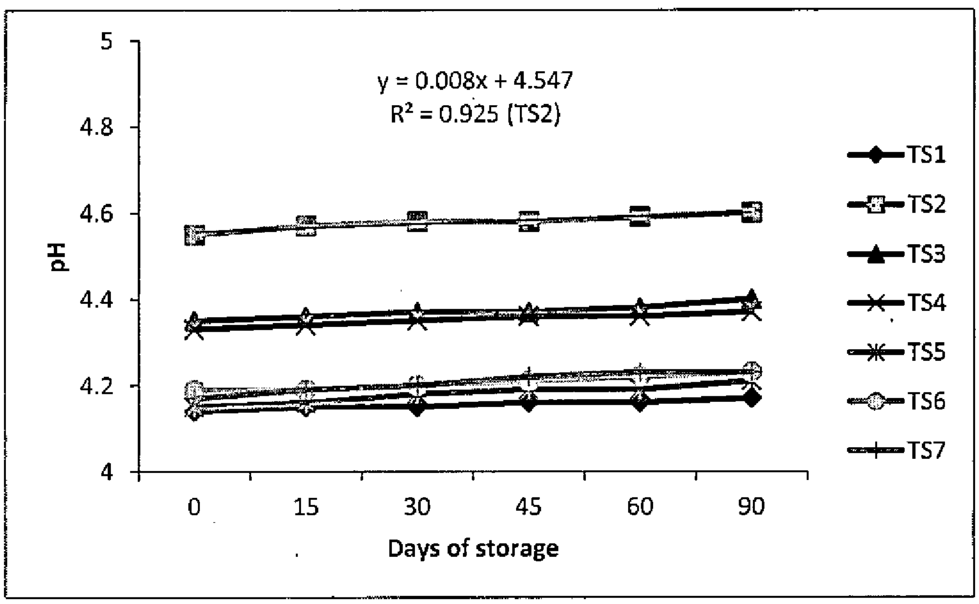


Fig.4.19 Effect of storage period and preservatives on pH for sterilized samples

4.2.2.7 Effect of preservatives and storage period on L* value

a) Effect of preservatives and storage period on L* value of pasteurized and retort packed tender jackfruit.

L* value of fresh sample was 70.11 and it showed a decreasing trend with storage period, mean value decreased from 67.42 to 62.43. L* value was maximum and significantly the highest for tender jackfruit with filling solution as TP7 (72.52) and it was found to be the minimum for the jackfruit with filling solution as TP3 (53.21). The effect of treatment was the same pattern as from the start of the experiment till the 90th day of observation. The effect may be more or less ordered in the descending order as TP7, TP1, TP4, TP2, TP6, TP5 and TP3. Minimum percentage reduction in L* value (4.82%) was noticed in TP7. The effects of different preservatives and storage period on colour parameter representing the transition from black to white, 'L*' value of pasteurized tender jackfruit is shown in Fig. 4.20 and tabulated in Table C13 of Appendix C. From the result, it was found that citric acid, KMS, its combination (citric + KMS) and citric + KMS + brine combination showed higher L* value than the fresh sample. Su *et al.* (2013) reported that major cause for the decline of L* is thought to be breakdown of the starch into dextrin and reducing sugar by heating for a long time at a high temperature.

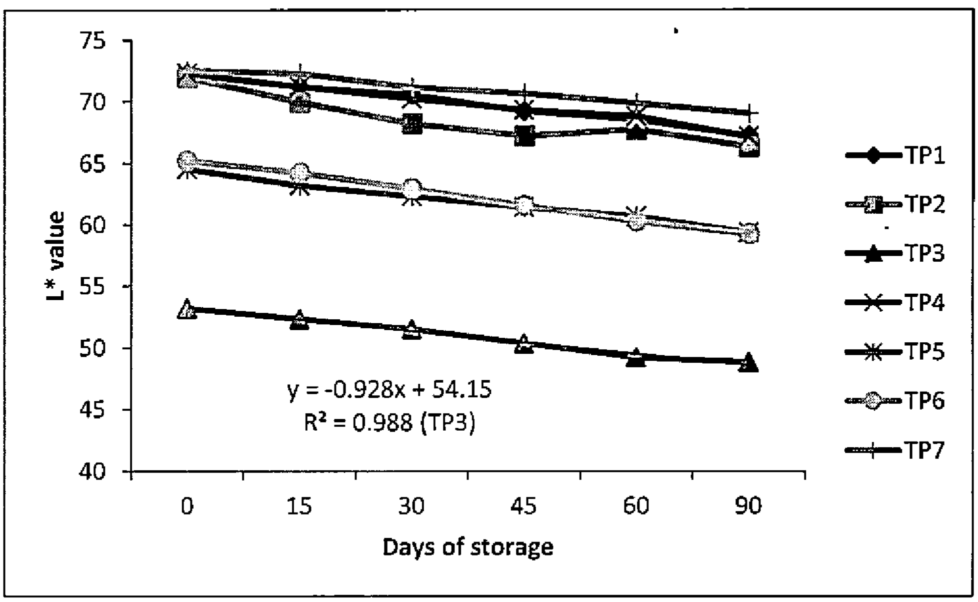


Fig.4.20 Effect of storage period and preservatives on L* value of pasteurized samples

b) Effect of preservatives and storage period on L* value of sterilized and retort packed tender jackfruit.

'L*' value of sterilized tender jackfruit is visualized in Fig. 4.21. The result of statistical analysis of the observation is detailed in Table C14 of Appendix C. The mean L* value decreased from 49.14 to 40.84 and the minimum percentage reduction was found in TS7 during the three month storage period. From the result it was revealed that citric acid, KMS, its combination (citric acid + KMS) and citric acid + KMS + brine treatments showed higher L* value than the fresh sample. Least L* value was observed in brine treatment. Combination of brine with KMS and or citric acid also showed lesser L* value compared to fresh sample.

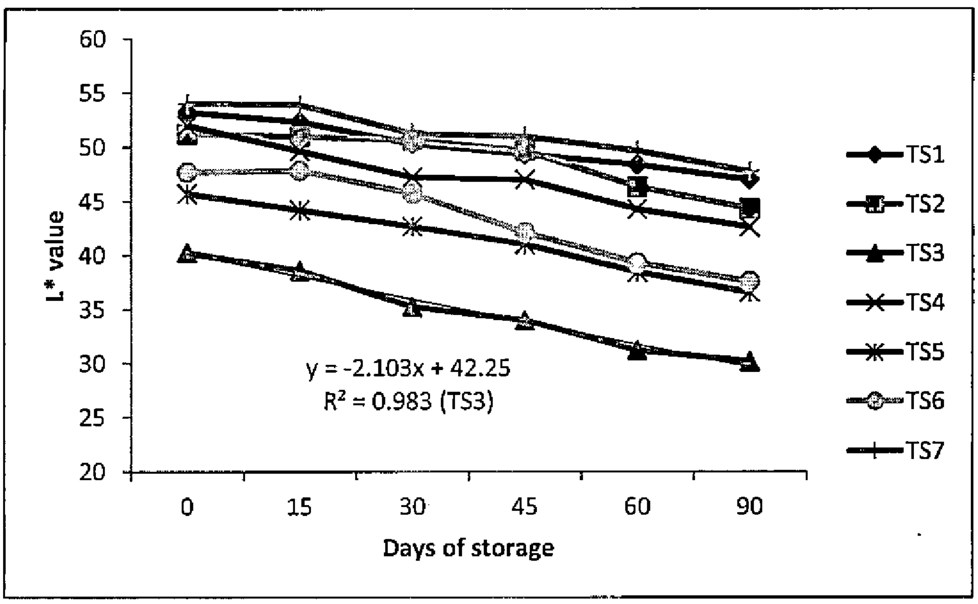


Fig. 4.21 Effect of storage and preservatives on L* value of sterilized samples

4.2.2.8 Effect of preservatives and storage period on a* value

a) Effect of preservatives and storage period on a* value of pasteurized and retort packed tender jackfruit.

The a* value measure the transition of colour from green to red. The effect of treatment TP2 (5.49) on a* value was significantly the highest throughout the experimental period. Similar observation was noticed during the storage of canned tender 'Varikka' jackfruit by Pritty *et al.* (2014). But in contrast the observations with respect to the predecessor variables the a* values under the effect of different treatments had a wider variation starting with the least value for TP2 followed by TP1 and with a steeped up increase with respect to the effect of treatment TP7, TP4, TP6, TP5 and TP3; the increase in pattern being strictly followed. Individually the a* value observable through the effect of the different treatments was following only a slight tilt towards a negative impact. The table revealed that 'a*' value increased with the increase in storage period from 3.02 to 3.38. The results of statistical analysis of a* value of thermally processed retort packed tender jackfruit with different preservatives is detailed in C15 of Appendix C and shown in Fig. 4.22. Increment in a* value indicating that the colour of the product is approaching to redness. Rattanathanaler *et al.* (2005) reported that non-enzymatic browning and pigment destruction could be considered as the major causes of colour change in pineapple.

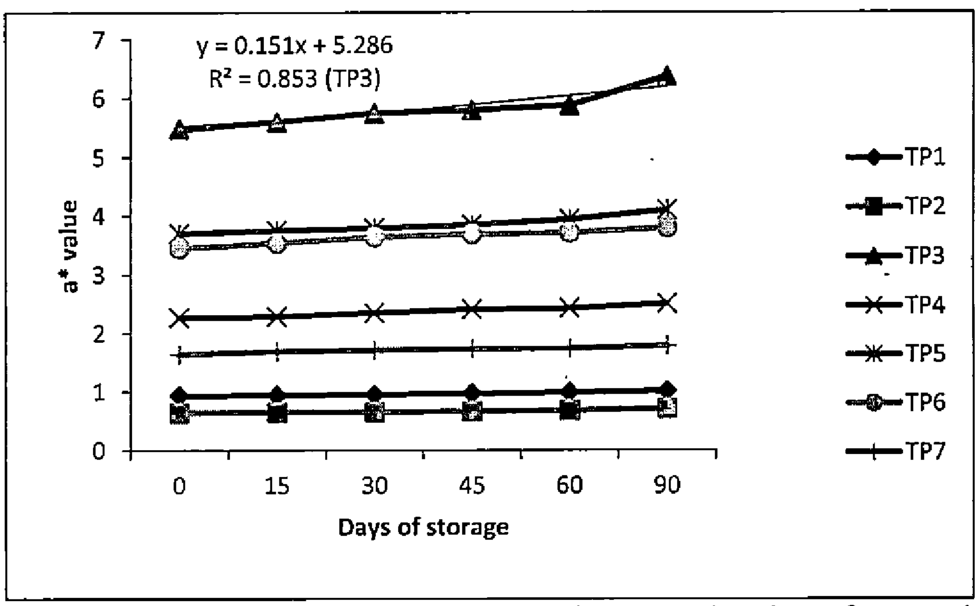


Fig. 4.22 Effect of storage period and preservatives on a* value of pasteurized samples

b) Effect of preservatives and storage period on a* value of sterilized and retort packed tender jackfruit.

The effect of treatment TS3 (16.15) was significantly the highest throughout the experimental period. But in contrast the observations with respect to the predecessor variables the a* values under the effect of different treatments had a wider variation starting with the least value for TS1 followed by TS4 and with a steeped up increase with respect to the effect of treatment TS2, TS6, TS7, TS5 and TS3; the increase in pattern being strictly followed. Individually the a* value observable through the effect of the different treatments was following only a slight tilt towards a negative impact. Similar observations were noted during the storage of canned and sterilized tender 'Varikka' jackfruit by Pritty *et al.* (2014). The a* value of sterilized and retort packed tender jackfruit with different preservatives is shown in Fig. 4.23 and statistical results detailed in Table C16 of Appendix C.

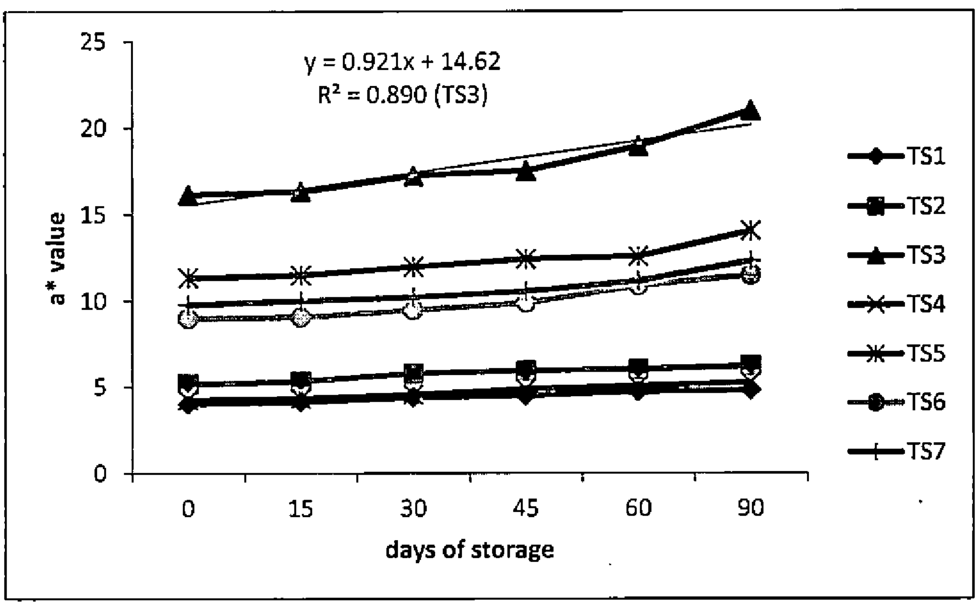


Fig.4.23 Effect of storage period and preservatives on a* value of sterilized sample

4.2.2.9 Effect of preservatives and storage period on b* value

a) Effect of preservatives and storage period on b* value of pasteurized and retort packed tender jackfruit.

b* value of the colour which adds to the acceptability of products on a visual basis with an increased acceptability traverses from blue to yellow was significantly evident from the sample treated with TP7. In general treatment TP7 followed by TP1, TP6, TP4, TP2, TP5, TP3 had significantly different decreased value of b* and the same pattern was more or less evident over the different periods of observation till the last day of observation i.e. 90 days, of course with a slightly decreased value of b* for all the products. The effect of storage period and preservatives on b* value of pasteurized samples is shown in Fig. 4.24. The result of statistical analysis is detailed in Table C17 of Appendix C.

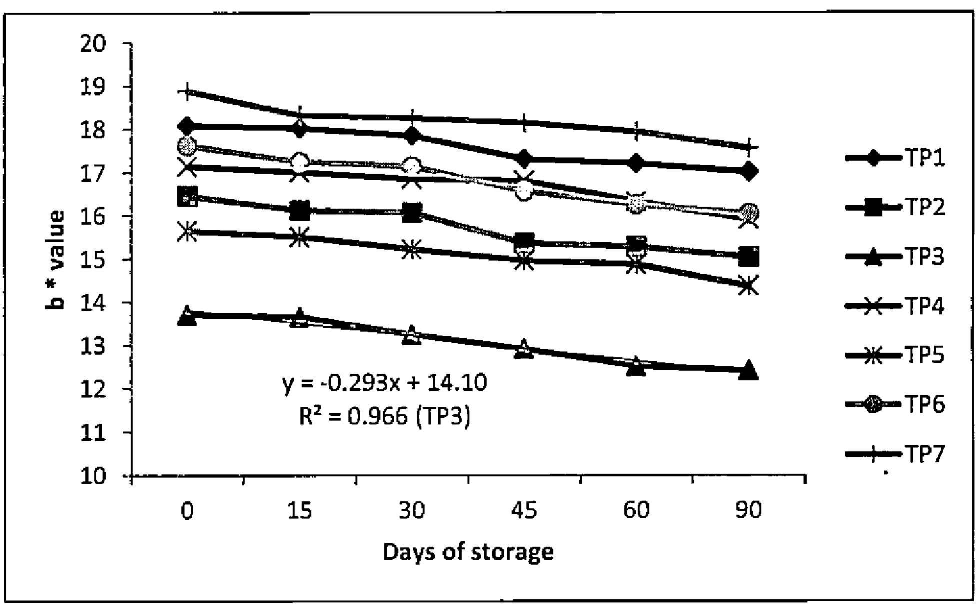


Fig. 4.24 Effect of storage period and preservatives on b* value of pasteurized samples

Effect of preservatives and storage period on b* value of sterilized and retort packed tender jackfruit.

The b* value found to be maximum in the sample treated with TS6. In general treatment TS6 followed by TS7, TS1, TS5, TS4, TS2 and TS3 had significantly different decreased value of b* and the same pattern was more or less evident over the different periods of observation till the last day of observation i.e. 90 days, of course with a slightly decreased value of b* for all the products (Fig. 4.25). The results of statistical analysis is shown in Table C18 of Appendix C.

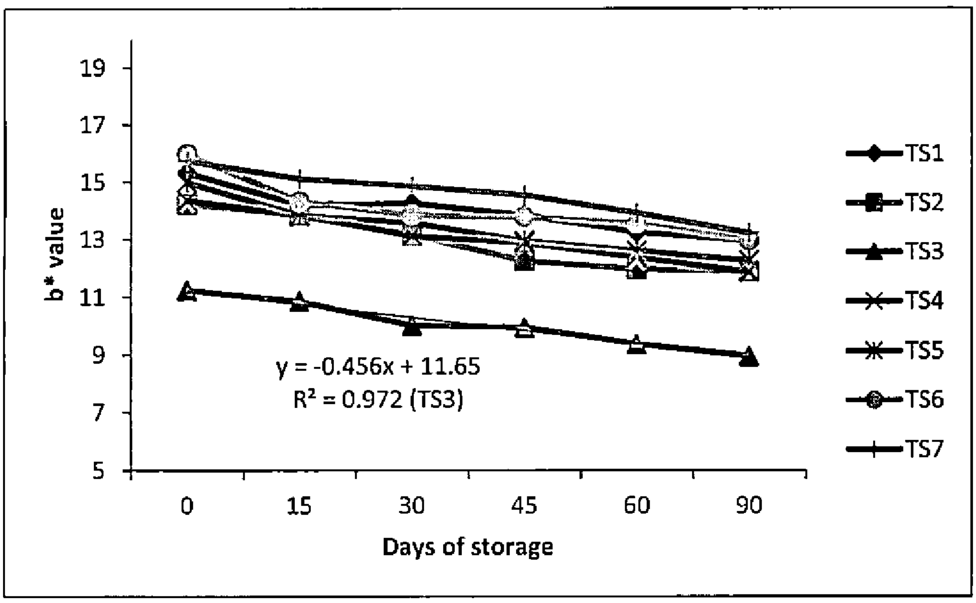


Fig.4.25 Effect of storage period and preservatives on b* value of sterilized samples

4.2.2.10 Effect of preservatives and storage period on crude fibre content

a) Effect of preservatives and storage period on crude fibre content of pasteurized and retort packed tender jackfruit.

Crude fibre content showed a decreasing trend with storage period. This agrees well with an earlier study on canning of tender jackfruit by Pritty *et al.* (2014). It is invarient under any mode of preservation as is typical of 'Koozha' tender jackfruit.

b) Effect of preservatives and storage period on crude fibre content of sterilized and retort packed tender jackfruit.

In crude fibre content, the same trend as that of pasteurization was observed in sterilization also. Crude fibre content was insignificant with storage and preservatives.

4.2.2.11 Effect of preservatives and storage period on microbial content

a) Effect of preservatives and storage period on microbial content of pasteurized and retort packed tender jackfruit.

The pasteurized and retort packed tender jackfruit samples (Plate 4.6) were subjected to the microbial analysis such as total bacterial, yeast and fungal count (Plate 4.4). The microbial load in terms of yeast and fungi were found to be zero $cfug^{-1}$ after 90 days of storage, and bacterial load (at 37°C) of 20/ml and 30/ml was observed in TP4 and TP5 respectively. The observed bacterial counts were within permissible limit i.e. not more than 50/ml prescribed by Prevention of Food Adulteration Rules, 1956 (PFA, 2000). Colony counter (Plate 4.5) was used for counting the microbial colony. The results of microbial analysis revealed that all the pasteurized samples were microbiologically safe and results of microbial analysis given in tables C.21 and C.22.

b) Effect of preservatives and storage period on microbial content of sterilized and retort packed samples.

The sterilized and retort packed tender jackfruit samples were subjected to the microbial analysis such as total bacterial, yeast and fungal count. The microbial load in terms of bacteria, yeast and fungi were found to be zero $cfug^{-1}$ after 90 days of storage. The permissible limit of microbial level is not more than 50/ml prescribed by Prevention of Food Adulteration Rules, 1956 (PFA, 2000). Commercial sterility test

(Plate 4.3) also revealed that the processed product contain zero spore. The results of microbial analysis revealed that all the sterilized samples were microbiologically safe and results of microbial analysis given in tables C.21 and C.22.

4.2.3 Ranking of treatments

To summarize it is of course desirable that a rank ordering of treatments is done, so as to comparatively evaluate the processed product based on all the desirable qualities that is conceivable for a processed product

a) Ranking of treatments for pasteurization

To identify, the best treatment a scoring of the treatments for each parameter was done based on the one way ANOVA (Table 4.9 and 4.10). The scores for each treatment parameter wise and the total score are presented in Table 4.10. The sum total of score for each treatment was calculated for identification of the most suitable treatment. From Table 4.10 it is evident that TP1 and TP7 obtained a minimum score of 23 and 27 respectively, and they possessed almost all the quality parameters in a higher order ranking. Hence the treatment with citric acid (TP1) and combination of citric acid, KMS and brine were selected for further sensory evaluation study.

Table 4.9 Ranking of treatments for pasteurization

	Ranked order of treatments						
Parameters	R1	R2	R3	R4	R5	R6	R7
Crude fibre	T7	T4	T5	T1	T3	T6	T2
L* value	T7	T4	T1	T2	T6	T5	T3
a* value	T2	T1	T7	T4	T6	T5	T3
b* value	T7	T1	T6	T4	T2	T5	T3
pH	T1	T7	T6	T4	T2	T5	T3
vitamin C	T2	T4	T7	T6	T1	T5	T3
Titrable acidity	T1	T7	T6	T4	T5	T3	T2
Toughness	T1	T4	T2	T7	T6	T5	T3
Firmness	T1	T2	T4	T7	T6	T5	T3
TSS	T3	T6	T1	T2	T4	T7	T5

Table 4.10 Scoring of treatments for pasteurization

Parameters	T1	T2	T3	T4	T5	T6	T7
Crude fibre	4	7	5	2	3	6	1
L* value	3	4	7	2	6	5	1
a* value	2	1	7	4	6	5	3
b* value	2	5	7	4	6	3	1
pH	1	5	7	4	6	3	2
vitamin C	5	1	7	2	6	4	3
Titrable acidity	1	7	6	4	5	3	2
Toughness	1	3	7	2	6	5	4
Firmness	1	2	7	3	6	5	4
TSS	3	4	1	5	7	2	6
Total score	23	39	61	32	57	41	27

b) Ranking of treatments for sterilization

The rank ordering of treatments based on the quality parameters of processed products is presented in Table 4.11 and 4.12. From Tables, it is evident that TP1 and TP2 obtained a minimum score of 23 and 35 respectively, and they possessed almost all the quality parameters in a higher order ranking. Hence the treatment with citric acid (TS1) and KMS (TS2) were selected for further sensory evaluation study.

Table 4.11 Ranking of treatments for sterilization

Parameters	Ranked order of treatments						
	R1	R2	R3	R4	R5	R6	R7
L* value	T7	T1	T4	T2	T6	T5	T3
a* value	T1	T4	T2	T6	T7	T5	T3
b* value	T6	T7	T1	T5	T2	T4	T3
Toughness	T1	T2	T4	T7	T5	T6	T3
Firmness	T1	T2	T4	T7	T5	T6	T3
pH	T1	T5	T7	T6	T4	T3	T2
vitamin C	T2	T4	T7	T6	T1	T5	T3
TSS	T1	T5	T7	T4	T3	T6	T2
Titrable acidity	T2	T3	T5	T6	T7	T1	T4

Crude fibre	T4	T1	T2	T5	T3	T7	T6

Table 4.12 Scoring of treatments for sterilization

Parameters	T1	T2	T3	T4	T5	T6	T7
Crude fibre	2	3	5	1	4	7	6
L* value	2	4	7	3	6	5	1
a* value	1	3	7	2	6	4	5
b* value	3	5	7	6	4	1	2
pH	1	7	6	5	2	4	3
vitamin C	5	1	7	2	6	4	3
Titrable acidity	6	1	2	7	3	4	5
Toughness	1	2	7	3	5	6	4
Firmness	1	2	7	3	5	6	4
TSS	1	7	5	4	2	6	3
Total score	23	35	62	36	43	47	36

4.2.4 Sensory evaluation

The scores given for different treatments on different organoleptic traits namely, colour, flavour, texture and overall acceptability are presented in Table 4.13.

Table 4.13 Mean score for sensory evaluation

Treatment	Colour	Flavour	Texture	Over all acceptability
TP1	7.9375	7.6875	7.9375	8.0625
TP7	7.0000	7.4375	7.3750	7.1875
TS1	7.8750	7.5625	7.1250	7.6875
TS2	7.0625	7.5000	6.8125	7.4375

The Kendall's coefficient of concordance was worked out to evaluate the degree of agreement among the judges with respect to the quality parameters colour, flavour, texure and overall acceptability (Table 4.12). Kendall's W was found to be significant for all the parameters except for flavour signifying that the mean value scores be taken as the criteria to differentiate the products based on acceptability. It was observed that the pasteurization treatment with citric acid filling solution (TP1) was the best for all the parameters followed by sterilization treatment with citric acid as filling solution (TS1).

Table 4.14 Kendall's coefficient of concordance test for mean rank for sensory evaluation

Treatments	Colour	Flavour	Texture	Overall acceptability
TP1	3.13	2.84	3.31	3.16
TP7	1.91	2.31	2.59	2.03
TS1	3.06	2.53	2.28	2.63
TS2	1.91	2.31	1.81	2.19
W	0.348	0.060	0.295	0.184

4.2.5 Cost of retort processing

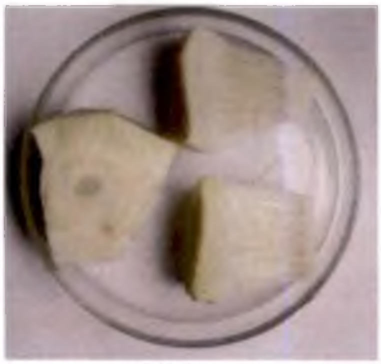
The computation for cost of retort processing is given in Appendix D. The cost of production of thermally processed tender jackfruit per pouch was found to be Rs 11.51/-. This price is economically affordable to common people. A brief description of cost analysis for one pouch is follows.

Total cost for packing operation : Rs. 1.25/-
Labour cost wage : Rs. 3.75/-

Cost of pouch : Rs. 4.00/-

Cost of jackfruit : Rs. 2.50/-

TP1



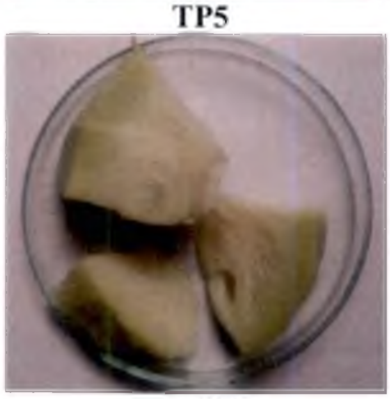
TP2

TP3

TP4

TP5

TP6



TP7

Plate 4.1 Pasteurized tender jackfruit on 90th day of storage


TS1


TS2


TS3


TS4


TS5


TS6


TS7

Plate 4.2 Sterilized tender jackfruit on 90^{th} day of storage

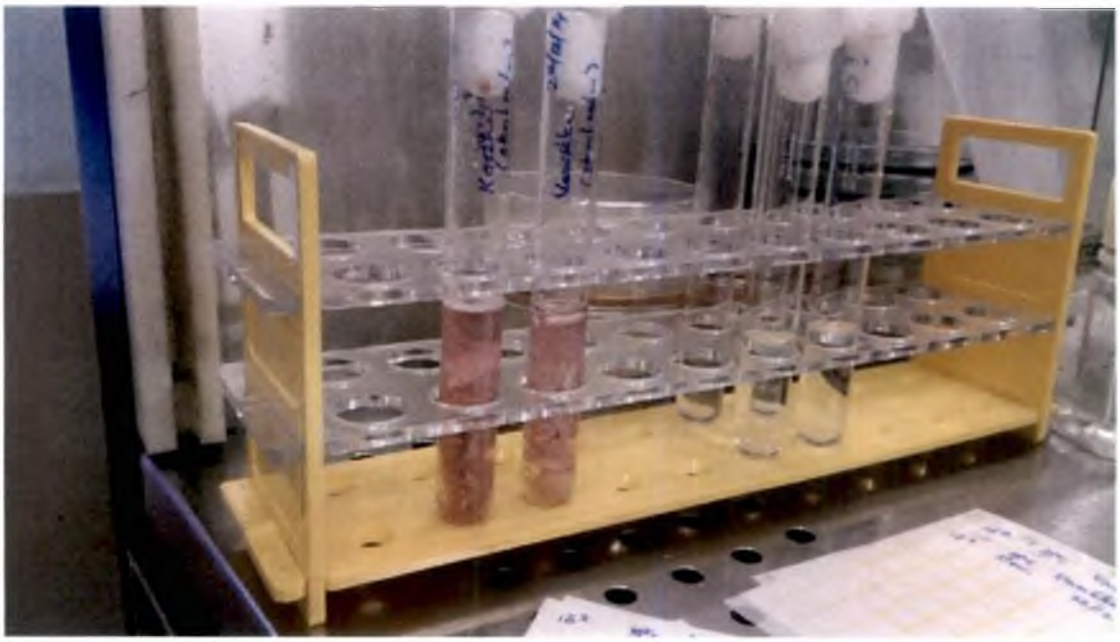


Plate 4.3 Commercial sterility test

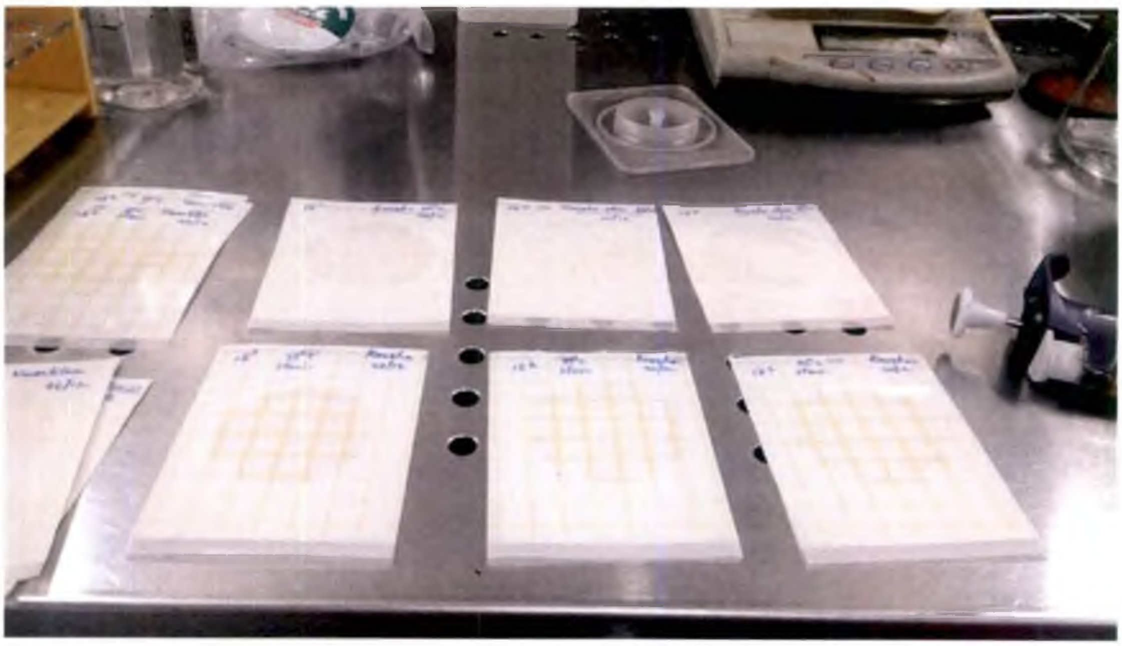


Plate 4.4 Microbial analysis

Plate 4.5 Colony counter

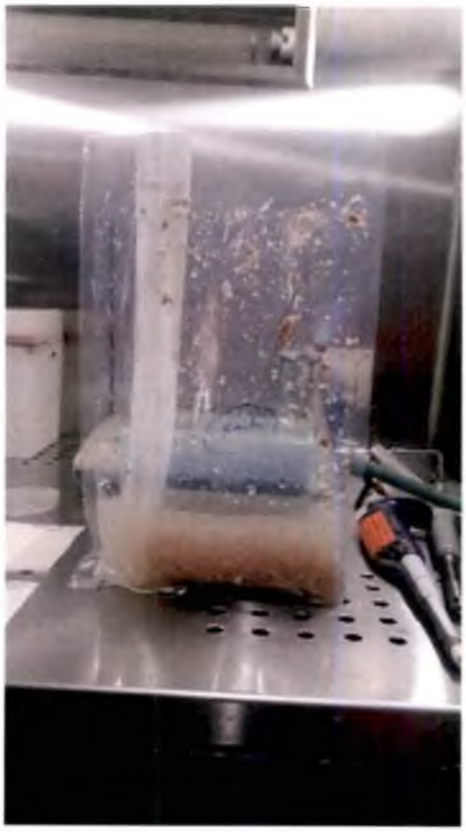


Plate 4.6 Sample preparation

Summary and conclusion

CHAPTER IV

SUMMARY AND CONCLUSION

Jackfruit is a seasonal organic fruit and it is popularly used as vegetable in its tender stage. This under exploited fruit is considered as heavenly fruit by the ancient people in Kerala because of its nutritive composition. Though it is a highly nutritious commodity, the post harvest wastage is huge due to its perishable nature. There are two types of jackfruits namely 'Koozha' and 'Varikka'. The wastage of 'Koozha' jackfruit is more compared to 'Varikka' and the former has a less consumer acceptance due to its poor texture after ripening. Canned tender jackfruit ('Varikka') was proved to be a good ready to cook option available for consumers throughout the year. Owing to the high cost of canning, an alternative which should not only be economical but also ensure longer shelf life had to be developed. Retort pouch packaging system is an ideal alternative to metal cans to achieve these goals.

The significant wastage of 'Koozha' variety necessitated the design of a viable processing and packaging technology to extend its shelf life. Hence the present study on "Development and quality evaluation of retort pouch packed tender jackfruit (*Artocarpus heterophyllus* L.)" has undertaken in the Dept. of F & APE, KCAET, Tavanur with specific objectives of standardization of blanching process, standardization of thermal process in retort pouch package, shelf life study and quality evaluation of retort pouch packed tender jackfruit.

Optimization of blanching treatment was carried out in two stages. In the first stage the blanching time was optimized. It was carried out at 100°C for one minute to seven minutes. During the initial screening process, presence of the POD and catalase were detected during the one minute and two minutes process (B_1 and B_2 respectively). So it was concluded that at least three minutes blanching was necessary. A minimum percentage reduction in firmness, toughness, colour value were observed in three minutes blanching process Blanching time of three minutes for tender jackfruit was optimized based on the enzyme test and the results of the quality parameters like texture, colour and crude fibre content. Subsequently based on the optimum blanching time the best blanching preservative was identified. At a default of three minutes blanching time at 100°C, four blanching treatments namely blanching in boiling water, blanching in boiling water containing 0.3% citric acid, blanching in boiling water containing 0.1% KMS and blanching in boiling water containing 0.3% citric acid + 0.1% KMS were carried out in the departmental lab. Among the treatments, 0.3% citric acid is identified as the best blanching treatment in terms of textural properties, colour attributes and crude fibre content.

The blanched samples were subjected to a pasteurization temperature of 90°C for F value 10 and sterilization temperature of 121°C for F_0 value one and the time required to heat the product for particular F and F_0 values were obtained from heat penetration curve. Thermal processing was done in a steam generated type autoclave (John Fraser and Son Ltd, UK) at CIFT, Cochin, in retort pouches (15× 20 cm). Process times were determined using the cold point method with the help of valsuite software. Further, the products were subjected to microbial analysis and the results of which revealed that both pasteurized and sterilized samples were microbiologically safe. Blanched tender jackfruit pieces (140 g) and filling solution (140 ml) were filled manually in the retort pouch. The different filling solutions used were 0.3% citric acid, 0.1% KMS, 2% Brine, 0.1% KMS + 0.3% citric acid, 0.1% KMS + 2% Brine, 0.3% citric + 2% Brine and 0.1% KMS+ 2% Brine+ 0.3% citric acid. After filling the retort pouch with tender jackfruit and filling solution, the entrapped air was removed by steam flushing method using steam from thermal cooker. Exhausting steam temperature was around 100°C. The pouches were sealed immediately after exhausting using a hydraulic sealer (125°- 135°C). Then it was subjected to thermal processing in high pressure autoclave. The processed pouches were later cooled and stored in clean and dry place.

The sterilized and pasteurized pouches were stored for three months for the shelf life study. The tender jackfruit samples in sterilized pouches were stored in ambient condition (20 - 25°C, 50 - 60% RH) and those samples in pasteurized pouches were stored in refrigerated condition (10°C). The quality of the processed samples was assessed in terms of TSS, titrable acidity, pH, vitamin C, texture and colour. Standardization of thermal process and optimum preservative concentration for maximum shelf life was determined by post hock tests, following analysis of variance.

In the case of pasteurization and sterilization, TSS showed an increasing trend with storage period and maximum TSS was noticed in brine processed treatment and maximum percentage increase in total soluble solid was noted in citric acid treatment during the three months of storage. Firmness of fresh sample was 76.21 N with citric acid treatment was found to be the best in terms of firmness and significantly superior at all stages of observation for both pasteurization and sterilization. A gradual decrease in firmness was noticed over the periods of storage with more or less the same quantum of decrease for all the treatments. The mean firmness value decreased from 37.68 to 33.044 N and 6.02 to 2.11 N in pasteurization and sterilization respectively during three months of storage. A gradual decrease in toughness of tender jackfruit under all the treatments was noticed during the storage period. Significant variation due to the effect of different preservatives was observed. The maximum percentage reduction in toughness was noticed in brine processed treatment and minimum in KMS treatment. The mean value of toughness decreased from 129.87 to 115.51 N.sec. and 11.46 N.sec to 5.33 N.sec in pasteurization and sterilization respectively.

Minimum percentage reduction in titrable acidity was noticed in citric acid treatment. Jackfruit samples which were preserved in citric acid or combination of citric acid with other preservatives, initial values of titrable acidity was comparatively higher than that of treatments without citric acid. The mean value of ascorbic acid slightly decreased from 9.98 to 9.79 mg/ 100 g and 8.20 to 8.00 mg/100 g in pasteurization and sterilization respectively. Minimum percentage reduction in vitamin C during storage period was found in treatment with KMS, because of its better anti - oxidant capacity and maximum percentage reduction in vitamin C was found in brine processed treatment.

The pH of tender jackfruit treated with brine was relatively maximum and the minimum pH was noticed in the case of citric acid treatment. The pH of retort packed tender jackfruit exhibited an increasing trend in 90 days of storage. Mean value of pH increased from 4.11 to 4.16 and 4.26 to 4.31 in pasteurization and sterilization respectively. In case of retort packed tender jackfruit samples which were preserved in citric acid or combination of citric acid with KMS and brine, increment in pH was comparatively lower than that of treatments without citric acid. It was observed that there is a significant variation in pH of thermally processed jackfruit having citric acid as preservative, since acidity lowers the pH value.

L* value of fresh sample was 70.11 and it showed a decreasing trend with storage period, mean value decreased from 67.42 to 62.43 and 49.14 to 40.84 for pasteurization and sterilization respectively. The processed sample with combination of citric acid + KMS + brine filling solution offered significantly highest L* value. It was found to be the minimum for the jackfruit with filling solution as brine. The a* value measure the transition of colour from green to red. The effect of treatment KMS on a* value was significantly the highest throughout the experimental period. The results revealed that 'a*' value increased with the increase in storage period from 3.02 to 3.38 and 9.93 to 12.51 for pasteurization and sterilization respectively. In the case of b* value, combination of citric acid, KMS and brine showed significantly highest value. Crude fibre content showed a decreasing trend with storage period. It is invarient under any mode of preservation as is typical of 'Koozha' tender jackfruit

The experiments were statically analyzed with one way ANOVA. The samples preserved in citric exhibited good property in most cases of quality evaluation and sensory evaluation. Microbial analysis also showed that the product was safe upto 90 days storage. Development of ready to eat tender jackfruit product can be a future scope of this study. It was concluded that 0.3% citric acid blanching and 0.3% citric acid preservative as filling solution was best in terms of quality parameters and microbial analysis for the development of thermally processed and retort packed tender jackfruit. The cost of operation per pouch (140 g) of tender jackfruit was calculated as Rs. 11.51/-. This study is useful for the production of good quality, safe, affordable priced tender jackfruit in ready to cook form throughout the year.

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Appendices

APPENDIX A

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 B

Sensory evaluation

Treatment	Mean scores			
	Colour	Flavour	Texture	Over all acceptability
TP1				
TP7				
TS1				
TS7				

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 C

C.1 Changes in TSS (°B) of pasteurized tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TP1	4.21^{c}	4.23^{b}	4.24^{c}	4.25^{c}	4.27^{b}	4.27^{c}	1.43	4.25
TP2	4.15^{d}	4.16^{c}	4.16^{d}	4.17^{d}	4.18^{c}	4.19^{d}	0.95	4.17
TP3	4.64^{a}	4.64^{a}	4.66^{a}	4.67^{a}	4.68^{a}	4.69^{a}	1.19	4.66
TP4	4.13^{e}	4.14^{d}	4.14^{e}	4.15^{e}	4.15^{d}	4.16^{e}	0.71	4.15
TP5	3.81^{f}	3.82^{f}	3.83^{f}	3.84^{f}	3.84^{f}	3.86^{f}	1.19	3.83
TP6	4.24^{b}	4.24^{b}	4.25^{b}	4.27^{b}	4.28^{b}	4.29^{b}	1.19	4.26
TP7	3.82^{f}	3.84^{e}	3.84^{f}	3.85^{f}	3.86^{e}	3.87^{f}	1.19	3.85

C.2 Changes in TSS (°Brix) of sterilized retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TS1	4.14^{g}	4.15^{f}	4.15^{f}	4.16^{e}	4.16^{f}	4.17^{g}	1.2	4.19
TS2	4.55^{a}	4.57^{a}	4.58^{a}	4.58^{a}	4.59^{a}	4.59^{a}	0.88	4.59
TS3	4.35^{b}	4.36^{b}	4.37^{b}	4.37^{b}	4.38^{b}	4.39b	0.92	4.38
TS4	4.33^{c}	4.34^{c}	4.35^{c}	4.37^{b}	4.37^{c}	4.38^{c}	1.38	4.37
TS5	4.15^{f}	4.16^{e}	4.18^{e}	4.19^{d}	4.19^{d}	4.21^{f}	1.2	4.19
TS6	4.19^{d}	4.19^{d}	4.20^{d}	4.22^{c}	4.23^{e}	4.24^{d}	1.56	4.53
TS7	4.17^{e}	4.19^{d}	4.20^{d}	4.22^{c}	4.23^{e}	4.23^{e}	1.43	4.22

C.3 Changes in firmness (N) of pasteurized and retort packed jackfruit and its interaction between thermal processing, treatments and storage period

Treatments	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	42.92^{a}	42.12^{a}	41.57^{a}	40.40^{a}	39.98^{a}	38.14^{a}	11.14	40.86
TP2	41.23^{b}	40.19^{b}	39.95^{b}	39.01^{b}	38.52^{ab}	36.43^{b}	11.64	39.22
TP3	32.42^{f}	31.82^{g}	30.81^{e}	29.85^{f}	28.57^{e}	27.45^{g}	15.33	30.15
TP4	40.82^{b}	39.79^{c}	39.27^{b}	38.75^{b}	36.97^{b}	35.54^{c}	12.93	38.52
TP5	33.54^{e}	32.91^{f}	31.47^{e}	31.04^{e}	30.54d	29.70^{f}	11.45	31.53
TP6	34.89^{d}	33.65^{e}	32.74^{d}	31.88^{d}	30.74d	29.81^{e}	14.56	32.29
TP7	37.98^{c}	36.36^{d}	35.86^{c}	35.37^{c}	34.07c	33.24^{d}	12.48	35.44

C.4 Changes in firmness (N) of sterilized and retort packed jackfruit and its interaction between thermal processing, treatments and storage period

	Storage interval (days)							
Treatment	0	15	30	45	60	90	% decrease	Mean
TS1	7.56^{a}	7.12^{a}	6.88^{a}	6.27^{a}	5.94^{a}	4.54^{a}	39.95	6.39
TS2	7.08^{a}	6.88^{ab}	6.22^{a}	5.98^{b}	5.24^{b}	4.22^{b}	40.4	5.94
TS3	4.21^{d}	3.21^{e}	2.85^{d}	2.23^{g}	1.95^{g}	1.19^{g}	71.73	2.61
TS4	6.98^{a}	5.56^{c}	4.31^{bc}	3.57^{d}	3.28^{d}	2.15^{e}	69.2	4.31
TS5	5.12^{c}	4.52^{d}	3.83^{c}	2.75^{f}	2.21^{f}	2.05^{f}	59.96	3.41
TS6	5.00^{c}	4.58^{d}	4.11^{bc}	3.54^{e}	3.05^{e}	2.99^{e}	40.20	3.88
TS7	6.25^{b}	5.96^{bc}	4.65^{b}	4.03^{c}	3.85^{e}	2.32^{d}	62.88	4.51

C.5 Changes in toughness (N.sec) of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	135.62^{a}	133.21^{a}	132.85^{a}	128.54^{a}	125.95^{a}	121.65^{a}	10.30	129.64
TP2	133.24^{c}	131.14^{b}	126.95^{c}	124.85^{b}	123.87^{c}	120.65^{b}	9.45	126.78
TP3	123.21^{g}	120.65^{f}	118.61^{f}	115.54^{e}	113.87^{g}	105.24^{g}	14.58	116.19
TP4	134.52^{b}	132.65^{a}	130.98^{b}	125.10^{bb}	124.41^{b}	120.01^{c}	10.79	127.95
TP5	125.32^{f}	123.65^{e}	120.98^{e}	118.54	115.03^{f}	110.41^{f}	11.90	118.99
TP6	127.54^{e}	126.74^{d}	124.32^{d}	120.95^{d}	117.36^{e}	114.32^{e}	10.37	121.87
TP7	129.65^{d}	128.10^{c}	127.65^{c}	123.98^{c}	121.32^{d}	116.02^{d}	10.51	124.45

C.6 Changes in toughness (N.sec) of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period

	Storage interval (days)							
Treatment	0	15	30	45	60	90	% increase	Mean
TS1	15.23^{a}	13.25^{a}	12.54^{a}	10.21^{a}	9.54^{a}	8.61^{a}	43.47	11.56
TS2	13.22^{b}	12.35^{b}	10.87^{b}	9.85^{b}	8.10^{c}	7.21^{b}	45.46	10.27
TS3	8.21^{c}	7.51^{g}	6.32^{f}	4.21^{g}	3.21^{g}	2.28^{g}	72.23	5.29
TS4	12.35^{c}	11.01^{d}	9.65^{d}	8.54^{d}	7.32^{d}	5.32^{d}	56.92	9.03
TS5	9.65^{d}	7.60^{f}	6.01^{g}	5.21^{f}	4.21^{f}	3.27^{f}	66.11	5.99
TS6	9.31^{d}	8.54^{e}	7.01^{e}	6.29^{e}	5.21^{e}	4.41^{e}	52.63	6.80
TS7	12.31^{c}	11.65^{c}	10.21^{c}	9.24^{c}	8.14^{b}	6.21^{c}	49.55	9.63

C.7 Changes in titrable acidity (%) of pasteurized retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	0.96^{a}	0.96^{a}	0.84^{a}	0.84^{a}	0.84^{a}	0.84^{a}	12.50	0.88
TP2	0.48^{c}	0.48^{c}	0.48^{b}	0.48^{bc}	0.36^{c}	0.36^{c}	25.00	0.44
TP3	0.48^{c}	0.48^{c}	0.48^{b}	0.48^{bc}	0.36^{c}	0.36^{c}	25.00	0.44
TP4	0.72^{b}	0.72^{b}	0.60^{b}	0.60^{b}	0.60^{b}	0.60^{b}	16.67	0.64
TP5	0.48^{c}	0.48^{c}	0.48^{b}	0.36^{c}	0.36^{c}	0.36^{c}	25.00	0.42
TP6	0.72^{b}	0.72^{b}	0.60^{b}	0.60^{b}	0.60^{b}	0.60^{b}	16.67	0.64
TP7	0.72^{b}	0.72^{b}	0.60^{b}	0.60^{b}	0.60^{b}	0.60^{b}	16.67	0.64

C.8 Changes in titrable acidity (%) of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TS1	0.84^{a}	0.84^{a}	0.84^{a}	0.72^{a}	0.72^{a}	0.72^{a}	14.29	0.78
TS2	0.48^{c}	0.48^{c}	0.48^{c}	0.48^{c}	0.36^{c}	0.36^{c}	25.00	0.44
TS3	0.48^{c}	0.48^{c}	0.48^{c}	0.48^{c}	0.36^{c}	0.36^{c}	25.00	0.44
TS4	0.84^{a}	0.84^{a}	0.72^{b}	0.72^{a}	0.72^{a}	0.72^{a}	14.29	0.76
TS5	0.48^{c}	0.48^{c}	0.48^{c}	0.36^{d}	0.36^{c}	0.36^{c}	25.00	0.42
TS6	0.72^{b}	0.72^{b}	0.72^{b}	0.72^{a}	0.60^{b}	0.60^{b}	16.67	0.68
TS7	0.72^{b}	0.72^{b}	0.72^{b}	0.60^{b}	0.60^{b}	0.60^{b}	16.67	0.66

C.9 Changes in ascorbic acid (mg/100 g^{-1}) of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	9.52^{c}	9.48^{e}	9.43^{e}	9.38^{e}	9.38^{e}	9.33^{e}	2.00	9.42
TP2	10.95^{a}	10.91^{a}	10.85^{a}	10.85^{a}	10.83^{a}	10.79^{a}	1.68	10.86
TP3	8.81^{d}	8.76^{g}	8.71^{g}	8.66^{g}	8.61^{g}	8.57^{g}	2.52	8.69
TP4	10.71^{a}	10.71^{b}	10.66^{b}	10.61^{b}	10.55^{b}	10.52^{b}	2.00	10.63
TP5	9.43^{cd}	9.38^{f}	9.38^{f}	9.33^{f}	9.3^{f}	9.25^{f}	1.89	9.35
TP6	10.00^{bc}	9.97^{d}	9.90^{d}	9.85^{d}	9.85^{d}	9.81^{d}	2.00	9.90
TP7	10.48^{ab}	10.42^{c}	10.38^{c}	10.34^{c}	10.29^{c}	10.27^{c}	2.21	10.36

C.10 Changes in ascorbic acid (mg/100 g^{-1}) of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TS1	7.99	7.94	7.94	7.89	7.84	7.79	2.50	7.90
TS2	8.87	8.82	8.76	8.73	8.69	8.65	2.48	8.75
TS3	7.52	7.47	7.43	7.41	7.38	7.32	2.66	7.42
TS4	8.79	8.75	8.7	8.67	8.62	8.58	2.39	8.69
TS5	7.68	7.62	7.59	7.56	7.52	7.49	2.47	7.58
TS6	8.02	7.98	7.94	7.9	7.86	7.81	2.62	7.92
TS7	8.59	8.54	8.51	8.47	8.42	8.38	2.44	8.49

C.11 Changes in pH of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TP1	3.8[g]	3.81[d]	3.81[g]	3.82[g]	3.82[g]	3.83[g]	0.79	3.82
TP2	4.15[c]	4.16[bc]	4.16[c]	4.17[c]	4.18[c]	4.20[c]	1.20	4.17
TP3	4.62[a]	4.64[a]	4.66[a]	4.67[a]	4.68[a]	4.69[a]	1.52	4.66
TP4	4.13[d]	4.14b[c]	4.14[d]	4.15[d]	4.15[d]	4.17[d]	0.97	4.15
TP5	4.20[b]	4.24[b]	4.25[b]	4.27[b]	4.27[b]	4.28[b]	1.90	4.25
TP6	4.02[e]	4.03[c]	4.03[e]	4.04[e]	4.04[e]	4.06[e]	1.00	4.04
TP7	3.83[f]	3.84[d]	3.84[f]	3.85[f]	3.86[f]	3.87[f]	1.04	3.85

C.12 Changes in pH of sterilized retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TS1	4.14[f]	4.15[d]	4.15[f]	4.16[e]	4.16[f]	4.17[f]	0.72	4.16
TS2	4.55[a]	4.57[a]	4.58[a]	4.58[a]	4.59[a]	4.60[a]	1.09	4.58
TS3	4.35[b]	4.36[b]	4.37[b]	4.37[b]	4.38[b]	4.40[b]	1.14	4.37
TS4	4.33[c]	4.34[b]	4.35[c]	4.36[b]	4.36[c]	4.37[c]	0.92	4.35
TS5	4.15[f]	4.16[d]	4.18[e]	4.19[d]	4.19[e]	4.21[e]	1.43	4.18
TS6	4.19[d]	4.19[c]	4.20[d]	4.21[c]	4.22[d]	4.23[d]	0.95	4.21
TS7	4.17[e]	4.19[c]	4.20[d]	4.22[c]	4.23[d]	4.23[d]	1.42	4.21

C.13 Changes in 'L*' (black - white) value of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	72.24^{c}	71.21^{b}	70.54^{ab}	69.21^{b}	68.54^{b}	67.21^{b}	6.96	69.82
TP2	71.96^{d}	69.95^{c}	68.21^{c}	67.21^{c}	67.74^{c}	66.32^{d}	7.83	68.56
TP3	53.21^{g}	52.32^{f}	51.51^{e}	50.36^{e}	49.21^{e}	48.81^{g}	8.26	50.90
TP4	72.32^{b}	71.21^{b}	70.21^{b}	69.32^{b}	68.78^{b}	67.13^{c}	7.17	69.82
TP5	64.53^{f}	63.21^{e}	62.31^{d}	61.41^{d}	60.65^{d}	59.32^{e}	8.07	61.90
TP6	65.21^{e}	64.25^{d}	62.95^{d}	61.55^{d}	60.23^{d}	59.21^{f}	9.20	62.23
TP7	72.52^{a}	72.30^{a}	71.14^{a}	70.65^{a}	69.85^{a}	69.02^{a}	4.82	70.91

C.14 Changes in 'L*' (black - white) value of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TS1	53.21^{b}	52.32^{b}	50.28^{c}	49.32^{b}	48.36^{b}	46.98^{a}	11.70	50.07
TS2	51.24^{d}	50.98^{c}	50.65^{b}	49.67^{b}	46.32^{c}	44.32^{b}	13.50	48.86
TS3	40.21^{g}	38.56^{g}	35.24^{g}	33.98^{f}	31.21^{g}	30.15^{f}	25.01	34.89
TS4	51.98^{c}	49.65^{d}	47.21^{d}	46.98^{c}	44.25^{d}	42.58^{c}	18.08	47.10
TS5	45.69^{f}	44.19^{f}	42.64^{f}	40.98^{e}	38.41^{f}	36.54^{e}	20.02	41.40
TS6	47.69^{e}	47.85^{e}	45.69^{e}	42.10^{d}	39.25^{e}	37.52^{d}	21.32	43.35
TS7	54.01^{a}	53.87^{a}	51.25^{a}	50.98^{a}	49.65^{a}	47.74^{a}	11.60	51.25

C.15 Changes in 'a*' (green – red) value of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TP1	0.93^{f}	0.94^{d}	0.95^{f}	0.97^{f}	0.99^{f}	1.01^{f}	8.60	0.97
TP2	0.64^{g}	0.65^{d}	0.65^{g}	0.66^{g}	0.68^{g}	0.71^{g}	10.94	0.67
TP2	5.49^{a}	5.60^{a}	5.75^{a}	5.80^{a}	5.88^{a}	6.37^{a}	16.03	5.82
TP4	2.27^{d}	2.29^{c}	2.35^{d}	2.41^{d}	2.43^{d}	2.51^{d}	10.57	2.38
TP5	3.70^{b}	3.75^{b}	3.79^{b}	3.85^{b}	3.94^{b}	4.10^{b}	10.81	3.86
TP6	3.45^{c}	3.54^{b}	3.64^{c}	3.69^{c}	3.71^{c}	3.80^{c}	10.14	3.64
TP7	1.64^{e}	1.69^{c}	1.71^{e}	1.73^{e}	1.74^{e}	1.79^{e}	9.15	1.72

C.16 Changes in 'a*' (green – red) value of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% increase	Mean
TS1	4.01^{g}	4.14^{g}	4.38^{g}	4.49^{g}	4.71^{g}	4.81^{g}	19.95	4.42
TS2	5.14^{e}	5.32^{e}	5.77^{e}	5.94^{e}	6.02^{e}	6.22^{e}	21.01	5.74
TS3	16.15^{a}	16.32^{a}	17.23^{a}	17.51^{a}	18.93^{a}	20.98^{a}	29.91	17.85
TS4	4.23^{f}	4.32^{f}	4.54^{f}	4.87^{f}	5.04^{f}	5.24^{f}	23.88	4.71
TS5	11.32^{b}	11.48^{b}	11.96^{b}	12.41^{b}	12.56^{b}	14.04^{b}	24.03	12.30
TS6	8.98^{d}	9.04^{d}	9.46^{d}	9.87^{d}	10.87^{d}	11.48^{d}	27.84	9.95
TS7	9.77^{c}	9.99^{c}	10.21^{c}	10.54^{c}	11.13^{c}	12.32^{c}	26.10	10.66

C.17 Changes in 'b*' (green – red) value of pasteurized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatments	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	18.08^{b}	18.02^{b}	17.85^{b}	17.31^{b}	17.20^{ab}	17.01^{b}	5.92	17.58
TP2	16.46^{e}	16.12^{e}	16.07^{e}	15.36^{e}	15.28^{cd}	15.04^{e}	8.63	15.72
TP3	13.71^{g}	13.66^{g}	13.25^{g}	12.92^{g}	12.51^{e}	12.41^{g}	9.48	13.08
TP4	17.14^{d}	17.01^{d}	16.85^{d}	16.81^{c}	16.32^{bc}	15.91^{d}	7.18	16.67
TP5	15.65^{f}	15.51^{f}	15.22^{f}	14.96^{f}	14.87^{d}	14.37^{f}	8.18	15.10
TP6	17.62^{c}	17.25^{c}	17.14^{c}	16.56^{d}	16.25^{bc}	16.04^{c}	8.97	16.81
TP7	18.88^{a}	18.32^{a}	18.25^{a}	18.14^{a}	17.94^{a}	17.56^{a}	6.99	18.18

C.18 Changes in 'b*' (green – red) value of sterilized and retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

	Storage interval (days)							
Treatment	0	15	30	45	60	90	% decrease	Mean
TS1	15.32^{c}	14.21^{c}	14.25^{b}	13.84^{b}	13.24^{bc}	12.95^{bc}	15.47	13.97
TS2	14.24^{f}	13.84^{d}	13.14^{e}	12.25^{f}	11.95^{d}	11.88^{d}	16.57	12.88
TS3	11.24^{g}	10.85^{e}	10.01^{g}	9.94^{g}	9.36^{e}	8.95^{e}	20.37	10.06
TS4	14.36^{e}	13.84^{d}	13.12^{f}	12.87^{e}	12.36^{d}	11.85^{d}	17.48	13.07
TS5	14.98^{d}	13.84^{d}	13.57^{d}	12.95^{d}	12.58^{cd}	12.25^{bc}	18.22	13.36
TS6	15.98^{a}	14.32^{b}	13.85^{c}	13.78^{c}	13.54^{ab}	12.95^{bc}	18.96	14.07
TS7	15.74^{b}	15.11^{a}	14.85^{a}	14.54^{a}	13.91^{ab}	13.21^{a}	16.07	14.56

C.19 Changes in crude fibre content of pasteurized retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TP1	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	0.85	2.34
TP2	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.89	2.34
TP3	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	0.89	2.34
TP4	2.36[a]	2.35[a]	2.35[a]	2.35[a]	2.34[a]	2.34[a]	0.85	2.35
TP5	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34
TP6	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34
TP7	2.36[a]	2.35[a]	2.35[a]	2.35[a]	2.34[a]	2.34[a]	0.85	2.35

C.20 Changes in crude fibre content of sterilized retort packed tender jackfruit and its interaction between thermal processing, treatments and storage period.

Treatment	Storage interval (days)							
	0	15	30	45	60	90	% decrease	Mean
TS1	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34
TS2	2.35[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	2.33[a]	0.85	2.34
TS3	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	0.85	2.34
TS4	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34
TS5	2.35[a]	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	0.85	2.34
TS6	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34
TS7	2.35[a]	2.34[a]	2.34[a]	2.34[a]	2.33[a]	2.33[a]	0.85	2.34

C.21 Bacterial count (10^1 cfu g^{-1}) during the storage period

Treatment	Storage interval (days)											
	0		15		30		45		60		90	
	55°C	37°C	55°C	37°C	55°C	37°C	55°C	37°C	55°C	37°C	55°C	37°C
TP1	0	0	0	0	0	0	0	0	0	0	0	0
TP2	0	0	0	0	0	0	0	0	0	0	0	0
TP3	0	0	0	0	0	0	0	0	0	0	0	0
TP4	0	0	0	0	0	0	0	0	0	1	0	2
TP5	0	0	0	0	0	0	0	0	0	2	0	3
TP6	0	0	0	0	0	0	0	0	0	0	0	0
TP7	0	0	0	0	0	0	0	0	0	0	0	0
TS1	0	0	0	0	0	0	0	0	0	0	0	0
TS2	0	0	0	0	0	0	0	0	0	0	0	0
TS3	0	0	0	0	0	0	0	0	0	0	0	0
TS4	0	0	0	0	0	0	0	0	0	0	0	0
TS5	0	0	0	0	0	0	0	0	0	0	0	0
TS6	0	0	0	0	0	0	0	0	0	0	0	0
TS7	0	0	0	0	0	0	0	0	0	0	0	0

C.22 Fungus and Yeast count (10^1 cfu g^{-1}) during the storage period

Treatment	Storage interval (days)											
	0		15		30		45		60		90	
TP1	F	Y	F	Y	F	Y	F	Y	F	Y	F	Y
TP2	0	0	0	0	0	0	0	0	0	0	0	0
TP3	0	0	0	0	0	0	0	0	0	0	0	0
TP4	0	0	0	0	0	0	0	0	0	0	0	0
TP5	0	0	0	0	0	0	0	0	0	0	0	0
TP6	0	0	0	0	0	0	0	0	0	0	0	0
TP7	0	0	0	0	0	0	0	0	0	0	0	0
TS1	0	0	0	0	0	0	0	0	0	0	0	0
TS2	0	0	0	0	0	0	0	0	0	0	0	0
TS3	0	0	0	0	0	0	0	0	0	0	0	0
TS4	0	0	0	0	0	0	0	0	0	0	0	0
TS5	0	0	0	0	0	0	0	0	0	0	0	0
TS6	0	0	0	0	0	0	0	0	0	0	0	0
TS7	0	0	0	0	0	0	0	0	0	0	0	0

F – Fungus Y- yeast

C.23. ANOVA table for changes in TSS of pasteurized retort packed tender jackfruit

Days	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	1.439	6	0.240	2650.789	S
	Within Groups	0.001	14	0.000		
	Total	1.440	20			
15	Between Groups	1.379	6	0.230	2681.833	S
	Within Groups	0.001	14	0.000		
	Total	1.380	20			
30	Between Groups	1.435	6	0.239	2283.000	S
	Within Groups	0.001	14	0.000		
	Total	1.436	20			
45	Between Groups	1.434	6	0.239	2788.833	S
	Within Groups	0.001	14	0.000		
	Total	1.435	20			
60	Between Groups	1.461	6	0.244	2435.000	S
	Within Groups	0.001	14	0.000		
	Total	1.462	20			
90	Between Groups	1.436	6	0.239	2393.000	S
	Within Groups	0.001	14	0.000		
	Total	1.437	20			

S : Significant
NS : Non significant

C.24. ANOVA table for changes in TSS content of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.494	6	0.082	823.857	S
	Within Groups	0.001	14	0.000		
	Total	0.496	20			
15	Between Groups	0.475	6	0.079	791.429	S
	Within Groups	0.001	14	0.000		
	Total	0.476	20			
30	Between Groups	0.452	6	0.075	753.429	S
	Within Groups	0.001	14	0.000		
	Total	0.453	20			
45	Between Groups	0.470	6	0.078	783.857	S
	Within Groups	0.001	14	0.000		
	Total	0.472	20			
60	Between Groups	0.455	6	0.076	757.714	S
	Within Groups	0.001	14	0.000		
	Total	0.456	20			
90	Between Groups	0.493	6	0.082	822.429	S
	Within Groups	0.001	14	0.000		
	Total	0.495	20			

S : Significant
NS : Non significant

C.25. ANOVA table for changes in firmness of pasteurized retort packed tender jackfruit

Days	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	307.802	6	51.300	179.506	S
	Within Groups	4.001	14	0.286		
	Total	311.803	20			
15	Between Groups	296.102	6	49.350	32900.229	S
	Within Groups	0.021	14	0.001		
	Total	296.123	20			
30	Between Groups	346.227	6	57.704	201.915	S
	Within Groups	4.001	14	0.286		
	Total	350.228	20			
45	Between Groups	321.330	6	53.555	239.599	S
	Within Groups	3.129	14	0.224		
	Total	324.459	20			
60	Between Groups	369.674	6	61.612	86.771	S
	Within Groups	9.941	14	0.710		
	Total	379.615	20			
90	Between Groups	289.592	6	48.265	405487.68	S
	Within Groups	0.002	14	0.000		
	Total	289.594	20			

S : Significant
NS : Non significant

C.26. ANOVA table for changes in firmness of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	28.787	6	4.798	33.226	S
	Within Groups	2.022	14	144		
	Total	30.809	20			
15	Between Groups	35.192	6	5.865	20.524	S
	Within Groups	4.001	14	286		
	Total	39.193	20			
30	Between Groups	35.269	6	5.878	41.122	S
	Within Groups	2.001	14	143		
	Total	37.270	20			
45	Between Groups	42.440	6	7.073	70732.14	
	Within Groups	0.001	14	0.000		
	Total	42.441	20			
60	Between Groups	39.818	6	6.636	66362.857	S
	Within Groups	0.001	14	0.000		
	Total	39.819	20			
90	Between Groups	26.684	6	4.442	44424.000	S
	Within Groups	0.001	14	0.000		
	Total	26.656	20			

S : Significant
NS : Non significant

C.27. ANOVA table for changes in toughness value of pasteurized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	409.732	6	68.289	468.464	S
	Within Groups	2.041	14	0.146		
	Total	411.773	20			
15	Between Groups	399.685	6	66.614	465.927	S
	Within Groups	2.002	14	0.143		
	Total	401.687	20			
30	Between Groups	473.899	6	78.983	185.481	S
	Within Groups	5.962	14	0.426		
	Total	479.86	20			
45	Between Groups	307.233	6	51.205	358.259	S
	Within Groups	2.001	14	0.143		
	Total	309.234	20			
60	Between Groups	421.048	6	70.175	545802.78	S
	Within Groups	0.002	14	0.000		
	Total	421.05	20			
90	Between Groups	694.622	6	115.77	2426.083	S
	Within Groups	0.668	14	0.048		
	Total	695.29	20			

S : Significant
NS : Non significant

C.28. ANOVA table for changes in toughness of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	111.857	6	18.643	129.144	S
	Within Groups	2.021	14	0.144		
	Total	113.878	20			
15	Between Groups	100.194	6	16.699	146116.88	S
	Within Groups	0.002	14	0		
	Total	100.196	20			
30	Between Groups	113.928	6	18.988	102243	S
	Within Groups	0.003	14	0		
	Total	113.931	20			
45	Between Groups	103.052	6	17.175	11450.2	S
	Within Groups	0.021	14	0.001		
	Total	103.073	20			
60	Between Groups	98.665	6	16.444	164441.71	S
	Within Groups	0.001	14	0		
	Total	98.666	20			
90	Between Groups	88.379	6	14.73	103.047	S
	Within Groups	2.001	14	0.143		
	Total	90.381	20			

S : Significant
NS : Non significant

C.29. ANOVA table for changes in titrable acidity of pasteurized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.592	6	0.099	987.429	S
	Within Groups	0.001	14	0.000		
	Total	0.594	20			
15	Between Groups	0.592	6	0.099	1152.000	S
	Within Groups	0.001	14	0.000		
	Total	0.594	20			
30	Between Groups	0.296	6	0.049	11.406	S
	Within Groups	0.061	14	0.004		
	Total	0.357	20			
45	Between Groups	0.407	6	0.068	7.868	S
	Within Groups	0.121	14	0.009		
	Total	0.528	20			
60	Between Groups	0.609	6	0.102	30.111	S
	Within Groups	0.047	14	0.003		
	Total	0.656	20			
90	Between Groups	0.593	6	0.099	22.840	S
	Within Groups	0.061	14	0.004		
	Total	0.653	20			

S : Significant
NS : Non significant

C.30. ANOVA table for changes in titrable acidity of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.506	6	0.084	843.429	S
	Within Groups	0.001	14	0.000		
	Total	0.507	20			
15	Between Groups	0.506	6	0.084	843.429	S
	Within Groups	0.001	14	0.000		
	Total	0.507	20			
30	Between Groups	0.407	6	0.068	678.857	S
	Within Groups	0.001	14	0.000		
	Total	0.409	20			
45	Between Groups	0.383	6	0.064	42.113	S
	Within Groups	0.021	14	0.002		
	Total	0.404	20			
60	Between Groups	0.506	6	0.084	57.320	S
	Within Groups	0.21	14	0.001		
	Total	0.527	20			
90	Between Groups	0.506	6	0.084	28.800	S
	Within Groups	0.041	14	0.003		
	Total	0.547	20			

S : Significant
NS : Non significant

C.31. ANOVA table for changes in vitamin C value of pasteurized retort packed tender jackfruit

Day		Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	10.821	6	1.803	12.617	S
	Within Groups	2.001	14	1.143		
	Total	12.822	20			
15	Between Groups	11.047	6	1.841	18411.714	S
	Within Groups	0.001	14	0.000		
	Total	11.048	20			
30	Between Groups	10.825	6	1.804	18042.000	S
	Within Groups	0.001	14	0.000		
	Total	10.827	20			
45	Between Groups	11.173	6	1.862	21725.667	S
	Within Groups	0.001	14	0.000		
	Total	11.174	20			
60	Between Groups	11.107	6	1.851	18511.000	S
	Within Groups	0.001	14	0.000		
	Total	11.108	20			
90	Between Groups	11.266	6	1.878	21905.833	S
	Within Groups	0.001	14	0.000		
	Total	11.267	20			

S : Significant
NS : Non significant

C.32. ANOVA table for changes in Vitamin C of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	10.865	6	1.811	18108.429	S
	Within Groups	0.001	14	0.000		
	Total	10.866	20			
15	Between Groups	10.93	6	1.822	21252.5	S
	Within Groups	0.001	14	0.000		
	Total	10.931	20			
30	Between Groups	10.616	6	1.769	17693.714	S
	Within Groups	0.001	14	0.000		
	Total	10.618	20			
45	Between Groups	10.724	6	1.787	4265.386	S
	Within Groups	0.006	14	0.000		
	Total	10.73	20			
60	Between Groups	11.013	6	1.835	18354.714	S
	Within Groups	0.001	14	0.000		
	Total	11.014	20			
90	Between Groups	11.672	6	1.945	1284.689	S
	Within Groups	0.021	14	0.002		
	Total	11.694	20			

S : Significant
NS : Non significant

C.33. ANOVA table for changes in pH value of pasteurized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	1.358	6	0.226	2263.7140	S
	Within Groups	0.001	14	0.000		
	Total	1.360	20			
15	Between Groups	1.792	6	0.299	26.491	S
	Within Groups	0.158	14	0.011		
	Total	1.950	20			
30	Between Groups	1.478	6	0.246	2463.714	S
	Within Groups	0.001	14	0.000		
	Total	1.480	20			
45	Between Groups	1.486	6	0.248	2476.429	S
	Within Groups	0.001	14	0.000		
	Total	1.487	20			
60	Between Groups	1.503	6	0.250	2504.714	S
	Within Groups	0.001	14	0.000		
	Total	1.504	20			
90	Between Groups	1.500	6	0.250	2499.714	S
	Within Groups	0.001	14	0.000		
	Total	1.501	20			

S : Significant
NS : Non significant

C.34. ANOVA table for changes in pH of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.408	6	0.068	680.429	0.000
	Within Groups	0.001	14	0.000		
	Total	0.410	20			
15	Between Groups	0.429	6	0.071	714.429	0.000
	Within Groups	0.001	14	0.000		
	Total	0.430	20			
30	Between Groups	0.426	6	0.071	710.000	0.000
	Within Groups	0.001	14	0.000		
	Total	0.427	20			
45	Between Groups	0.399	6	0.067	665.429	0.000
	Within Groups	0.001	14	0.000		
	Total	0.401	20			
60	Between Groups	0.411	6	0.068	684.857	0.000
	Within Groups	0.001	14	0.000		
	Total	0.412	20			
90	Between Groups	0.414	6	0.069	689.857	0.000
	Within Groups	0.001	14	0.000		
	Total	0.415	20			

S : Significant
NS : Non significant

C.35. ANOVA table for changes in L* value of pasteurized retort packed tender jackfruit.

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	926.800	6	154.467	1544666.857	S
	Within Groups	0.001	14	0.000		
	Total	926.802	20			
15	Between Groups	920.137	6	153.356	1051.722	S
	Within Groups	2.041	14	0.146		
	Total	922.178	20			
30	Between Groups	896.276	6	149.379	1045.028	S
	Within Groups	2.001	14	0.143		
	Total	898.277	20			
45	Between Groups	923.070	6	153.845	1059.191	S
	Within Groups	2.033	14	0.145		
	Total	925.104	20			
60	Between Groups	1003.692	6	167.282	1170.388	S
	Within Groups	2.001	14	0.143		
	Total	1005.693	20			
90	Between Groups	926.897	6	154.483	1544829.000	S
	Within Groups	0.001	14	0.000		
	Total	926.899	20			

S : Significant
NS : Non significant

C.36. ANOVA table for changes in L* value of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	439.521	6	73.253	483.612	S
	Within Groups	2.121	14	0.151		
	Total	441.641	20			
15	Between Groups	504.754	6	84.126	257.174	S
	Within Groups	4.101	14	0.293		
	Total	508.555	20			
30	Between Groups	587.997	6	98.000	65333.048	S
	Within Groups	0.021	14	0.001		
	Total	588.018	20			
45	Between Groups	678.069	6	113.011	393.494	S
	Within Groups	4.021	14	0.287		
	Total	682.089	20			
60	Between Groups	773.614	6	128.936	17979.078	S
	Within Groups	0.100	14	0.007		
	Total	773.714	20			
90	Between Groups	732.707	6	122.118	423.139	S
	Within Groups	4.040	14	0.289		
	Total	736.748	20			

S : Significant
NS : Non significant

C.37. ANOVA table for changes in a* value of pasteurized retort packed tender jackfruit.

Day	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	53.834	6	8.972	104677.333	S
	Within Groups	0.001	14	0.000		
	Total	53.835	20			
15	Between Groups	56.036	6	9.339	64.031	S
	Within Groups	2.042	14	0.146		
	Total	58.078	20			
30	Between Groups	59.408	6	9.901	115514.833	S
	Within Groups	0.001	14	0.000		
	Total	59.409	20			
45	Between Groups	60.393	6	10.065	6464.064	S
	Within Groups	0.022	14	0.002		
	Total	60.415	20			
60	Between Groups	61.913	6	10.319	10387.714	S
	Within Groups	0.001	14	0.000		
	Total	61.914	20			
90	Between Groups	72.130	6	12.022	1666.366	S
	Within Groups	0.101	14	0.007		
	Total	72.231	20			

S : Significant

NS : Non significant

C.38. ANOVA table for changes in a* value of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	353.998	6	59.000	589996.857	S
	Within Groups	0.001	14	0.000		
	Total	354.000	20			
15	Between Groups	356.889	6	59.481	693950.167	S
	Within Groups	0.001	14	0.000		
	Total	356.890	20			
30	Between Groups	389.388	6	64.898	1135714.00	S
	Within Groups	0.001	14	0.000		
	Total	389.388	20			
45	Between Groups	398.848	6	66.475	664745.857	S
	Within Groups	0.001	14	0.000		
	Total	398.849	20			
60	Between Groups	470.041	6	78.340	913967.667	S
	Within Groups	0.001	14	0.000		
	Total	470.042	20			
90	Between Groups	613.907	6	102.318	1023178.07	S
	Within Groups	0.001	14	0.000		
	Total	613.909	20			

S : Significant
NS : Non significant

C.39. ANOVA table for changes in b* value of pasteurized retort packed tender jackfruit

Days	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	53.215	6	8.869	103474.500	S
	Within Groups	0.001	14	0.000		
	Total	53.217	20			
15	Between Groups	46.841	6	7.807	78068.857	S
	Within Groups	0.001	14	0.000		
	Total	46.843	20			
30	Between Groups	53.084	6	8.847	103219.500	S
	Within Groups	0.001	14	0.000		
	Total	53.086	20			
45	Between Groups	25.487	6	4.248	1.813	S
	Within Groups	32.808	14	2.343		
	Total	58.296	20			
60	Between Groups	33.922	6	6.654	15.678	S
	Within Groups	5.941	14	0.424		
	Total	45.863	20			
90	Between Groups	54.049	6	9.008	63057.200	S
	Within Groups	0.002	14	0.000		
	Total	54.051	20			

S : Significant
NS : Non significant

C.40. ANOVA table for changes in b* value of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	45.981	6	7.664	76635.429	S
	Within Groups	.001	14	0.000		
	Total	45.983	20			
15	Between Groups	32.437	6	5.406	66781.196	S
	Within Groups	0.001	14	0.000		
	Total	32.438	20			
30	Between Groups	43.646	6	7.274	101841.400	S
	Within Groups	0.001	14	0.000		
	Total	43.647	20			
45	Between Groups	40.598	6	6.766	78940.667	S
	Within Groups	0.001	14	0.000		
	Total	40.599	20			
60	Between Groups	46.905	6	7.817	40.417	S
	Within Groups	2.708	14	0.193		
	Total	49.613	20			
90	Between Groups	38.626	6	6.438	8953.199	S
	Within Groups	0.010	14	0.001		
	Total	38.636	20			

S : Significant
NS : Non significant

C.41. ANOVA table for changes in crude fibre of pasteurized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.000	6	0.000	0.000	NS
	Within Groups	0.001	14	0.000		
	Total	0.001	20			
15	Between Groups	0.001	6	0.000	0.857	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
30	Between Groups	0.000	6	0.000	0.429	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
45	Between Groups	0.000	6	0.000	0.429	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
60	Between Groups	0.001	6	0.000	0.857	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
90	Between Groups	0.000	6	0.000	0.429	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			

S : Significant
NS : Non significant

C.42 ANOVA table for changes in crude fibre content of sterilized retort packed tender jackfruit

Day	Sources of variation	Sum of Squares	df	Mean Square	F	Sig.
0	Between groups	0.000	6	0.000	0.000	NS
	Within Groups	0.001	14	0.000		
	Total	0.001	20			
15	Between Groups	0.000	6	0.000	0.429	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
30	Between Groups	0.000	6	0.000	0.714	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
45	Between Groups	0.000	6	0.000	0.579	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
60	Between Groups	0.001	6	0.000	1.714	NS
	Within Groups	0.001	14	0.000		
	Total	0.002	20			
90	Between Groups	0.001	6	0.000	1.857	NS
	Within Groups	0.001	14	0.000		
	Total	0.003	20			

S : Significant
NS : Non significant

APPENDIX D

Cost of retort processing

1. Cost of operation of plant/hr

Cost of machineries

i) Retorting autoclave and other accessories	: Rs.9,00,000/-
Initial cost (C)	: Rs. 9,00,000/-

Assumptions

Useful life (L)	: 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	: Rs. 5.2/unit
Labour wages (8 working hours/day)	: Rs.300/day
Cost of a pouch	: Rs.4/-
Time for peeling, cutting and blanching of a tender jack fruit (t1)	: 15 minutes
Time for filling and sealing the cans (t2)	: 3 minutes

a. Fixed cost

i) Depreciation	: $\frac{C-S}{L}$
	: Rs.54,000/year
ii) Interest on average investment	: Rs.59,400/year
iii) Insurance and taxes	: Rs.18,000/year
Total fixed cost	: Rs.1,31,400/year

b. Variable cost

i) Repair and Maintenance	: Rs.45000/-
ii) Electricity cost	
Total power consumption	: 8 HP = 6 kW
Cost of energy consumption/ year : $\frac{\text{power} \times \text{duration} \times \text{cost of one unit}}{1000}$	:
	: Rs.62,400/-
iii) Annual labour cost	: Rs.75,000/year
Total variable cost	: ` Rs.1,82,400/year
Total cost	: Fixed cost + Variable cost
	: Rs.3,13,800/year
Cost of operation of plant/hr (C_{oper})	: $\frac{\text{Total cost}}{T}$
	: Rs.156.90/-
Number of batches required for retorting 100 pouches (n)	: 2
Time required for canning under pasteurization temperature (tp)	: 24 minutes
Time required for retoring under sterilization temperature (ts)	: 15 minutes
Total cost of packing operation (C_{pouch})	: $\frac{Coper \times n \times tp(\,or\ ts)}{60}$
	: Rs.125.52/-

2. Labor cost for tender jackfruit

Cost of 100 pouches (Cp)	: Rs.400/-
Quantity of tender jack fruit bulbs	: 14 kg

Number of tender jackfruits required (Nj)	: 20
Cost of tender jackfruit, CTJ (10/ kg)	: Rs.250/-
Time required for peeling, cutting and Blanching	: 5 hrs
Total number of pouches (Nc)	: 100
Time required for filling and sealing the pouchs :	: 5 hrs
Total working hours	: 10 hrs
Labour cost wages (CL)	: $\frac{10 \times 300}{8}$
	: Rs. 375/-
Total expenditure for retorting 100 pouches of tender jackfruit	: $C_L + Cp + C_{TJ} + C_{pouch}$
	: 375 + 400 + 250+ 126
	: Rs.1151
Total expenditure for canning single tender jackfruit pouch	≈ Rs.**11.51/-**

DEVELOPMENT AND QUALITY EVALUATION OF RETORT POUCH PACKED TENDER JACKFRUIT (*Artocarpus heterophyllus* L.).

By
Praveena. N
(2013-18-103)

ABSTRACT OF THE THESIS

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In

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Department of Food & Agricultural Process Engineering
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
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ABSTRACT

Jackfruit is a seasonal organic fruit and it is popularly used as vegetable in its tender stage. Though it is a highly nutritious commodity, post harvest wastage is huge due to its perishable nature. 'Koozha' jackfruit can be better used in tender stage since the wastage of ripened 'Koozha' variety jackfruit is more compared to 'Varikka'. The significant wastage of 'Koozha' variety is because of less consumer acceptance due to its poor texture after ripening, necessitated the design of a viable processing and packaging technology to extend its shelf life. Hence the present study on "Development and quality evaluation of retort pouch packed tender jackfruit (*Artocarpus heterophyllus* L.)" was undertaken with specific objectives of standardization of blanching process, standardization of thermal process in retort pouch package, shelf life study and quality evaluation of retort pouch packed tender jackfruit. Blanching treatment was optimized as three minutes with 0.3% citric acid preservative based on the enzyme test and the results of the quality parameters like texture, colour and crude fibre content. The standardized thermal process time for pasteurization at 90°C to reach F_{10} was 24 minutes and for sterilization at 121°C for attaining F_0 value one was 15 minutes. After optimal blanching, the samples were packed in retort pouches with prior addition of preservatives like brine (2%), citric acid (0.3%), KMS (0.1%) and their combination using the optimized thermal process time - temperature. Shelf life study and quality evaluation in terms of TSS, titrable acidity, pH, vitamin C, crude fibre, texture and colour were done. The experiments were statistically analyzed with one way ANOVA. The samples preserved in citric acid exhibited good quality attributes and better acceptability in sensory evaluation. Microbial analysis also showed that the product was safe upto 90 days of storage. It was concluded that 0.3% citric acid blanching and 0.3% citric acid preservative as filling solution was best in terms of quality parameters and microbial analysis for the development of thermally processed and retort packed tender jackfruit. The cost of operation per pouch (140 g) for tender jackfruit was calculated as Rs. 11.51/-. This

study is useful for the production of good quality, safe, affordable priced tender jackfruit in ready to cook form throughout the year.