DEVELOPMENT AND QUALITY EVALUATION OF THERMALLY PROCESSED CASSAVA IN RETORT POUCH

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THESIS

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND

TECHNOLOGY, TAVANUR – 679573

KERALA, INDIA

2018

DECLARATION

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

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Date:

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CERTIFICATE

Certified that this thesis entitled **"Development and Quality Evaluation of Thermally Processed Cassava in Retort Pouch"** is a bonafide record of research work done independently by Er. Rasmi Janardhanan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory Committee of **Er. Rasmi Janardhanan (2016-18-005)**, a candidate for the degree of Master of Technology in Agricultural Engineering with major in Agricultural Processing and Food Engineering, agree that the thesis entitled **"Development and Quality Evaluation of Thermally Processed Cassava in Retort Pouch"** may be submitted by **Er. Rasmi Janardhanan**, in partial fulfillment of the requirement for the degree.

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LIST OF SYMBOLS AND ABBREVATIONS

%	: Per cent
&	: And
/	: Per
°	: Degree
° C	: Degree Celsius
µs	: Micro second
ANOVA	: Analysis of variance
AOAC	: Association of Official Analytical Chemists
cfu	: Colony forming unit
cm	: Centimetre
cm^3	: Cubic centimetes
CO_2	: Carbon-di-oxide
CoH	: College of Horticulture
CRD	: Completely randomised design
dm	: Decimetre
et al.	: And others
etc.	: Etcetera
FAO	: Food and Agriculture Organisation of the United Nations
FDA	: Food and Drug Administration
FFA	: Free fatty acid
Fig.	: Figure

g	: Gram
GC	: Gas chromatography
GOK	: Government of Kerala
h	: Hour
H_2SO_4	: Sulphuric acid
ha	: Hectare
HCN	: Hydrogen cyanide
HPLC	: High performance liquid chromatography
Hz	: Hertzs
KAU	: Kerala Agricultural University
KCAET	: Kelappaji College of Agricultural Engineering and Technology
kg	: Kilogram
kg.s	: Kilogram second
kg/ha	: Kilogram per hectare
kg^{-1}	: Per kilogram
kGy	: Kilogray
km^2	: Square kilometer
kV	: Kilovolt
l	: Litre
m	: Metre
M	: Molar
m^{-1}	: per metre

MAP	: Modified atmosphere packaging
mg	: Milligram
min	: Minutes
ml	: Millilitre
mm	: Millimetre
MPa	: Mega pascal
N	: Newton
N	: Normal
n.d	: no date
NaOH	: Sodium hydroxide
nm	: Nanometre
No.	: Number
$^{o}C^{-1}$	: Per degree Celsius
PDA	: Potato dextrose agar
PEF	: Pulsed electric field
PP	: Polypropylene
PPD	: Physiological post harvest deterioration
ppm	: Parts per million
s	: Second
TPC	: Total plate count
TNAU	: Tamil Nadu Agricultural University
UHT	: Ultra high temperature

V	: Volt
viz.	: *Videlicet*
wb	: wet basis
yr	: Year(s)

CHAPTER I

INTRODUCTION

India is the second largest producer of fruits and vegetables in the world, but the production of processed products is less than 2 per cent of the total production (Sudheer and Indira, 2018). Fruits and vegetable sector can be boosted by improving the processing techniques and its value addition.

As per the global scenario, cereals are considered as the most important food crop, followed by roots and tuber crops (Edison *et al.*, 2006). Majority of the calorie demand is also met by cereals followed by tuber crops. Tuber crops have a higher production potential in humid regions compared to cereals (Balagopalan, 2002). Tuber crops like cassava, yam, sweet potato are some of the under tapped vegetables which can be processed and value added so that their market potential could be improved.

Cassava (*Manihot esculenta Crantz*), a tropical root crop is consumed and cultivated in around 102 countries around the world (Dinakaran *et al.*, 2017). It is a staple for more than 500 million people (Falade and Akingbala, 2010). Cassava is a stress resistant crop cultivated mostly in Africa and tropical countries. Annual production statistics of tapioca, sweet potato and potato are very high in developing countries such that these tuber crops come under the first positions when production volume is considered (Mesta *et al.*, 2017). Cassava is the third-most important tropical crop after rice and maize, providing livelihoods and food security for hundreds of millions of people in the tropical regions (Hyman *et al.*, 2012). It can be cultivated in most of the soil types and climate should be such that the temperature is around 25-30ºC and the area receives an annual rainfall of about 800 mm. The input labour requirement is also comparatively less and infestation by pests and diseases are also considerably less (Coursey and Haynes, 1970). India stood eighth in the world production of cassava for the year 2016, with a total production of 4.55 million tonnes in an area of 0.204 million hectares (FAO, 2018). The total area of cultivation in Kerala during the year 2016-17 is 0.069 million hectares, with a total production of 2.51 million tonnes (GOK, 2017).

Cassava has several health benefits which include the ability to help in healthy weight gain, increase blood circulation and red blood cell count, protect against birth defects, improve digestion, lower cholesterol, protects heart health and maintains fluid balance within the body. Therefore effort has to be put in so that cassava is made available to all the people year-round either in raw, preserved or processed manner (Dinakaran *et al.*, 2017).

According to studies by various researchers, unique phenomena known as post harvest physiological deterioration (PPD) sets in immediately after harvesting the crop. This is linked to oxidative burst and enzymatic stress response to wounding (Beeching *et al.*, 2002). The development of dark bluish, brownish and black radical veins or streaks found as a ring around the inner part of the pith signals the same which leads to the deterioration of nutritional values, colour and taste (Andres and Dimuth, 2011). The tuber is not marketable after 48 to 72 h as the process of deterioration starts minutes after harvesting the crop which adversely affects the farmers, consumers and processors (Reilly *et al.*, 2007).

Fresh cassava roots are traditionally marketed without post-harvest treatment or protection and therefore have to reach the consumer within a very short time before deterioration becomes visible. The negative effects of the rapid deterioration of fresh roots reduce its market value which particularly discourages consumption of cassava in urban areas where the roots have to compete with other foodstuffs (Janssen and Wheatley, 1985). It is an excellent dietary source of energy in tropical countries and is regarded as a "famine reserve crop" and "food security crop" in many parts of the world. Since cassava is considered as poor man's crop, significant research and development works are remarkably less. This reduced scientific aspiration has led to very poorly developed processing methods for cassava (Uarrota and Maraschin, 2015).

The lack of proper post harvest technology during harvesting and storage results in post harvest losses; in India the post harvest loss in cassava is 9.8 per cent (DARE, 2018). To avoid wastage and to ensure its availability throughout the year, the tubers should be properly processed and preserved by effective storage techniques.

Novel food processing technologies like thermal processing, high pressure processing, ohmic heating etc. have been developed for the preservation of food products, but wide acceptance has been attained by thermal processing alone (Chen and Ramaswamy, 2002). Thermal processing of foods implies the use of controlled application of heat energy to process and preserve foods and it is one of the major techniques used for manufacturing packaged shelf stable food products (Ahmad *et al.*, 2017). At present, the commercialisation of canned food is declining due to high cost of tin used for the production of cans (Nair and Girija, 1994; Dileep and Sudhakara, 2007; Srivasta *et al.*, 1993). Retort processing of foods is an advanced form of food preservation by thermal processing which imparts increased shelf life, good retention of nutrients and sensory parameters (Gokhale and Lele, 2012). Retort pouch can withstand thermal processing temperature (121°C) and combine the advantages of the metal can and plastic packaging. Being flexible they can be easily stacked in shelves and moreover, it reduces the transportation and storage cost over cans. The pouches provide a smooth surface for printing which adds its acceptability among the commercial producers (Dushyanthan, 2002).

The retort pouch is a packaging material that allows faster heat transfer than the traditional metal or glass containers, owing to their slimmer profile, or more specifically, the higher surface area to volume ratio (Awuah *et al.,* 2007; Rodriguez *et al.*, 2002). The same microbial lethality could be achieved with a 30-50 per cent shorter processing time, as compared to retorting of metal cans. Most retort pouches are constructed as four-ply laminates of different packaging films that can withstand high process temperature and pressure (Jun *et al.*, 2006).

Retort processed foods have an additional advantage that they could be stored for a period of several months without employing cold chain or preservatives. Being highly perishable, cassava tubers are to be processed or consumed immediately after harvesting. . Cassava tubers in retort pouches not only meet the demand but also ensure its availability throughout the year. Due to the low economic value of cassava, there is a lack of research in the field of technologies to extend the shelf life of cassava. Therefore to extend the shelf life of cassava, improve its economic value and to make it easily available to consumers in a ready to serve form, thermal processing could be employed. Due to the presence of varied amount of antinutrients, hyadrocyanic acid, in cassava different varieties require different pretreatments. With this point of view, a project was under taken at Kelappaji College of Agricultural Engineering and Technology, Tavanur to study the thermal processing of raw cassava tubers with the following objectives.

1. To analyse the physico-chemical properties of raw cassava tubers.

2. To optimise the process parameters of thermally processed cassava tubers *viz.,* time temperature combination.

3. To conduct the shelf life studies and the quality evaluation of thermally processed cassava tubers in retort pouch under ambient and refrigerated conditions.

CHAPTER II

REVIEW OF LITERATURE

A critical comprehensive review of literature is inevitable for any scientific investigation. A brief report of research works carried on the storage studies of cassava roots are reviewed and presented in this chapter.

2.1 CASSAVA (*Manihot esculenta Crantz)*

2.1.1 Origin and Distribution

Cassava was unknown to the old world before the discovery of America. Cassava (*Manihot esculenta Crantz*) belongs to the family *Euphorbiaceae* and is believed to have originated in South America (Edison *et al.*, 2006).

The crop was introduced into the Asian countries like Singapore, Malaya and Java during mid 17th century. The productions in some places were soon replaced by even more profitable cash crops (Edison *et al*., 2006).

The crown King of Travancore Sri Visakham Thirunal promoted the production of cassava in Kerala, the varieties fit for the climate of Kerala were selected and brought even from Malaysia (Edison *et al.*, 2006). Cassava is one of the most important starchy root-crop and is grown throughout the tropical world.

2.1.2 World Production and Trade

Cassava is a root crop which is produced widely in many parts of the world. It is a drought resistant crop which adapts to water stress. It is a staple food in the tropical regions. In Thailand, cassava is considered as a commercial crop (Santisopasri *et al.*, 2001; Nhassico *et al.*, 2008)

According to the world production statistics during the year 2016, cassava was harvested in an area of 23 Mha with a yield of 118 tonnes/ha. The total global production of cassava during 2016 was 277 million tonnes (FAO, 2018).

Nigeria was the leading producer of cassava in 2016 with a production volume of 40 million tonnes, followed by Brazil, Thailand and Indonesia with a production of 23, 22 and 19 million tonnes, respectively (Fig. 2.1 and 2.2). India stood eighth position in the world production of cassava for the year 2016, with a total production of 4.5 million tonnes (FAO, 2018).

Considering the continental breakdown of production data, it was observed that for the year 2016, Africa took the major share of production with 115 million tonnes of cassava, closely followed by America and Asia with a production of 65 and 31 million tonnes, respectively.

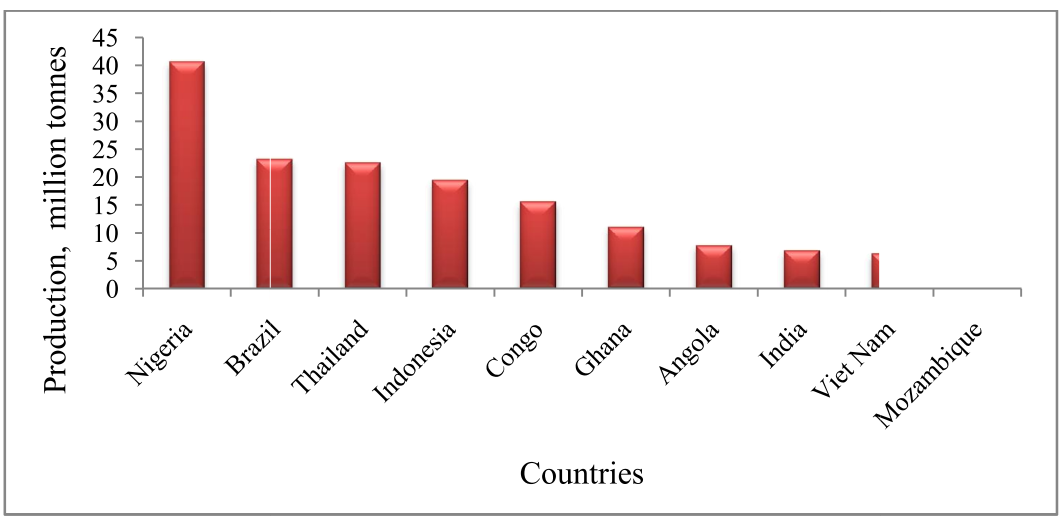


Figure 2.1 World production of cassava

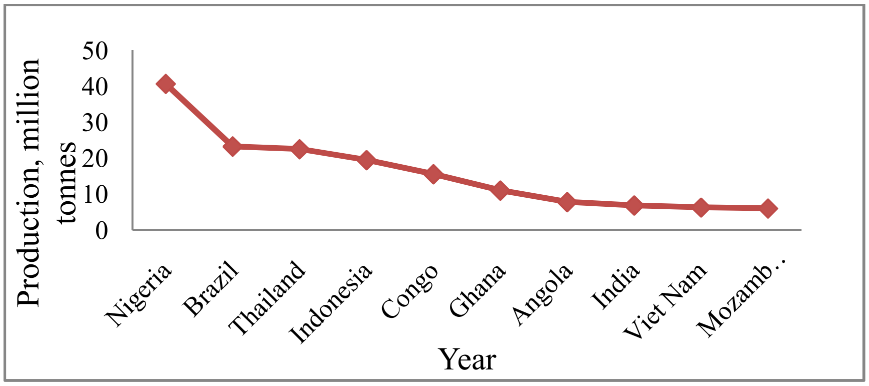


Figure 2.2 Year-wise world production data of cassava

2.1.3 World Cassava Utilisation and Consumption:

The world consumption of cassava during the year 2014 was 20.7 million tonnes and a FAO forecast for the year 2016 was about 21.0 million tonnes (FAO, 2016). In 2016, the consumption was marked to be lower than the forecast and it yielded to 20.3 million tonnes (FAO, 2017).

According to International Food Policy Research Institute (IFPRI), a future projection shows that the world utilisation of cassava will reach 275 million tonnes by the year 2020 (Westby, 2002).

Cassava roots can be boiled and consumed directly or used for the production of chips or other processed products. Cassava is a major source of carbohydrate in the human and animal diet. It is also used as animal feed (Westby, 2002).

2.1.4 Common Cassava Varieties in Kerala

There are several cassava varieties in Kerala and they are characterized based on their differences in colour of rind or flesh, size of tuber, duration of cropping, colour and pattern of stem, leaf and petiole and starch content

(Fregene *et al.*, 2003; Manu *et al.*, 2005). The common cassava varieties grown in Kerala include large variants of traditional, hybrid and improved cultivars (Edison *et al.*, 2006).

H-97:- It is a hybrid of local variety Manjavella and a Brazilian variant. It has conical stout tubers. The average yield is about 25-35 tonnes/ha. It contains approximately 27-29 per cent starch. It requires 10 months to reach maturity.

H-165:– It is a hybrid between two traditional varieties Chadayamangalam Vella and Kalikalan. This relatively unbranched variety has a yield of about 33-38 tonnes/ha. The time required to reach maturity is about 8-9 months.

H-226:– It is a hybrid of 'Etthhakka Karuppan" and M4. The crop has characteristic green leaves and it is tall in nature. In Tamil Nadu and Andhra Pradesh, H-165 and H-226 are cultivated largely considering their industrial value.

Sree Visakham (H 1687):- It is a hybrid variety between the local indigenous variant and the Madagascar variety. It has yellow coloured flesh due to the increased amount of carotene content in the tuber. The yield of this variety is about 35-38 tonnes/ha and the time required for cropping is about 7-8 months. The starch content is about 25-27 per cent.

Sree Sahya (H 2304):– It is a hybrid of 5 varieties. These tubers have creamy rind and a white colured flesh. Tuber yield is 35-40 tonnes/ha.

Sree Rekha (TCH 1) :- It is grown in both upland and low lying lands. The crop yield of this variant is about 48 t/ha. The starch content of the tuber is about 28 per cent.

Sree Prabha (TCH 2) :– It is the top cross hybrid of cassava. The tuber yields about, 42 tonnes/ha and its cooking quality is moderately good. The starch content in the tuber is about 26 per cent.

Sree Harsha :- These tubers have good cooking quality and the yield is found to be 35- 40 tonnes/ha. The starch content in this variety is 38-41 per cent.

M-4 :- The tuber has very good cooking qualities and it is a high yielding variety. The crop duration is 10 months.

Sree Jaya :- The tuber variety is an early maturing variety with seven months growth period.

2.1.5 Nutritive Value

Cassava roots are rich source of carbohydrate. Most of the carbohydrate is present as starch which is 31 per cent of fresh weight with smaller amounts of free sugars. The Cassava roots are low in protein (1.12 per cent) and fat (0.41 per cent), although higher concentrations of protein of 1.5 per cent have been reported by Ekpenyong (1984). Protein from other sources is therefore needed if cassava is to be part of a balanced diet. Cassava is generally considered to have a high content of dietary fibre, magnesium, sodium, riboflavin, thiamin, nicotinic acid and citrate (Bradbury and Holloway, 1988). The nutritive value of cassava is mentioned in the table 2.1.

Bitter varieties of cassava have about 30 per cent starch content. Cyanide is the most toxic factor restricting the consumption of cassava roots and leaves. Cassava leaves have a cyanide content (HCN) ranging from 53 to 1,300 mg/kg of dry weight and cassava root parenchyma has a range of 10 to 500 mg/kg of dry weight (Siritunga and Sayre, 2003).

Table 2.1 Nutritive value of cassava (Ekpenyong, 1984)

Properties	Values
Moisture (%wb)	70.25
Starch (%)	21.45
Sugar (%)	5.13
Protein (%)	1.12
Fat (%)	0.41
Fibre (%)	1.11
Ash (%)	0.54

2.1.6 Tuber Deterioration

Cassava is a remarkable tropical crop in which the deterioration onsets after 24-48 h followed by harvesting. The post harvest life of cassava is comparatively less and spoilage can be observed shortly (Janssen and Wheatley, 1985).

Averre (1967) reported that the deterioration in cassava can be considered to be imparted either by vascular streaking, due to post harvest physiological deterioration, or by microbial action.

Post harvest deterioration (PPD), has been found to be a major constraint, equally for farmers, distributors and consumers. The onset of this symptom in cassava roots leads to the vascular streaking which in turn leads to the unpleasant odour and colour development in the roots; the organoleptic properties of the tuber are largely affected by this phenomenon. The development of PPD depends on the cultivar and the growing conditions of the crop (Reilly *et al.*, 2007).

2.2 QUALITY PARAMETERS

2.2.1 pH

Cserhalmi *et al.* (2006) investigated the effect of pulsed electric field treatment on pH, degree brix, electrical conductivity, viscosity, non enzymatic browning index and other properties of citrus juices. It was found that when an electric field of strength 28 kV per cm was applied on the sample, there were no significant changes on non enzymatic browning index, electrical conductivity, pH, viscosity and degree brix.

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 per cm^2 till the centre of can attains these high temperatures.

2.2.2 Colour

In food processing, colour is one of the most important quality attribute, since it affects the consumer's perspective toward the product. Instrumental and visual measurements are used for the quantification of colour as a quality parameter (Pathare *et al.*, 2013).

Padonou *et al.* (2005) conducted studies to find the correlation between instrumental characteristics, physicochemical properties and sensorial characteristics of 20 different varieties of cassava and he concluded that the change in colour value measured instrumentally closely correlated with the analytical and sensorial characteristics.

Andersen *et al.* (1990) conducted studies on the colour kinetics of minced beef and recorded the changes in the colour stability of hot and cold processed meat. Tristimulus colorimetry was used for studying the variations in the colour in the minced beef. The hot processed minced beef retained the red colour in comparison with the cold processed one. The addition of salt and increase in pH lead to the further production of brown met-myoglobin from the red oxy-myoglobin due to its autoxidation.

Silva and Silva (1999) studied the effect of thermal processing on colour in cupuacu puree and reported that with the increase in temperature of processing the normalised L* reduced and the total colour difference increased; both followed the power law. The power was found to be temperature dependent and could be obtained using Arrhenius law. The colour measurement was conducted using a tristimulus colorimeter. A pasteurisation process with minimal color degradation could be designed using this model in cupuacu puree.

The changes in the quality parameters of thermally processed and high pressure processed navel orange juice was conducted by Polydera *et al.* (2005) and it was reported that browning of orange juice, treated by both the processes, followed a fist order kinetics. A linear dependence of colour change on ascorbic acid degradation was observed in both thermally processed and high pressure processed orange juices.

Barreiro *et al.* (1997) conducted a study on the kinetics of colour change in tomato paste which is thermally processed. The colour and colour change were measured using hunter tristimulus L*, a*, b* values. It was reported that the colour parameters followed a first order reaction whereas the colour difference was found to adhere to zero order kinetics. It was found that ‘a*’ was less sensitive to temperature change compared to parameter ‘b*’. It could be further used as a colour change prediction model in thermal processing for double concentration of tomato paste.

Colour degradation of kiwi fruit when subjected to hot air drying, microwave drying and combination of both were studied and Maskan (2001) concluded that drying lead to a colour shift to a darker region. Hunter lab colorimeter was used for measuring the colour values. The parameters ‘L*’ and ‘b*’ decreased whereas ‘a*’ increased as drying proceeded. The colour kinetics of hot air drying and microwave drying were found to follow a first and zero order reactions whereas all the parameters in the combination drying followed a first order reaction.

2.2.3 Texture

Textural properties of raw and cooked tubers depend on variety, maturity, growing environment, physico-chemical and starch properties. Thermal softening takes place in cassava when it is cooked (Sajeev and Sreekumar, 2010).

Sajeev *et al*. (2004) conducted studies on the textural characteristics of cassava taro and concluded that 1^{st} order model or dual order model could be used to characterise degradation of texture due to cooking.

The texture change in fresh peeled peaches, apricots, pears were studied during refrigerated storage, and the effect of various chemical treatments on texture were studied by Bolin and Huxsoll (1989) and reported that addition of calcium and zinc dips relatively reduced the browning and texture loss. The addition of oxygen scavengers had a comparable retention of the original texture. The structural polymer break down was retarded in these samples which helped in maintaining the texture of peaches and apricots whereas in the pears oxygen scavengers had no much effect in maintaining the texture.

Trejo *et al.* (2007) studied the changes in the microstructure and biochemical aspects of high pressure processed carrots with respect to its texture. A reduction in hardness of 5, 25, 50 per cent was observed in samples treated at 100, 200, 300 MPa respectively. The rupture of the cell wall due to the applied pressure was observed to follow linear correlation with the hardness of the carrots. It was concluded that changes in microstructure had significant effect on the degradation of the structure whereas no evident effect of biochemical parameters on the texture was observed.

In fishes, the degradation of texture is considered as a result of protein denaturation. Chu and Sterling (1970) conducted studies to characterise the effect of myosin degradation on texture of fish. The muscle samples from Sacromento blackfish was frozen, dehydrated and cooked and the changes in myosin were examined. It was found that all the characteristics comparable to denaturation followed an increasing trend.

Pritty and Sudheer (2012) observed that the texture of pasteurised tender jackfruit was better compared with the sample sterilised and canned. At two months of storage 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.s and 78.45 ± 1.72 to 58.46 ± 1.7 N.s for sterilised and pasteurised samples, respectively.

2.2.4 Carbohydrate content

Carbohydrates in food are classified as available carbohydrates and unavailable carbohydrates according to its digestibility. Dietary fibre includes the indigestible polysaccharides and lignin. Resistant starch is a component included in dietary fibre but current analysis cannot quantify the complete forms of resistant starch; complex carbohydrate includes the digestible polysaccharides (Asp, 1994).

Olano *et al.* (1989) conducted studies to evaluate the changes in carbohydrate content in heat treated milk and it was reported that, when sterilised and dried milk samples were analysed using gas chromatography, the galactose and lactulose concentrations increased with the increase in the severity of the processing whereas the glucose content did not alter much from the untreated samples. Epilactulose existed in sterilised milk alone moreover it was confirmed that the concentration of these fractions could be used to distinguish UHT milk from sterilised milk.

Aguilera *et al.* (2009) investigated the effect of dehydration on carbohydrates in legumes; it was concluded that dehydration increased the total dietary fibre content in legumes, extent of increase depended on the type of legume and the process adopted. The digestibility of starch improved on processing and the flatulence compounds decreased, the reduction of soluble compounds varied in different legumes; 57 per cent in chickpea, 76 per cent in white beans and 41 per cent in pink molted cream bean. Starch was determined by a procedure based on the total enzymatic digestion of glucose and HPLC was used for the determination of soluble carbohydrates.

2.2.5 Cyanide Content

Cassava contains two cyanogenic glycosides namely lotaustralin and linmarin. These compounds can be removed either by sun drying or soaking in water followed by boiling or boiling alone (Padmaja, 1995). The reduction of cyanide in cassava chips depends on the boiling time, the size of the tuber pieces and its volume.

The relationship between boiling time and cyanide removal was investigated by Cooke and Maduagwut (1978) and it was concluded that about 90 per cent of free cyanide was removed by boiling for 15 minutes. The bound cyanide could be removed only slowly; 55 per cent of bound cyanide can be removed by boiling for 25 minutes. It was observed that the amount of free cyanide in the boiling water primarily increased and then decreased, since HCN is volatile but the amount of bound cyanide was found to increase with the processing time.

Bourdoux *et al*. (1982) conducted experiments and stated that the safe limit of cyanide content in cassava was 50 ppm, 50–100 ppm was found to be moderately poisonous and above 100 ppm was dangerously poisonous to human beings.

Enzyme hydrolysis can be adopted for the removal of cyanogenic glycosides, since β-glucosidases first convert cyanogenic glycosides to cyanohydrins which further hydrolysed to hydrocyanic acid and keto-compounds. Linmarinase can be used for the hydrolysis of linmarin at a pH range of 5-6 (Oke, 1994).

The presence of phenolic compounds and cyanogenic glycosides in liqueurs made from cherry and apricot pits were studied by Senica *et al.* (2016) and it was concluded that liqueurs had lower amounts of these compounds compared with the fruit kernels. HPLC and mass spectroscopy were used for the analysis of these compounds. It was found that steeping of the fruit kernels reduced the cyanide content in the fruit kernels.

2.3 THERMAL PROCESSING

2.3.1 Blanching

Blanching is a pretreatment employed in fruits and vegetables before the advent of thermal processing, drying, freezing etc. It is usually carried out to arrest the enzymatic activity in fruits and vegetables and often to reduce the microbial load in the food samples or to remove the trapped air inside the product. It is carried out in such a manner that the fruits and vegetables are subjected to thermal treatment for a predetermined time at a predetermined temperature and then rapidly cooled according to the product (Xiao *et al.*, 2017).

Blanching studies on carrot, combined with sonication, were conducted by Jabbar *et al.* (2014) and it was concluded that by blanching at 100˚C for 4 minutes lead to remarkable increase in the pigments like carotene, lycopene and leutin in the samples, and the result was even more prominent in the samples subjected to combined with sonication at 20Hz at 15˚C for 2 minutes.

The cause of change in the protein agglomeration in blanched soymilk was studied by Wang *et al.* (2017) and it was found that when soy beans were blanched a specific protein called b-conglycinin, which inhibits aggregation, was denatured. The lack of this protein was identified as the reason for formation of precipitates in blanched soymilk.

Mehta *et al.* (2017) conducted studies on drying characteristics of capsicum and bitter-gourd in combination with blanching and reported that solar dried capsicum combined with hot water blanching gave maximum flavanoid and polyphenol retention. The samples subjected to solar drying showed highest score for sensory analysis too.

Chen *et al.* (2017) conducted blanching studies combined with hot air drying on yam flour to study the activity of peroxidase and polyphenonl oxidase in the samples. The quantity of total flavanones and polyphenols were found out and it was concluded that blanching effectively reduced enzymatic browning in the flour. The soluble amylose, protein contents and the swelling power and solubility of the flour produced from the blanched samples were lower than the control samples.

Green peas have very less storage life due to oxidation of the unsaturated fatty acids. It was found that frozen peas retained their organolepltic and nutritional qualities when blanched at 97˚C for two minutes followed by treatment with *ilex paraguariensis* extract, which has high antioxidant property, for 2 minutes at 25˚C. The treatment is considered as the best method to improve the oxidative stability of green peas (Yonny *et al.*, 2018).

Priecina *et al.* (2018) studied the effect of convective drying and microwave drying in steam blanched and unblanched Celery leaves and it was concluded that the flavanoid and phenolic compounds in the microwave dried – steam blanched samples showed the best results. The flavanoid and phenolic content in the samples were analysed and the best sample was found out with the maximum retention.

Chhe *et al.* (2018) studied the enzymatic and physico-chemical properties of sweet potato and it was concluded that the activity of peroxidase and pectin methyl esterase were arrested by blanching at 94˚C. It was also noted that the firmness of the samples preheated at 60˚C for 40 minutes were the best.

In canned carrots, it was found that by blanching at lower temperatures, the firmness, pH and free menthol increased whereas when the temperature was raised, the properties showed a comparable reduction. It was concluded that the increasing trend was exhibited at a temperatures from 55 to 77˚C because the enzyme pectin methyl esterase, which imparted firmness, was activated at lower temperatures and denatured at higher temperatures (Lee *et al.*, 1979).

Blanching and its combination with microwave heating on asparagus leaves were studied for changes in peroxidase and ascorbic acid by Zheng and Lu (2011). It was found that the effect on both ascorbic acid and peroxidase were first order reactions; moreover microwave pretreatment before blanching reduces the loss of ascorbic acid and accelerates the rate of inactivation of the enzyme peroxidase, maintaining the quality of the product.

Wang *et al.* (2017) conducted a comparative study on hot water blanching, microwave blanching, infrared blanching and hot air impingement blanching. The effect of these techniques on weight loss, enzyme inactivation, bioactive compounds, antioxidant levels, drying kinetics of red pepper were studied and it was found that the effects varied depending on the technique used. Enzyme inactivation was found to depend on the temperature and the time of microwave treatment and power of the same alone whereas the pepper treated with microwave blanching and infrared blanching showed excellent results in the case of reduced weight loss compared to hot water and hot air impingement blanching. The retention of pigments, ascorbic acid and antioxidants were remarkable in microwave blanched, infrared blanched and hot air impingement blanched samples. It was seen that the drying kinetics increased in all the blanched samples compared to the un-blanched pepper samples.

The enzyme activity of peroxidase and polyphenol oxidase activity was investigated in mangoes and it was found that steam blanching for 5 minutes inactivated peroxidase and poyphenol oxidase for 7 minutes (Ndiaye *et al.*, 2009).

Carrot slices were subjected to microwave, steam and hot water blanching and then frozen, the effect of these treatments on the structure, colour, carotene, drip loss and sugar content were investigated. It was concluded that the properties other than structure were enhanced by microwave blanching whereas structure became more heterogenic after microwave blanching (Kidmose and Martens, 1999).

The leafy vegetables subjected to steam blanching then followed by hot air drying were found to be superior in quality compared to the solar dried samples. The addition of sodium bicarbonate and ammonium bicarbonate improved the quality and acceptability over water blanched samples. The steam blanched samples had improved retention of ascorbic acid, carotene and mineral content moreover the colour, texture and the overall acceptability of the samples were remarkable compared to other samples (Onayemi and Badifu, 1987).

Carrots were water blanched for about 300 seconds and the changes in volatiles and the sensory parameters were analysed. By using GC, it was found that terpenoids reduced to 50 per cent after blanching for 60 seconds. The sensory attributes like aroma, colour, texture, flavour improved during blanching (Shamaila *et al.*, 1996).

2.3.2 Canning

It had been speculated that the nutrient quality of foods decreased by thermal processing, but in contradiction with this theory it was found that in tomatoes the antioxidant content increased by thermal processing. Ewanto *et al.* (2002) investigated this effect and found that in tomatoes the bioavailability of the lycopene was improved by thermal processing. The raw tomato had 0.76 ± 0.03 μmol of vitamin C per g of tomato. Heating at 88˚C for 2, 15, 30 minutes reduced the ascorbic acid levels to 0.68 ± 0.02, 0.64 ± 0.01, and 0.54 ± 0.02 μmol of vitamin C per g of tomato, respectively. The raw tomato had 2.01 ± 0.04 mg of lycopene content, when thermally processed at the same conditions yielded 3.11 ± 0.04, 5.45 ± 0.02, and 5.32 ± 0.05 mg of trans–lycopene per gram of tomato. It was concluded that during thermal processing the cell membrane disrupted and the bio-accessible lycopene increased.

Thermal processing denatures protein and thereby enhances texture, flavour, digestibility, food safety etc. and to a large extend, it leads to thermal modification and reduction of allergenicity of proteins. The processing history, intrinsic characteristics of the food and the composition of food are the major factors which affects the potential of a food, to be an allergen. Thermal processing breaks down the tertiary structure of the protein leading to the destruction of the active sites; leading to the production of hypoallergenic food (Davis and Williams, 1998).

Assan *et al.* (2000) conducted a study on the temperature distribution on the surface of cans filled with tuna fish in industrial scale static retort with saturated steam sterilisation and the changes in the sterilisation value due to the difference in the temperature were recorded. 570 cans were loaded and the surface temperature of 23 cans were evaluated; a temperature difference of 40˚C in the come-up time causing for a lag time of 3 minutes was observed, after the come-up time no further comparable difference was recorded. In the total process time of 80 minutes a 40˚C difference during the come-up period contributed a 30 per cent difference in the sterilisation value for the thermal process.

Thermal processing leads to the disintegration of semi-crystalline structure of starch; it transforms into an amorphous homogeneous material which is used for the production of starch based polymers. The process is accomplished by the addition of a small amount of gelatinising agent or plasticizers; a transformed material known as thermoplastic polymer is thereby produced (Liu *et al.*, 2009).

Thermal processing of stuffed potato had shown to improve its shelf life for about 12 months when processed at an F_0 value of 3.5 minutes. A slight increase in the thiobarbituric acid content, free fatty acid content was observed during the storage period but the product remained microbiologically safe for 12 months (Khan *et al.*, 2014).

Bourne and Comstock (1986) conducted texture analysis of thermally processed fruits and vegetables, using puncture and texture press and found out that the texture always decreased with increase in process temperature.

2.3.3 Retort Pouch Processing

Williams *et al.* (1981) conducted studies to evaluate the economic viability of three different thermal processing lines including a new canning line, an existing canning line and a retort pouch line for the thermal processing of fruits and vegetables. It was concluded that retort pouch processing line was the best alternative from all the reviewed processing lines.

The vitamin retention and physical properties like colour and texture of thermally processed green beans were studied in both retort pouches and cans.

The nutritive value retention and physical properties were better in the ones packed in retort pouches (Abou and Miller, 1983).

A comparative study on thermal processing in retort pouches over metal cans was conducted by Cynthia and Jerald (1989) and it was reported that the pouches required less processing time than cans.

Shashidhar *et al.* (2016) developed ready to drink calcium fortified shrimp soup in retort pouches. It was found that thermally processed calcium fortified shrimp soup was in acceptable condition during the storage period of 90 days at ambient temperature without any significant change in calcium content. During sensory evaluation, the product processed at 121ºC at F_0 6 was found to be the best among the treatments.

Mahwash *et al.* (2015) optimised the process conditions for retort processing of ready to eat dhal. Retort processing of the dhal at 121°C for 25 minute with ratio of water to dhal being 2.5 was found to be the best.

Tribuzi *et al.* (2015) conducted a study on the pretreatments required for thermally processing mussels. Salted chopped mussel meat retorted at 118ºC showed the best results.

Abhishek and George (2014) conducted thermal processing of soy-peas curry as a meat alternative in multilayer flexible retort pouches and concluded that the changes in free fatty acids and peroxide value of thermally processed soya peas curry were insignificant. The product was found to be shelf stable and of good quality at ambient temperature.

Anandh *et al.* (2014) conducted a study to optimise and standardise retort processed shelf stable ready-to-drink rose flavoured milk. Thermal processing to lethality values of F_0 3.95 and 3.8, respectively were found to be optimal.

Lakshmana *et al.* (2013) carried out the thermal processing of ready to-eat tender jackfruit in retort pouch and found that hardness of the tender jack fruit was reduced from 39 to 9 N. Hardness of thermally processed product was reduced due to heat induced softening of tissue. Further, no significant changes were observed in free fatty acids and peroxide value during storage.

Mohammedali *et al.* (2013) prepared retort processed ready-to-drink traditional thari kanchi payasam in flexible retort pouches. The optimum process time was found to be 35 minutes with a F_0 value of 3.64.

Retorting decreased the pH, thiobarbituric acid reactive substances and shear force values in goat meat. Rajkumar *et al.* (2009) found that the optimal F_0 value of goat meat was 12.1 minutes.

Ready to consume retort pouch processed black clam product retained its natural texture and succulence when thermally processed for 44 minutes with a F_0 value of 9 and cook value of 99 minutes (Bindu *et al.*, 2007).

The traditional Kerala fish curry thermally processed at F_0 value of 8.43 had a shelf life of one year (Gopal *et al.*, 2001). The texture and properties were found to be acceptable.

Njie *et al.* (1998) estimated the thermal properties of cassava roots and found that thermal conductivity value, k value and the C_p value varied between 0.16 to 0.57 $Wm^{-1}\,{}^{o}C^{-1}$ and 1.636 to 3.26 kJ $kg^{-1}{}^{o}C^{-1}$, respectively.

Dhal was thermally processed in retort pouches and found that it was microbiologically safe. The total process time was found to be 11.56–40.25

minutes for Fo value of 2.30–27.30 minutes. The optimum processing condition was found to be 25 minutes at 121˚C, which rendered the packets microbiologically safe (Jafri *et al.*, 2014).

Olivas *et al.* (2002) investigated the effect of residual gas volume on the sensory and physicochemical properties of retort pouch processed wet pack pears for six months. The 10, 15, 20 and 30 cm^3 were the varied gas volumes used for the study and it was found out that the pouches with residual gas volume of 30 cm^3 stimulated faster darkening and higher degree of ascorbic acid degradation. It was concluded that 20 cm^3 was the maximum residual gas volume which assisted in enhancing the shelf life of wet packed pears.

Bindu *et al.* (2004) developed ready to eat retort pouch processed mussel meat which had a shelf life of over one year with a very good retention of sensory characteristics and texture. The pouches filled with the meat were vacuum packed and further retort processed. Total process time of 35 minutes with a F_0 value of 9.8 minutes was found to be optimum.

Kumar *et al.* (2015) conducted process optimisation and shelf life study of retort pouch processed egg curry and egg burji. Steam air retort was used for processing the pouches and the optimum processing conditions were found out. F_0 values for the best samples were 7.77 and 7.46 minutes for egg curry and egg burji, respectively.

2.4 STORAGE STUDIES

Srinivasa *et al.* (2002) conducted storage studies on modified atmosphere packaging of mango where they were stored in carton boxes covered either with chitosan films or low density polyethylene. It was found out that the fruits stored in polyethylene had a shelf life of 9±1 days, where as the fruits stored in chitosan had a shelf life of about 18 days without any sort of microbiological spoilage or production of off-flavor. Physicochemical characteristics of the fruits such as the colour, ascorbic acid, acidity, chlorophyll and sugar contents were analysed during the storage period.

Rogan josh, a traditional meat product of Kashmir, was retort processed and the storage study was conducted. The optimum processing condition was found to be 121˚C for 7 minutes. The product had a shelf life of about 12 months. The physicochemical attributes like pH, shear force, FFA, thiobarbituric acid reactive content and the microbiological stability were analysed and the sample with the best sensory characteristics was selected as the one treated at the optimum conditions (Ahmad *et al.*, 2017).

Nienaber and Shellhammer (2001) conducted the shelf life study of fresh orange juice subjected to high pressure processing combined with heat treatment, a pressure range of 500 to 800 MPa at a temperature range of 25 to 50˚C. It was found that the juice had a shelf life of two months with a best acceptance value when pasteurised pulp was processed at 800 MPa at 25˚C for 1 minute. The pectin-methyl-esterase and the cloud stability during the storage period were evaluated as a part of the shelf life studies.

Martinez *et al.* (2006) conducted a comparative study on high intensity pulsed electric field treated, thermally treated and untreated orange juice to evaluate the effect of these various treatment on the shelf life of the samples. The electric field strength was 35 kV/cm for 1,000 μs; bipolar 4-μs pulses at 200 Hz were used. The shelf life of PEF treated orange juice was about 56 days at refrigerated conditions and 30 days at ambient conditions. PEF inactivated about 81 per cent of pectin-methyl-esterase activity whereas heat treatment inactivated 100 per cent of the enzyme activity. 100 per cent inactivation of peroxidase was ensured using PEF. The physicochemical properties like acidity, colour, °Brix, pH, vitamin C were found to be better retained in PEF treated samples. The antioxidant activity of both treated and untreated juices decreased during the storage period.

Prakash *et al.* (2000) investigated the effect of low dose of irradiation on the shelf life of modified atmosphere packaged cut romaine lettuce and it was found that when the sample was irradiated with a dose of 0.35 kGy its shelf life extended to 22 days. The oxygen concentration was not effected whereas the CO_2 concentration decreased and a 10 per cent reduction in the firmness of the samples were also observed. The sensory and physicochemical characteristics were also similar to the untreated samples whereas the colour improved in the irradiated samples.

Leizerson and Shimoni (2005) conducted studies on the effect of continuous ohmic heating of orange juice. It was found that shelf life of the treated juice was more than hundred days which is twice the shelf life of pasteurised juice. The ascorbic acid content decrease was found to be similar in ohmic heated and pasteurised orange juice; the pectin esterase activity was also similar in both conditions whereas the particle size was lesser in ohmic heated juice.

2.5 MICROBIAL QUALITY

Jacxsens *et al.* (2002) conducted studies to investigate the temperature dependence of fresh cut produce on sensory and microbial growth in MAP samples. It was reported that for the samples to remain microbiologically safe it has to be stored at 4˚C. The study was carried out at 2, 4, 7 and 10˚C with mixed lettuce-cucumber slices on ball pepper. It was reported that the pH, initial microbial load and storage temperature had influence on the growth of microbes in the minimally processed samples packed under modified atmosphere packaging.

Reilly *et al.* (2000) conducted studies to record the microbial inactivation of high pressure processed cheese and it was evident from the study that when the processing was carried out at 400 MPa a two log reduction of the *P. roqueforti* and *E. coli* were not detected in samples when processed above 400 MPa.

Commercial sterility for low acid foods may be defined as that condition in which all *C. 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).

2.6 SENSORY QUALITY OF FOOD

According to ISO (5492) 2008, sensory evaluation is the examination of organoleptic attribute of a product by the sense organ. Rajkumar *et al.* (2009) conducted sensory evaluation of thermally processed Chetinad styled goat meat curry in retort pouches and it was evaluated on a 9 point Hedonic scale. The optimised sample with an F_0 value of 12.1 minutes had a mean sensory scores of the samples in a range of 8.0 to 8.4 and it was rated as highly acceptable throughout a storage period of one year at ambient conditions.

Sensory evaluation of ready to drink calcium fortified shrimp soup was carried out for every 30 days using nine point hedonic scale and the optimised sample had higher and reasonable scores even after three months. During the storage period the scores decreased but were in acceptable limit (Shashidhar *et al.*, 2016).

Sensory analysis of tender jackfruit curry in retort pouches was conducted by Lakshmana *et al.* (2013) and it was scored on a nine point hedonic scale. The overall acceptability of the product processed with an F_0 of 6.8 minutes, was acceptable up to 12 months of storage. The attributes like colour, texture, flavour, taste, overall acceptability were scored by the panelists. During the storage period the sensory scores decreased but were within the acceptable limit for 12 months.

CHAPTER III

MATERIALS AND METHODS

The experimental set up and techniques used for the production of thermally processed cassava in retort pouch are discussed in this chapter. The quality evaluation and shelf life studies of stored product are also presented.

3.1 SAMPLE COLLECTION

M-4 and Sree Jaya varieties of cassava were collected from progressive farmers at Kuttipuram. Sree Jaya is an early maturing variety with seven months growth period (KAU, 2016).

Cassava tubers were manually peeled and washed in running tap water. Tubers were then cut into dices of 15 x 15 mm sizes using a fruit and vegetable dicer.

3.2 DETERMINATION OF PHYSICO-CHEMICAL ANALYSIS OF RAW CASSAVA

3.2.1 Quality Parameters

The quality characteristics of raw cassava were determined according to the procedure given below.

3.2.1.1 Moisture content

The moisture content of the sample was analysed according to AOAC, 1992 method. Sample of 5 g (w_1) was taken in dry petriplate and kept in air oven at a temperature of 105˚C for 24 h. Drying was continued till the weight of the samples became constant and then the samples were taken out and kept in a descicator to cool to the room temperature. The cooled samples were weighed (w_2) and moisture content of the sample was found out using the equation given below. The moisture content was expressed in wet basis (AOAC, 1992).

$$\text{Moisture content (\%wb)} = \frac{W1 - W2}{W1} \;\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

3.2.1.2 Total acidity

Sample of 5 g was taken and ground in a mortar and pestle and made up to 150 ml with distilled water. Ten ml of the sample was taken and titrated against 0.1*N* sodium hydroxide with a few drops of 1 per cent phenolphthalein as indicator. Titration was carried out till the disappearance of pink colour. Total acidity was calculated using the equation given below (Ranganna, 1995).

The materials required for the analysis included NaOH pellets, beaker, conical flask, burette, phenolphthalein indicator, measuring cylinder, distilled water. Sodium hydroxide of 0.1*N* was prepared by dissolving 2 g NaOH pellets in 500 ml of distilled water.

$$\%\text{ Acidity} = \frac{\text{Titre} \times \text{normality of alkalinity} \times \text{volume made up} \times \text{equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{weight of sample taken} \times 100} \ldots\ldots(2)$$

3.2.1.3 pH

Cassava sample of 10 g was ground using a mortar and pestle and 90 ml of distilled water was added to it. A pH meter (Plate 3.3a) was used to find out the pH of the sample. The electrode was dipped in the sample and the pH shown in the digital monitor was recorded (Ahaotu *et al*., 2017).

3.2.1.4 Carbohydrate

Carbohydrate was analysed using anthrone-sulphuric acid colorimetric method (Yemm and Willis, 1954). Anthrone reagent, 75 per cent sulphuric acid and glucose standard solution were the reagents required for carbohydrate analysis.

H_2SO_4 (75 per cent) - 75 ml sulphuric acid was added to 25 ml of distilled water in a beaker, since the reaction is highly exothermic ice buckets were used while the solution was prepared.

Anthrone reagent - 0.1 g anthrone was weighed and dissolved in 5 ml of ethanol. After thorough mixing, the solution was made up to 50 ml by addition of 75 per cent H_2SO_4.

Glucose standard solution - 0.1g glucose was weighed and dissolved in 100 ml of distilled water in a volumetric flask.

A standard curve for glucose was plotted using a spectrophotometer (Plate 3.3b) at a wavelength of 578 nm from which the carbohydrate content of the cassava sample was extracted. For plotting the standard curve aliquots of 0.2, 0.4, 0.6, 0.8 and 1 ml of glucose standard solution were taken in a test tube using a 1 ml micropipette. To the test tube, 1 ml of 75 per cent H_2SO_4 and 4 ml of anthrone reagent were added. A blank with 1 ml distilled water added with the reagents was also prepared. For colour development, the samples were kept in a water-bath at 100˚C for 15 min. A green colour is developed for the samples, and a yellow colour for the blank. The cooled samples are mixed again using a test tube shaker and further filled into the cuvettes and analysed using a spectrophotometer at 578 nm. From the absorbance values obtained, the microgram per ml of glucose present can be found using the standard curve.

Cassava sample of 5 g was taken and extracts of 150 ml were prepared using distilled water. One ml of the extract was taken and diluted 10 fold; 1 ml from this was taken and reagents were added. Blank was prepared in the similar manner as described above. The samples were kept in a water-bath at 100˚C for 15 min. The samples were cooled and mixed thoroughly using a test tube shaker. Aliquots of the sample were taken for analysis using the spectrophotometer and the absorbance values at 578 nm were recorded. From the standard plot, the concentration of glucose in mg per ml present in the sample was found out. The carbohydrate content was found out using the formula given below

$$\text{Carbohydrate content (mg/ml)} = \frac{\text{Concentration} \times 10 \times 150 \times 100}{5000} \ldots\ldots\ldots\ldots(3)$$

3.2.1.5 Crude fibre content

Crude fibre content was carried out according to the AOAC, 1982 method. Acid-alkali hydrolysis was used for the estimation. The reagents required for the analysis included 1.25 per cent H_2SO_4 and 1.25 per cent NaOH. The materials required for the analysis were crucibles, petriplates, weighing balance, measuring cylinder and muffle furnace.

H_2SO_4 (1.25 per cent) - 7 ml H_2SO_4 was added to 98.75 ml of distilled water.

NaOH (1.25 per cent) - 13.16 g NaOH was added to 1 L of distilled water.

Dried cassava samples were ground and 2 g (w) ground samples were taken and boiled for 30 min with 100 ml of 1.25 per cent H_2SO_4 for acid digestion. It was then filtered using a Whatman 1 filter paper. The filter cake was then washed with 50-75 ml boiling water. After complete draining off of water, it was boiled for 30 min with 1.25 per cent NaOH. The alkali hydrolysed samples were filtered again in the similar manner and the filter cake was washed with 25 ml of boiled 1.25 per cent H_2SO_4. It was then further washed 2-3 times with 50 ml of boiled water each. After complete draining of water, the filter cake was washed with 25 ml of alcohol and then dried at 130˚C for 2 h. The samples were allowed to cool in desiccators and their weights were recorded (w_1). The samples were then transferred into crucibles and ignited at 600˚C in a muffle furnace. The ignited samples were allowed to cool in desiccators and their weights were recorded (w_2). The crude fibre content was found out using the equation given below.

$$\%\text{Crude fibre} = \frac{W1-W2}{W} \times 100 \ldots\ldots\ldots\ldots\ldots(4)$$

3.2.1.6 Colour

The colour of the cassava samples were found out using a hunter lab colourimeter (Plate 3.3c). The colour of the samples were found out as a value of L*, a*, b* where, lightness (L*) ranges from 0 to 100 with 0 as black and 100 as white, a* is the degree of greenness/redness and b* is the degree of blueness/yellowness (Moodley, 1999).

Primarily the hunter lab colourimeter was calibrated by placing the white and black tile on the aperture. Cassava was filled in the sample cup and kept on the aperture for obtaining the colour values. The L*, a*, b* values which were shown on the screen were recorded (Patras *et al*., 2009).

3.2.1.7 Texture analysis

Firmness and toughness of the samples were evaluated using Stable Microsystems Texture Analyser (TA HD Plus, UK) (Plate 3.3d). It uses Exponent software which is user friendly and flexible at the same time. A 5 mm diameter cylindrical probe was used, which punctured the samples at 5 g trigger force. The pre test and test speed of the probe was set as 2 mm/s. The post test speed of the probe was set as 10 mm/s. The raw cassava was cut into 15 x 15 mm and placed on the platform where it is punctured by the probe. The highest peak value was taken as the hardness and the area under the curves was taken as the toughness of the sample (Sajeev *et al*., 2004).

3.2.1.8 Cyanide content

Acid hydrolysis was conducted for evaluating the cyanohydrin content in the cassava samples (Bradbury *et al*., 1991). Cassava sample of 20 g was taken and blended with 60 ml of 0.1*M* H_3PO_4 for 2-3 min. It was filtered and washed with 0.1*M* H_3PO_4 two to three times. The filtrate was made up to 100 ml with 0.1*M* H_3PO_4; 2 ml aliquot of the same was taken and added to 2 ml of 4*M* H_2SO_4. This solution was heated for 50 min in a water bath at 100˚C. This solution was kept at 4˚C overnight. NaOH of 5 ml (3.6*M*) was added to the cold solution and allowed to stand for 5 min. One milli-litre of this solution was added to test tubes with 7 ml, 0.2*M* phosphate buffer, which maintained the pH of the solution at 6. Distilled water of 2 ml was added to a test tube to prepare blank solution. All the test tubes were cooled; 0.4 ml aqueous chloramines T solution and 5 g/l pyridine-barbituric acid solution were added to all the test tubes. The samples were allowed to stand for 60-90 min for colour development and absorbance was found out at 583 nm using a spectrophotometer (Plate 3.3b). The absorbance values were compared with the standard curve for cyanide and the mg/kg of cyanide present in the cassava samples were found out.

$$\text{Cyanide content (mg/kg)} = \frac{\text{Concentration} \times 2 \times 50 \times 1000}{20} \quad \ldots\ldots\ldots\ldots(5)$$

3.2.1.9 Protein

Protein analysis of the sample was conducted at the laboratory, CoH, KAU, Vellanikkara. Kjeldahl method was used to find out the protein content of the sample. In Kjeldahl method organic components are digested by sulphuric acid which is promoted by a catalyst. The total organic nitrogen is converted to ammonium sulphate which is then neutralised with alkali and distilled to borate ion. The sample is then titrated against standardised acid where the borate ions are converted into boric acid. The protein content was then found out from the titre value (Chang and Zhang, 2017).

The reagents required included sulphuric acid, catalyst/salt mixture which contains potassium sulfate, titanium dioxide and cupric sulfate. 50 per cent w/v, NaOH was prepared. Boric acid of 160 g was added to 2 l hot distilled water, after mixing 1.5 l hot distilled water was again added to prepare boric acid solution. To the solution, 40 ml of bromocresol green solution (100 mg bromocresol green/100 ml ethanol) and 28 ml methyl red solution (100 mg methyl red/100 ml ethanol) was added. The solution was then made upto 4 l; 25 ml of this solution, acid, catalyst/salt mixture were distilled and digested as blank. The colour of the solution turned neutral grey. In to the solution, 0.1 g cassava was added, distilled and digested to prepare the sample.

HCl was standardised and the normality was noted. Both the blank and the sample were titrated against this standardised HCl with 3-5 drops of indicator which was prepared by mixing 3 parts of 0.1 per cent bromocresol green in ethanol with 1 part of 0.2 per cent methyl red in ethanol. The solution was titrated to a light pink endpoint.

The calculation used to find out the protein is given below,

%Nitrogen=

$$\frac{\text{normality of HCl}}{1000\text{ml}} \times \frac{(\text{ml of std. acid for sample} - \text{ml of std. acid for blank})}{0.1\text{g} \times 1000} \times 14 \times \frac{100}{1000}$$

……………………….(6)

$$\%\text{Nitrogen} \times 6.25 = \%\text{protein}$$ …………(7)

3.2.1.10 Fat

Fat analysis of the cassava sample was conducted at the laboratory, CoH, KAU, Vellanikkara. Slightly ground cassava of 3 g (W) was placed in a dried thimble and glass wool was used to plug its mouth. Weights of the thimble (W1), thimble with sample (W2) and with glass wool (W3) were separately noted. Petroleum ether of 350 ml and glass boiling beads were added and the samples were placed on Soxhlet extractor and extraction was carried out for 6 h. Samples were air dried overnight in a hood, then dried in a vacuum oven at 70°C for 24 h. The samples were then cooled and reweighed (W4). Moisture content of cassava is given as M (Nielsen and Carpenter, n.d).

$$\%\text{Fat} = \frac{W3 - W4}{W} - (\%M)$$ …………………..(8)

3.3 DESIGN OF THE EXPERIMENTS

3.3.1 Optimisation of Blanching Time

3.3.1.1 Independent variable

- ✓ Time – temperature combinations (100˚C for 5, 10, 15 min)

3.3.1.2 Dependent variables

- ✓ Colour

- ✓ Texture
- ✓ pH
- ✓ Carbohydrate content
- ✓ Crude fibre content
- ✓ Cyanide content

3.3.2 Quality Improvement by Addition of Hydrocolloids

3.3.2.1 Independent variable

- ✓ Blanched with guar gum (0.1 per cent guar gum)

3.3.2.2 Dependent variables

- ✓ Colour
- ✓ Texture
- ✓ Carbohydrate content
- ✓ Crude fibre content

3.3.3 Optimisation of Thermal Processing

3.3.3.1 Independent variable

- ✓ Time temperature combinations (temperature - 100, 110, 121˚C with different time combinations)

3.3.3.2 Dependent variables

- ✓ Microbial load
- ✓ Storage studies
- ✓ Sensory analysis

3.3.4 Storage Studies

3.3.4.1 Independent variable

- ✓ Storage period (3 months for ambient storage and 6 months for refrigerated storage)

3.3.4.2 Dependent variables

- ✓ Colour
- ✓ Texture
- ✓ pH
- ✓ Moisture content
- ✓ Crude fibre
- ✓ Carbohydrate
- ✓ Microbial load
- ✓ Sensory-scores

3.4 BLANCHING

Blanching is the process of subjecting the fruits and vegetables to high temperature followed by immediate cooling. Blanching is done as pretreatment before thermal processing.

Cassava tubers of 500 g were diced into pieces of 15 x 15 mm sizes. It was then hot water blanched. Blancher was filled with water and the temperature was set as 100˚C. Time-temperature combinations were set according to preliminary evaluation and from previous studies (Pritty and Sudheer, 2012). The time of blanching was varied and the optimum time was found out. The various treatments conducted were:

B1 – Cassava tubers blanched at 100˚C for 5 min

B2 – Cassava tubers blanched at 100˚C for 10 min

B3 – Cassava tubers blanched at 100˚C for 15 min

3.4.1 Optimisation of Blanching Time

The blanching time of cassava was found out based on the reduction of cyanide content during blanching and the quality of blanched samples. Optimisation of blanching time-temperature combination could not be done by the peroxidase and catylase test since cassava did not contain these enzymes. The blanching time was optimised based on the removal of cyanide content and the quality parameters of the blanched samples.

3.4.2 Quality Analysis of Blanched Samples

The quality attributes of the blanched samples *viz.,* colour, texture, cyanide content, carbohydrate content, crude fibre content, pH were analysed according to the section 3.2.1. Statistical analyses of the parameters were conducted as mentioned in the section 3.10. Mean tables and standard deviations of the parameters were determined and tabulated.

3.5 QUALITY IMPROVEMENT BY ADDITION OF HYDROCOLLOIDS

3.5.1 Addition of Guar Gum

Blanching process was conducted by addition of 0.1 per cent guar gum to reduce the leaching of amylose from the cassava cubes and to preserve the texture of the thermally processed cassava (Dinakaran *et al*., 2017). According to preliminary studies the thermally processed cassava without any quality improvement had unacceptable texture properties, therefore guar gum was used. The quality parameters of blanched samples as well as blanched with hydrocolloids were analysed. Blanching with guar gum was conducted at previously optmised blanching time.

Guar gum is the gum obtained from the seed of *Cyamonsis tetragonoloba*; it is a non-ionic seed polysaccharide with a straight chain mannan grouping with relatively regular branching on every second mannose by a single galactose unit (Featherstone, 2015). The various treatments conducted were:

Bg1 – M-4 variety blanched for 5 min in gum

Bg2 – Sree Jaya variety blanched for 15 min in gum

3.5.2 Quality Analysis of Blanched Samples

The quality attributes of the blanched samples *viz.,* colour, texture, carbohydrate content, crude fibre content, pH were analysed according to the section 3.2.1

3.6 THERMAL PROCESSING

Cassava was subjected to different time temperature combinations in retort pouches to improve its shelf life. A steam-air retort (Plate 3.1a & b) and ancillary equipments like compressor and hydraulic sealer (Plate 3.2) were required for retort pouch processing. All the processes carried out during thermal processing are presented in the Fig.3.1.

3.6.1 Packaging Material

Thermal processing of the blanched cassava samples were conducted in retort pouches. Prefabricated laminate pouches were used for thermal processing. The properties of the retort pouches used for thermal processing are tabulated in Table 3.1.

3.6.2 Pouch Filling, Exhausting and Sealing

About 100 g of blanched cassava cubes were filled into the pouches followed by filling with 150 ml of 0.4 per cent $CaCl_2$ brine. 0.4 per cent $CaCl_2$ was prepared by dissolving 10.4 g of $CaCl_2$ in 2.6 l of distilled water. Hot filling of brine was done to exhaust the pouches and the filled pouches were immediately sealed using a hydraulic sealer. The voltage of the sealer was adjusted to 39-40 V and the heating time and cooling time was set according to the requirement. The sealer operated at 1 bar gauge pressure; where compressed air was used as the medium for transferring pressure. Contact heating, used to seal the pouches were carried out at 9-10 V and water was used as the coolant.

3.6.3 Thermocouple Arrangement

Thermocouple was cleaned using 1per cent nitric acid and the probe was inserted into the centre of a cassava cube in a retort pouch and placed in the retort to get the cold point temperature accurately. The on-line temperature of the cold point is continuously recorded in the data logger which is logged into a system using software called Labview provided by National Instruments Laboratory, Texas.

3.6.4 Retort Processing

The retort used for thermal processing was a steam-air semiautomatic retort (Plate 3.1a). The sealed pouches were loaded on the trays and placed in the retort. The thermocouple and the temperature sensor, used for continuous data logging of the retort temperature, were placed at the centre of the retort for the retrieval of an average value. The retort was closed and the process was started when the steam pressure in the steam boiler was 2 bar gauge pressure. The steam air retort with overpressure was operated at an air pressure of 2.34 bar gauge pressure. Compressed air was used to maintain the pressure. The process was semiautomatic with automatic control of valves and manual operation during cooling. F_0 value is the time of thermal processing required for stated reduction of microorganisms at 121˚C. The F_0 value was continuously monitored and logged, and recorded in the system using the Labview software; the value was attained from cold point temperature logging. The operating temperature and the time were already set. The temperature at which the air vent closed, the time delay between heating and cooling, temperature to which the samples were to be cooled, time of cooling and the program selection for steam air retort processing were previously set according to the requirements.

When the process started the steam from the steam chamber was let into the retorting chamber. The temperature increased rapidly and when the sterilisation mode was reached the steam was administered frequently into the chamber to maintain the retort temperature. The temperature was automatically maintained by on-line correction of the process. After the completion of sterilisation mode, the operation shifted to cooling where cold water is circulated through the retort was operated manually. During cooling, cold water is circulated through the retort, due to the rapid temperature drop the pressure inside the retort drops rapidly whereas the pressure inside the pouches will be still high which will lead to bursting of pouches. Therefore during the initial stage of cooling operation a blast of compressed air was automatically administered into the retort to avoid the rapid pressure difference. After cooling, the retort was turned off and the pouches were unloaded.

3.6.5 Thermal Processing

The thermal processing was conducted at 100˚C, 110˚C, 121˚C in combinations with process time. Time-temperature combinations were selected based on preliminary studies. The various treatments conducted were:

T1 – M-4 thermally processed at 100˚C for 10 min

T2 – M-4 thermally processed at 100˚C for 20 min

T3 – M-4 thermally processed at 110˚C for 20 min

T4 – M-4 thermally processed at 110˚C for 40 min

T5 – M-4 thermally processed at 121˚C for 8 min

TV1 – Sree Jaya thermally processed at 100˚C for 10 min

TV2 – Sree Jaya thermally processed at 100˚C for 20 min

TV3 – Sree Jaya thermally processed at 110˚C for 10 min

TV4 – Sree Jaya thermally processed at 110˚C for 20 min

TV5 – Sree Jaya thermally processed at 121˚C for 2 min

3.6.6 Optimisation of Thermal Processing

The time temperature combination was optimised according to the microbial load (section 3.6.6.1), storage studies (section 3.7) and sensory analysis (section 3.8) of the thermally processed cassava. After thermal processing the microbiologically safe samples were only taken for further studies.

Table 3.1 Retort pouch properties

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
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
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

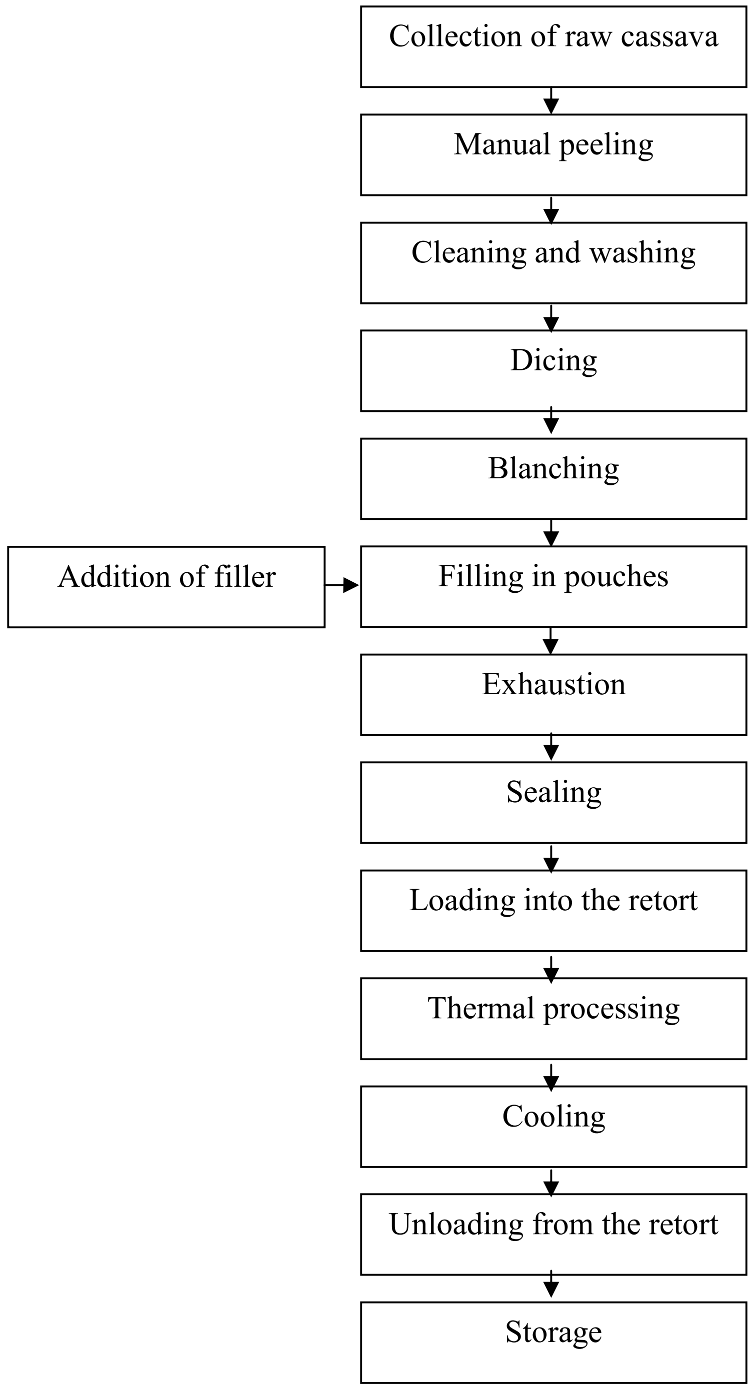


Fig. 3.1 Thermal processing in retort pouches

3.6.6.1 Microbial analysis

Microbiological analysis of the retort pouch processed cassava samples were conducted using the total plate count method (TPC). TPC for bacteria, fungus and moulds were conducted every month throughout the storage period.

Different culture media were prepared for different microorganisms; potato dextrose agar (PDA) for TPC analysis of fungi and mould whereas nutrient agar for the analysis of bacteria in the samples. Serial dilutions and pour plate method were adopted as the plating techniques (FDA, 2001). The nutrient media, petri plates, test tubes, distilled water and micropipette heads were sterilised in an autoclave at 121˚C for 20 min.

3.6.6.1.1 Total plate count

Primarily, 10 g cassava was ground in a sterile mortar and pestle and added to a conical flask with 100 ml sterile distilled water and it was then mixed thoroughly using an incubator shaker to prepare a sample of 10^{-1} dilution. From it 1 ml was taken and added to 9 ml of sterile distilled water in a test tube to prepare a sample of 10^{-2} dilution, from which 1 ml was taken and added to 9 ml of sterile distilled water to prepare a sample of 10^{-3} dilution. All the glass wares, ancillary equipments were sterilised before use.

Pour plate method was used as the plating technique, which was conducted in a laminar air flow chamber. One ml of sample from the 10^{-2} dilution was taken using a micropipette and inoculated into a petri dish. About 20 ml of sterile media, cooled to 45˚C, was poured into the petri dish with the sample and mixed by rotating the petri dish in clockwise and anticlockwise directions. It was allowed to cool till the media was set. Plating was done in triplicates to reduce error. Both nutrient agar and potato dextrose agar were used as the media for plating, the petri plates were then closed, inverted and incubated at 37±2˚C in an incubator for 24-48 h to promote the growth of microbial colonies. The colonies formed were then counted using a colony counter. The microbes were enumerated as cfu per ml. The same procedure was carried out with 10^{-3} dilution.

$$\text{CFU/ml} = \frac{\text{Mean number of CFUs} \times \text{dilution factor}}{\text{Volume of sample plated (ml)}} \quad \ldots\ldots\ldots\ldots..(9)$$

3.6.6.2 Quality Analysis of the Samples

The quality parameters like colour, texture, carbohydrate, crude fibre of the processed cassava were determined according to the method detailed in the section 3.2.1.

3.7 STORAGE STUDIES

A preliminary study on the storage life of retort processed cassava was conducted and it was observed that after 3 months storage at ambient conditions microbial load increased. Hence, the shelf life studies of retort pouch processed cassava were conducted for 3 months at ambient conditions and 6 months at refrigerated condition. The microbiologically safe samples processed at different combinations were stored at ambient conditions inside a shelf (25-30˚C) and refrigerated condition (4˚C). Quality parameters like titrable acidity, pH, moisture content, crude fibre, carbohydrate, colour, toughness, hardness, microbial load were analysed for every month according to the methods discussed in the section 3.2.1. The various treatments conducted were:

TS1 – M-4 thermally processed at 121˚C for 8 min with F_0 10.8 stored at ambient conditions

TS2 – M-4 thermally processed at 110˚C for 40 min with F_0 6.1 stored at ambient conditions

TS3 – Sree Jaya thermally processed at 121˚C for 2 min with F_0 4 stored at ambient conditions

TS4 - Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1 stored at ambient conditions

TR1 – M-4 thermally processed at 121˚C for 8 min with F_0 10.8 stored at refrigerated conditions

TR2 – M-4 thermally processed at 110˚C for 40 min with F_0 6.1 stored at refrigerated conditions

TR3 – Sree Jaya thermally processed at 121˚C for 2 min with F_0 4 stored at refrigerated conditions

TR4 - Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1 stored at refrigerated conditions

3.9 SENSORY ANALYSIS

Sensory analysis was conducted using the 9 point Hedonic scale test. The sensory analysis was conducted at three months of storage at ambient condition and six month at refrigerated condition. Properties like colour and appearance, texture, flavour, taste, overall acceptability were scored by expert panel and the average sensory score of the samples were analysed.

3.8 ESTIMATION OF ENERGY VALUE

The energy value of retort pouch processed cassava was estimated by analysing the protein, fat, crude fibre and carbohydrate content of the samples according to the procedure mentioned in the section 3.2.1, respectively. The results are tabulated in the Appendix.

3.10 STATISTICAL ANALYSIS

Completely randomised design (CRD) was used for analysis of the data obtained. The analysis of variance (ANOVA) was used as the statistical tool to find out the level of significance. The mean tables and standard deviations for different process parameters were tabulated. SPSS software was used for statistical analysis.

3.11 COST ANALYSIS

Cost analysis was conducted by considering the variable cost and the fixed cost. Fixed cost was found out according to the formula given below (Palanisami *et al*., 1997) and the cost analysis is given in the Appendix.

Fixed cost of unit/year = Initial cost of equipment x Capital recovery factor

$$\text{Capital Recovery Factor (CRF)} = \frac{Ri \times (1+Ri)^n}{(1+Ri)^n + 1} \text{ ……….(10)}$$

Ri = rate of interest

n = life period of the equipment in years

Plate 3.1a Steam-air semiautomatic retort

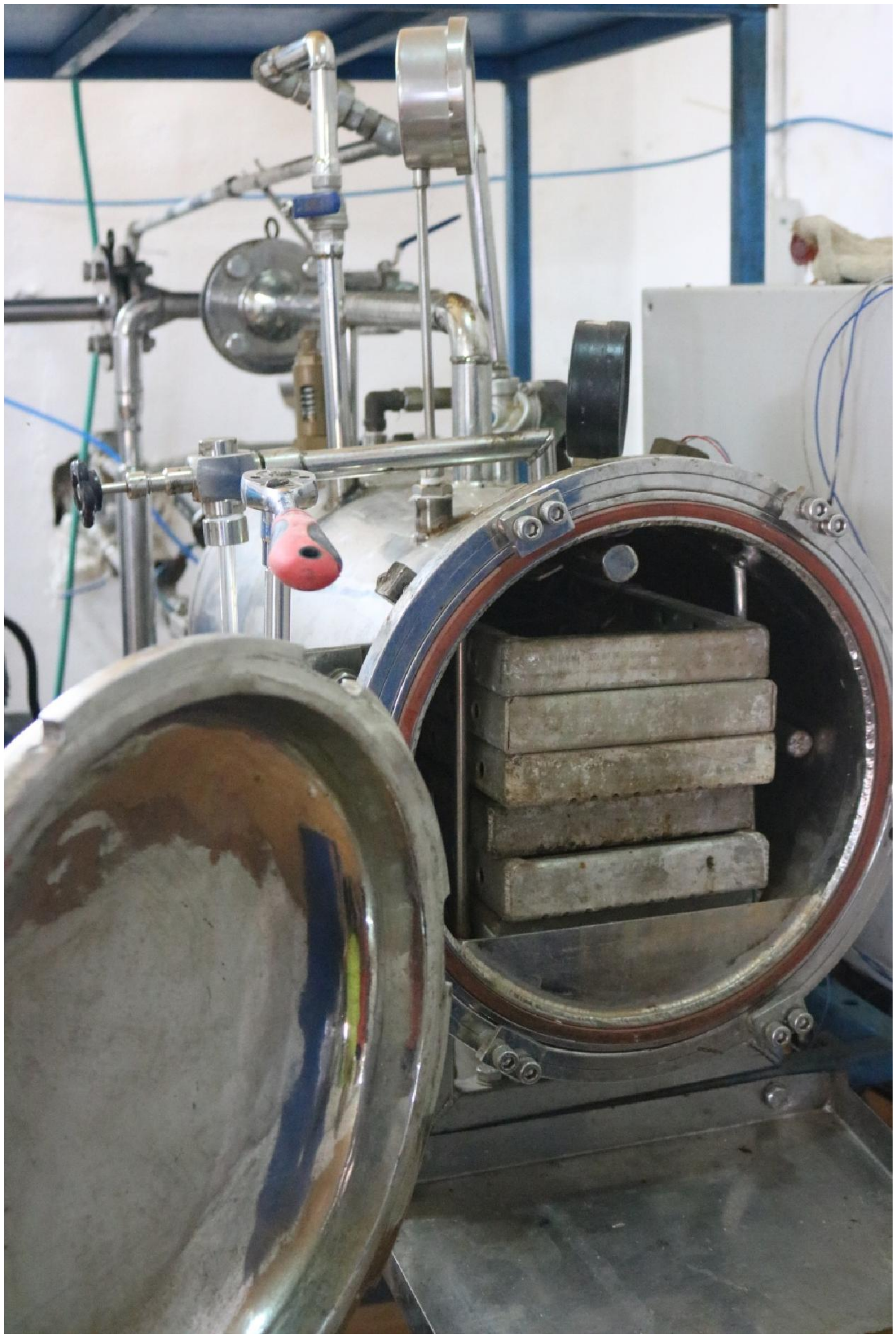
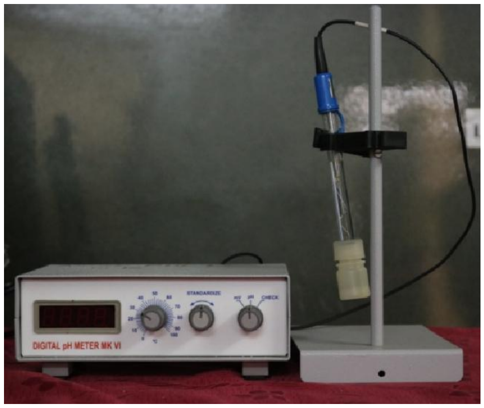


Plate 3.1b Interior of a retort with trays

Plate 3.2 Hydraulic sealer



(a) **pH meter** (b) **Spectrophotometer**

(c) Colourimeter **(d) Texture analyser**

Plate 3.3 Instruments for measuring quality

CHAPTER IV

4. RESULTS AND DISCUSSION

This chapter deals with the results obtained on characteristics of raw cassava, thermally processed cassava and retort pouch packaging of processed cassava. The optimised treatments and the shelf life studies of retort pouch processed cassava were also studied and discussed in this chapter.

4.1 PHYSICO-CHEMICAL CHARACTERISTICS OF RAW CASSAVA

The quality parameters of raw cassava (Plate 4.1) *viz.,* colour, pH, titrable acidity, carbohydrate content, firmness, toughness, cyanide content, moisture content, crude fibre content were evaluated and tabulated in Table 4.1 and 4.2.

Plate 4.1 Diced cassava

The pH of Sree Jaya variety cassava was found to be 6.81with a titrable acidity of 0. The carbohydrate content was found as 22.05 per cent. The cyanide content was estimated to be 107.05 ppm. The moisture content was found to be 76 per cent wet basis. The firmness and toughness of raw cassava were found to be 7.56 kg and 20.39 kg.s, respectively. The L*, a*, b* values were found as 73, 1.43, 17.89, respectively.

The pH of M-4 variety cassava was found to be 6.80 with a titrable acidity of 0. The carbohydrate content was found as 18.57 per cent. The cyanide content was estimated to be 76.01 ppm. The moisture content was found to be 74 per cent wet basis. The firmness and toughness of raw cassava were found to be 5.22 kg and 15.17 kg.s, respectively. The L*, a*, b* values were found as 71.70, 1.41, 18.13, respectively. Colour parameter L* value ($p \leq 0.05$), firmness, carbohydrate content, cyanide content and moisture content were found to be significant in both the varieties (Appendix I).

Table 4.1 Physico-chemical characteristics of cassava tubers, variety: M-4

Parameters		Mean	±	SD
pH		6.80	±	0.01
Titrable acidity		0.00	±	0.00
Carbohydrate content (%)		18.57	±	0.11
Cyanide content (ppm)		76.01	±	0.08
Moisture content (%wb)		74.00	±	0.56
Crude fibre content (%)		2.42	±	0.02
Texture	Firmness (kg)	5.22	±	0.76
	Toughness (kg.s)	15.17	±	3.50
Colour	L*	71.70	±	0.09
	a*	1.41	±	0.05
	b*	18.13	±	0.43

Table 4.2 Physico-chemical characteristics of cassava tubers, variety: Sree Jaya

Parameters		Mean	±	SD
pH		6.81	±	0.01
Titrable acidity		0.00	±	0.00
Carbohydrate content (%)		22.05	±	0.05
Cyanide content (ppm)		107.05	±	0.06
Moisture content (%wb)		76.00	±	0.76
Crude fibre content (%)		1.81	±	0.01
Texture	Firmness (kg)	7.56	±	0.01
	Toughness (kg.s)	20.39	±	0.04
Colour	L*	73.00	±	0.10
	a*	1.43	±	0.02
	b*	17.89	±	0.01

4.2 BLANCHING OF CASSAVA

Cassava was blanched at 100˚C in combination with three different time treatments. Since cassava did not contain catalase and peroxidase enzymes, the optimisation of blanching time was done based on the cyanide test quality of the blanched cassava instead of enzyme test.

4.2.1 Effect of Blanching on Quality Parameters

The effect of blanching on different quality parameters of cassava were studied and the mean tables for all the parameters are tabulated in the Table 4.3 and 4.4 for M-4 and Sree Jaya varieties, respectively.

4.2.1.1 Effect of blanching on colour of cassava

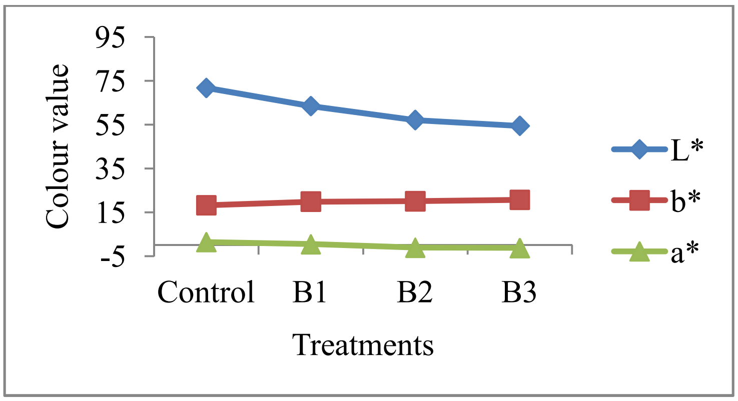


Figure 4.1 Colour values of blanched cassava tubers, variety: M-4

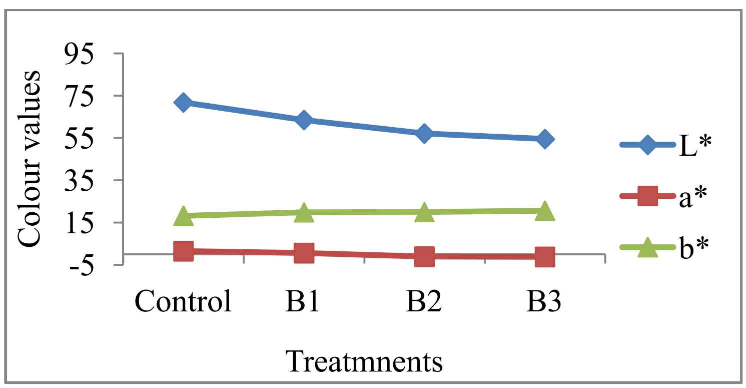


Figure 4.2 Colour values of blanched cassava tubers, variety: Sree Jaya

The colour values of M-4 variety of cassava blanched at different time period are presented in Fig. 4.1. The L*, a*, b* values for each treatment were found to be significant ($p \leq 0.05$) (Appendix II).

In M-4 variety, the L*, a*, b* values of 5 min blanched samples, B1 was observed as 63.39, 0.45 and 19.77, respectively. Similarly, the colour values for treatments B2 and B3 were 57.14, -1.13, 20.03 and 54.52, -1.32, 20.56, respectively. The L* and a* values of the blanched samples decreased significantly with increase in blanching time. Control sample had the maximum L* and a* values and minimum b* value. Sample blanched for 5 min was more brighter than samples blanched for 10 and 15 min. The b* value of the blanched samples increased significantly with increase in blanching time. The percentage increase in b* value of blanched samples (5, 10 and 15 min) compared to control sample were 8.85, 9.95 and 13.25 per cent, respectively which indicates an increase in yellowness of the sample.

The colour values of Sree Jaya variety of cassava blanched at different time period are presented in Fig. 4.2. The L*, a*, b* values for each treatment were found to be significant ($p \leq 0.05$) (Appendix II). From the graph, it can be understood that the colour value of Sree Jaya variety showed a trend similar to M-4 variety. For Sree Jaya variety, the L*, a*, b* values of B1, B2 and B3 treatments were observed as 65.5, 1.34, 18.2; 62.8, -0.37, 19.2 and 58.8, -1.25, 20.4, respectively.

During blanching, due to increase in temperature, gelatinisation process might have lead to the breakdown of starch into sugars which acts as a substrate for non-enzymatic browning reaction. Maillard reaction might have lead to the decrease in L*, a* values and increase in b* values of processed cassava (Basu and Shivhare, 2013; Imaizumi *et al*., 2017). Similar result was found by Chhe *et al*. (2018) while hot water blanching of sweet potato at 60˚C for 40 min.

4.2.1.2 Effect of blanching time on texture

Firmness and toughness are two important texture attributes. The textural properties of the blanched samples at different time interval are shown in Fig. 4.3 and 4.4. The effect of blanching time on texture for both variety was statistically analysed (Appendix II) and the variables were found to be highly significant ($p<0.05$).

The firmness and toughness of the raw cassava (M-4 variety) was 4.52 kg and 15.17 kg.s, respectively. The firmness values of samples blanched with B1, B2 and B3 treatments were 1.67, 0.49 and 0.47 kg, respectively. Similarly, the toughness values for the corresponding samples were 2.99, 1.62 and 1.57 kg.s, respectively (Fig. 4.3). The maximum percentage reduction of 89.5 per cent firmness was observed in B3 treatment whereas minimum reduction of 63.06 per cent was found in B1. The percentage reduction of toughness for B3 and B1 treatments were 89.65 and 80.25 per cent, respectively.

For Sree Jaya variety also, similar trend was observed for both textural values. The firmness and toughness of the raw sample was determined as 7.56 kg and 20.39 kg.s, respectively. For B1 treatment, the firmness and the toughness reduced to 4.2 kg and 14.5 kg.s, respectively. Similarly, the corresponding values for B2 and B3 treatments were 3.5 kg, 7.3 kg.s and 2.67 kg, 4.33 kg.s, respectively (Fig. 4.4).

From Fig 4.3 and 4.4, it is understood that the firmness and toughness values of both varieties decreased significantly with blanching period.

Lee *et al*. (1979) observed similar result on blanching experiments of carrots; with increased process time the loss in texture increased. The loss of texture might be both due to changes in pectin substances, cell wall polymers and turgor loss due to cell wall disruption (Greve *et al.*, 1994a; 1994b).

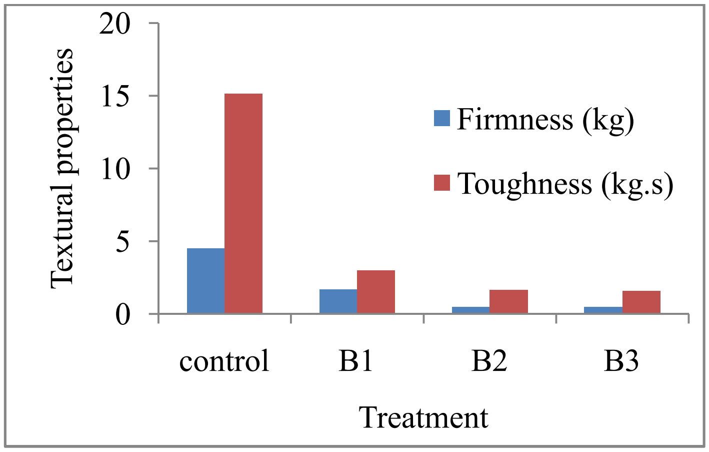


Figure 4.3 Effect of blanching on texture of cassava tubers, variety: M-4

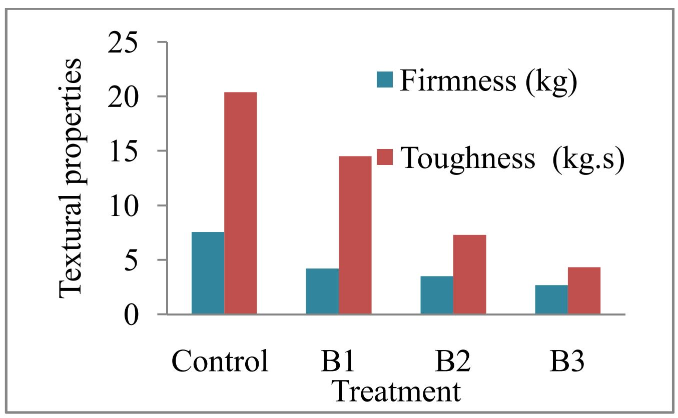


Figure 4.4 Effect of blanching on texture of cassava tubers, variety: Sree Jaya

4.2.1.3 Effect of blanching time on pH

The pH of the samples blanched at different time period is shown in Fig. 4.5 and 4.6. The effect of blanching time on pH was statistically analysed and the variables were not found to be significant (Appendix II). Equilibrium between splitting and formulation of hydrogen bonds might be the reason for the lack of change in pH (Drotz, 2012).

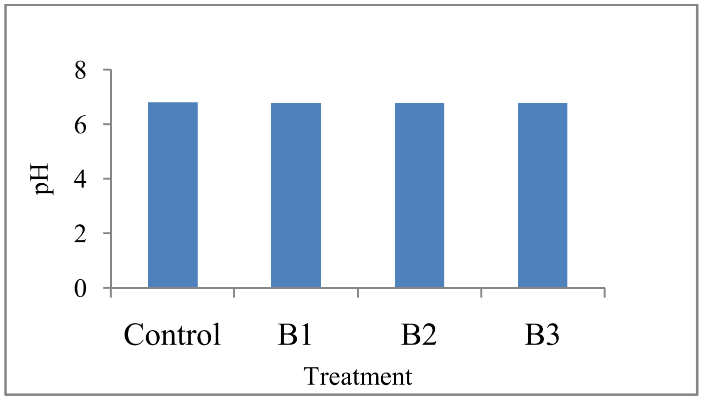


Figure 4.5 Effect of blanching on pH in cassava tubers, variety: M-4

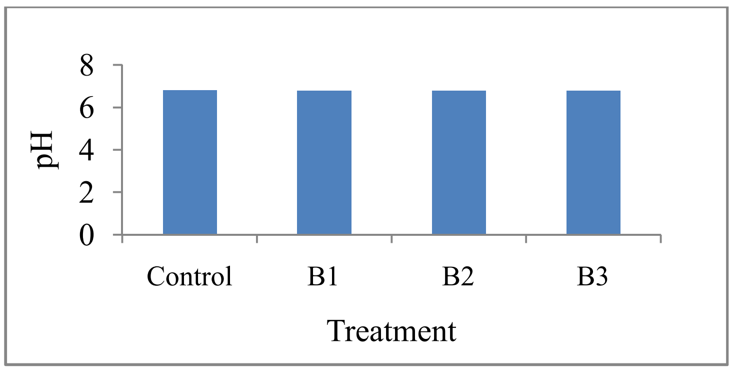


Figure 4.6 Effect of blanching on pH in cassava tubers, variety: Sree Jaya

4.2.1.4 Effect of blanching time on carbohydrate content

The effect of blanching time on carbohydrate content is presented in Fig. 4.7 and 4.8. The carbohydrate values for different blanching period were statistically analysed and found to be significant ($p<0.05$) (Appendix II).

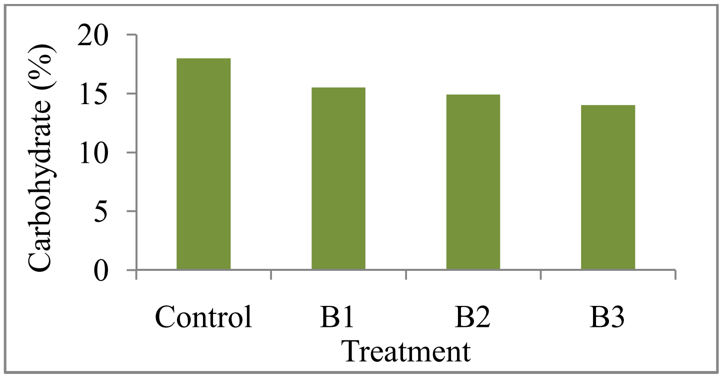


Figure 4.7 Effect of blanching on carbohydrate content in cassava tubers, variety: M-4

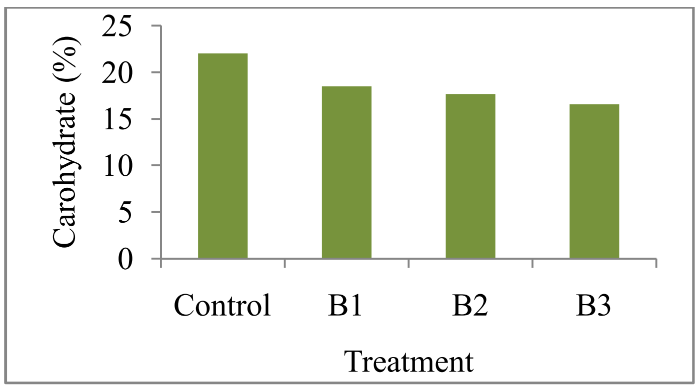


Figure 4.8 Effect of blanching on carbohydrate content in cassava tubers, variety: Sree Jaya

From Fig. 4.7 and 4.8, it is observed that the carbohydrate content reduced slightly with blanching time for both cassava varieties. The maximum value of carbohydrate was found in control sample and the minimum value in B3 treatment. In M-4 variety, the raw cassava having 18.57 per cent carbohydrate content was reduced to 15.57 per cent when blanched for 5 min (B1). The reduction in carbohydrate content during B2 and B3 treatments was 17.2 and 14.9 per cent, respectively.

From the graph, it can be seen that similar trend was observed in Sree Jaya variety too. The carbohydrate content of raw cassava was 24.46 per cent. The reduction in carbohydrate during blanching for B1, B2 and B3 treatments was 19.72, 18.6 and 15.9 per cent, respectively.

The loss in carbohydrate might be due to reduction of low molecular weight carbohydrate and leaching of carbohydrate content due to heat-moisture treatment of cassava. Similar results were found when blanching of soybean was conducted by Song *et al.* (2003).

4.2.1.5 Effect of blanching on crude fibre content

Fig. 4.9 and 4.10 shows the effect of blanching time on crude fibre content of the blanched cassava samples. In M-4 variety, the crude fibre content of the raw cassava was found to be 2.42 per cent. During blanching at 5, 10 and 15 min, the fibre content was reduced to 2.35, 2.28 and 2.0 per cent, respectively. In Sree Jaya variety also, the reduction in crude fibre content was similar to M-4 variety. In Sree Jaya variety, crude fibre content of 2.42 per cent in the raw sample reduced to 2.35, 2.28 and 2.14 per cent when it was subjected to blanching at B1, B2 and B3 treatments. The fibre content values of both varieties of cassava reduced significantly with blanching time.

The effect of blanching on crude fibre of both cassava varieties was statistically analysed and the variables were found to be significant ($p<0.05$) (Appendix II).

Decrease in crude fibre content in boiled cassava tuber was reported by Montagnac (2009). According to Wills *et al*. (1984) the reduction in crude fibre content maybe attributed to the increase in moisture content of the blanched peas and beans. The decrease in crude fibre content may be due to heat induced breakdown of complex carbohydrate (Bushway *et al*, 1985).

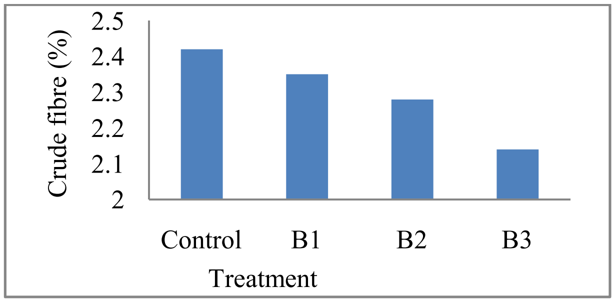


Figure 4.9 Effect of blanching on crude fibre content of cassava tubers, variety: M-4

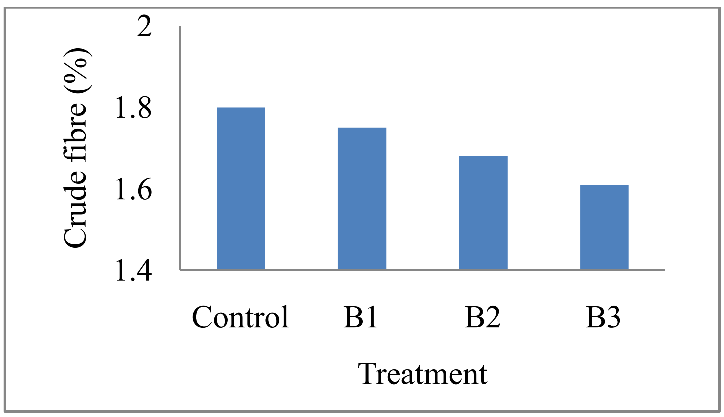


Figure 4.10 Effect of blanching on crude fibre content of cassava tubers, variety: Sree Jaya

Table 4.3 Mean table for blanched cassava tubers, variety: M-4

Parameter	Control			B1			B2			B3		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD
L*	71.70	±	0.09	63.39	±	0.23	57.14	±	0.23	54.52	±	0.20
a*	1.41	±	0.05	0.45	±	0.01	-1.13	±	0.02	-1.32	±	0.01
b*	18.13	±	0.43	19.77	±	0.18	20.03	±	0.15	20.56	±	0.17
Firmness	5.22	±	0.76	1.67	±	0.08	0.50	±	0.09	0.47	±	0.10
Toughness	15.17	±	3.50	3.00	±	1.25	1.52	±	0.63	1.55	±	0.48
Ph	6.80	±	0.01	6.78	±	0.01	6.78	±	0.01	6.77	±	0.01
Carbohydrate(%)	18.57	±	0.11	15.57	±	0.02	14.90	±	0.05	15.66	±	0.10
Crude fibre (%)	2.42	±	0.02	2.35	±	0.01	2.28	±	0.02	2.14	±	0.02

Table 4.4 Mean table for blanched cassava tubers, variety: Sree Jaya

Parameter	Control			B1			B2			B3		
	Mean	±	SD	Mean	±	SD	Mean	±	SD	Mean	±	SD
L*	73.00	±	0.10	65.50	±	0.01	62.80	±	0.01	58.80	±	0.01
a*	1.43	±	0.02	1.34	±	0.01	-0.37	±	1.27	-1.25	±	0.01
b*	17.89	±	0.01	18.20	±	0.02	19.20	±	0.01	20.40	±	0.01
Firmness	7.56	±	0.01	4.20	±	0.01	3.50	±	0.01	2.67	±	0.01
Toughness	20.39	±	0.04	14.50	±	0.10	7.30	±	0.02	4.34	±	0.01
pH	6.81	±	0.01	6.41	±	0.01	6.42	±	0.01	6.43	±	0.01
Carbohydrate(%)	22.05	±	0.05	18.51	±	0.01	17.66	±	0.02	16.55	±	0.02
Crude fibre (%)	1.81	±	0.01	1.75	±	0.02	1.68	±	0.02	1.61	±	0.01

4.2.1.6 Effect of blanching on cyanide content

The effect of blanching on cyanide content of cassava tubers of both varieties are shown in the Tables 4.5 and 4.6. The cyanide content of the blanched samples had a direct effect on blanching time. The cyanide content reduced significantly with time of blanching. In M-4 variety, the cyanide content of the samples reduced to 34.6 ppm at a blanching time of five min, which is far less than the permissible limit of 50 ppm. But in case of Sree Jaya variety, 15 min blanching time was recorded to reduce the cyanide content to permissible limit.

The effect of blanching on cyanide content of both cassava varieties was statistically analysed and the variables were found to be significant ($p<0.05$) (Appendix III).

Cooke and Maduagwu (1978) found that boiling for 15 min removes approximately 90 per cent of free cyanide and boiling for 25 min removes the bound moisture.

Table 4.5 Cyanide content of blanched cassava tubers, variety: M-4

Treatment	Cyanide content (ppm)
Raw	76.01 ± 0.08
B1	34.60 ± 0.10
B2	28.20 ± 0.02
B3	27.20 ± 0.01

Table 4.6 Cyanide content of blanched cassava tubers, variety: Sree Jaya

Treatment	Cyanide content (ppm)
Raw	107.05 ± 0.06
B1	68.20 ± 0.01
B2	52.30 ± 0.04
B3	45.00 ± 0.01

4.2.1.7 Optimisation of blanching time

The blanching time was optimised based on the time required for the removal of cyanide content below permissible limit. In M-4 variety, it required 5 min of blanching at 100˚C for the reduction of cyanide content below permissible limit. Also, the quality parameters of blanched cassava at 5 min were found to be good (Section 4.2.1.1 to 4.2.1.6). Hence, the blanching time for M-4 variety was optimised as 5 min and the further studies were conducted at this blanching time.

In the case of Sree Jaya, which requires higher cooking time, the time for optimum blanching was found to be higher. The cassava sample blanched at 100˚C for 15 min showed residual cyanide content of 45 ppm which is below the permissible level. Hence for this variety, the blanching time of 15 min was selected for further studies.

4.3 QUALITY IMPROVEMENT BY ADDITION OF HYDROCOLLOIDS – ADDITION OF GUAR GUM

In order to minimise the loss in texture due to heat treatment and leaching of amylose, the cassava cubes were soaked in 0.1 per cent guar gum solution at the optimised blanching time (Dinakaran *et al*., 2017). M-4 was blanched at 100˚C for 5 min with 0.1per cent guar gum solution and Sree Jaya was blanched at 100˚C for 15 min in 0.1 per cent guar gum solution (Plate 4.2). Guar gum breaks down at low pH (Featherstone, 2015); but since cassava has an almost neutral pH it could be used with cassava.


Plate 4.2 Gum treated blanched cassava

4.3.1 Physico-Chemical Characteristics of Guar Gum Treated Blanched Samples

The quality attributes of guar gum treated blanched cassava samples were evaluated and the effect of guar gum blanching on quality parameters was studied. The mean tables for guar gum treated blanched cassava tubers are tabulated in the Table 4.7 and 4.8, respectively.

4.3.1.1 Effect of guar gum on colour of blanched cassava tuber

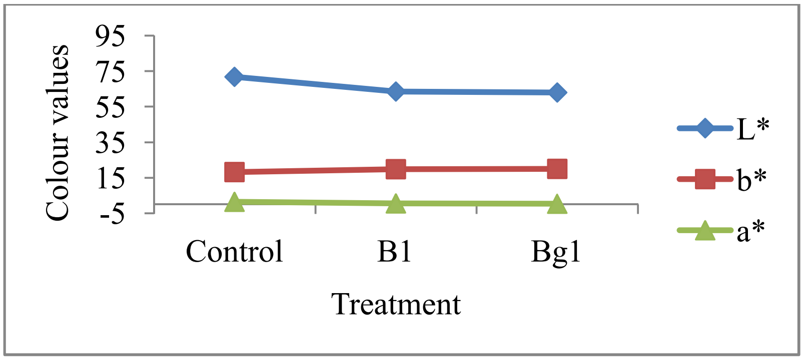


Figure 4.11 Effect of guar gum on colour of blanched cassava tubers, variety: M-4

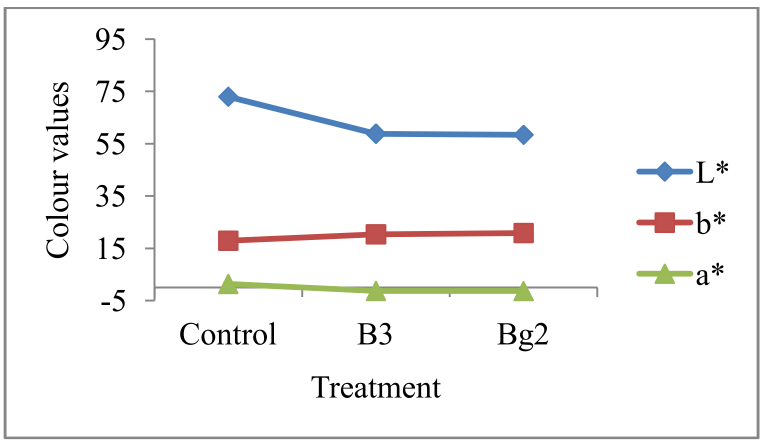


Figure 4.12 Effect of guar gum on colour of blanched cassava tubers, variety: Sree Jaya

The colour values of blanched samples treated with guar gum is shown in Fig. 4.11 and 4.12. The effect of guar gum added was statistically analysed and were found to be significant ($p \leq 0.05$) (Appendix IV).

In M-4 variety, the L*, a*, b* values of blanched cassava with guar gum were 63.01, 0.35 and 20.01, respectively. The corresponding values for blanched samples without guar gum were 63.39, 0.45 and 19.77, respectively. Similarly, in Sree Jaya variety, the L*, a*, b* values of blanched samples treated with and without guar gum were 58.4, -1.29, 20.94 and 58.8, -1.25, 20.4, respectively. Hence from Fig.4.11 and 4.12, it is understood that the addition of guar gum during blanching had significant effect on colour values.

Dinakaran *et al*. (2017) obtained similar result when tapioca was blanched in guar gum.

4.3.1.2 Effect of guar gum on texture of blanched cassava tubers

Guar gum at 0.1 per cent concentration level was added to the blanching water to improve the texture of the blanched cassava. The effect of adding guar gum on texture of blanched cassava cubes of M-4 and Sree Jaya varieties are shown in Fig. 4.13 and 4.14, respectively. A significant difference ($p \leq 0.05$) in the texture attributes like firmness and toughness was observed in the guar gum blanched samples compared with the samples blanched without guar gum (Appendix IV).

In M-4 variety, the firmness value of blanched samples treated without and with guar gum were 1.67 and 4.23 kg. The corresponding toughness values were 3.00 and 5.60 kg.s. The results reveal that the textural qualities were improved by the addition of guar gum during blanching process.

In Sree Jaya variety, firmness observed when the sample was blanched with guar gum was 4.61 kg and the toughness was 6.14 kg.s. The sample had a firmness of 2.67 kg and toughness of 4.34 kg.s when blanched without guar gum.

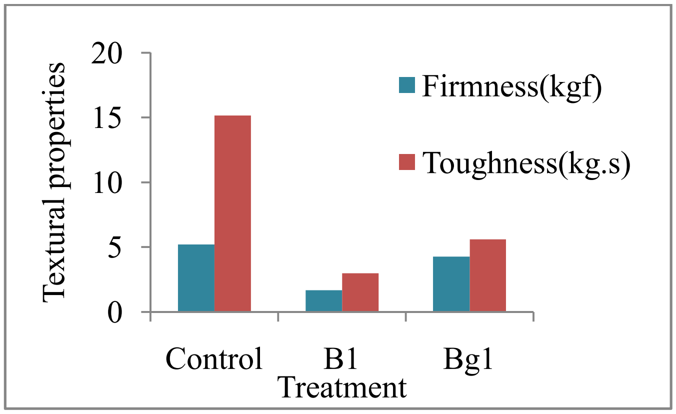


Figure 4.13 Effect of guar gum on texture of blanched cassava tubers, variety: M-4

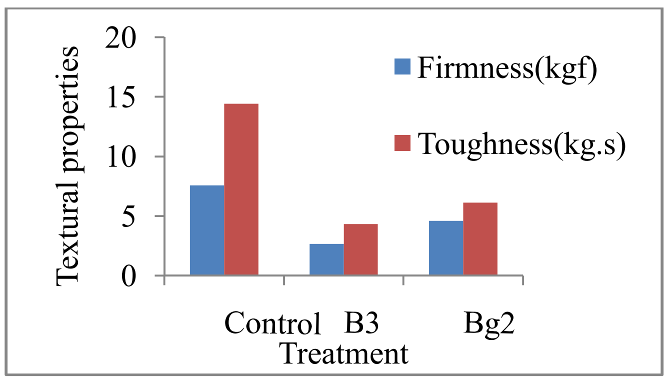


Figure 4.14 Effect of guar gum on texture of blanched cassava tubers, variety: Sree Jaya

Guar gum acts like a binding agent and reduce the loss of amylose into the blanching water leading to the improvement in texture. The hydrating and water binding ability of guar gum allows its use as food stabilising system (Dinakaran *et al*., 2017; Featherstone, 2015). Similar results were reported by Dinakaran *et al*. (2017) while conducting blanching experiment in cassava using guar gum.

4.3.1.3 Effect of guar gum on carbohydrate content of blanched cassava tubers

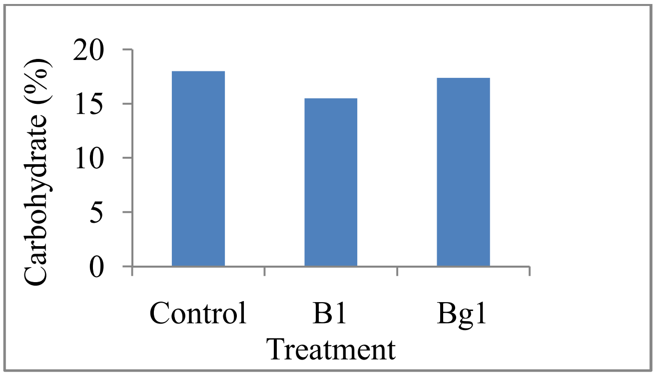


Figure 4.15 Effect of guar gum on carbohydrate content of blanched cassava tubers, variety: M-4

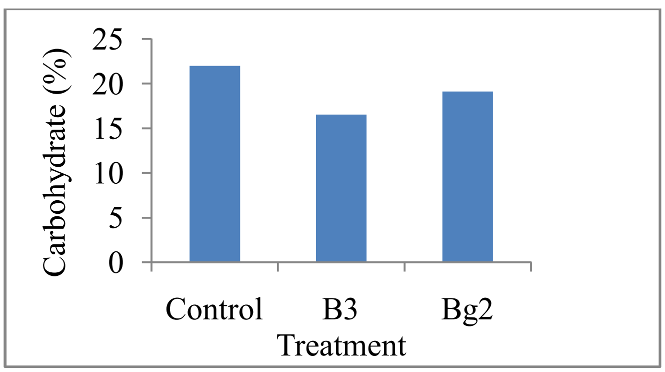


Figure 4.16 Effect of guar gum on carbohydrate content of blanched cassava tubers, variety: Sree Jaya

Quality improvement with guar gum was opted to reduce leaching during blanching and thermal processing. The effect of adding guar gum during blanching of M-4 and Sree Jaya varieties are presented in Fig. 4.15 and 4.16, respectively. The results were analysed statistically and the variable was found to be significant at 5 per cent level ($p \leq 0.05$) (Appendix IV). Therefore considerable increase in the carbohydrate content was expected in the sample blanched with gum and a significant difference was observed.

In M-4 variety, the carbohydrate content increased from 15.57 to 17.38 per cent when cassava was blanched with guar gum compared to cassava blanched without guar gum. In Sree Jaya variety the carbohydrate content increased from 16.55 to 19.19 per cent, when blanched with guar gum.

The carbohydrate content increased when cassava was blanched with guar gum compared to cassava blanched without gum. The leaching of amylose into the blanching water could have reduced leading to the increase in the carbohydrate content when compared with the cassava blanched without guar gum (Dinakaran *et al*., 2017). Similar result was reported by Rodge *et al*. (2012) while studying the effect of hydrocolloid incorporation into bread.

4.3.1.4 Effect of guar gum on crude fibre content of blanched cassava tubers

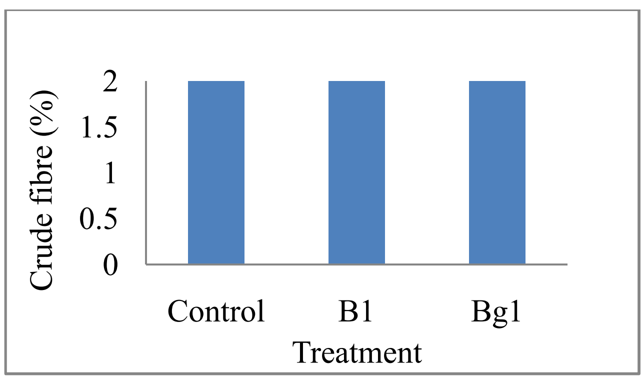


Figure 4.17 Effect of guar gum on crude fibre content of blanched cassava tubers, variety: M-4

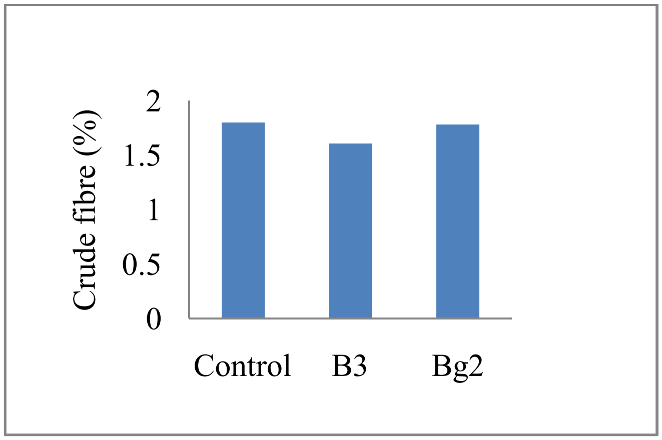


Figure 4.18 effect of guar gum on crude fibre content of blanched cassava tubers, variety: Sree Jaya

The crude fibre content of blanched cassava samples treated with guar gum is shown in Fig.4.17 and 4.18. The crude fibre content value for each treatment was found to be insignificant for both varieties of cassava ($p<0.05$) (Appendix IV).

The crude fibre content increased to 2.37 from 2.35 per cent in M-4 variety of cassava and in Sree Jaya variety, the crude fibre content increased to 1.78 from 1.61 per cent when blanched with guar gum in comparison with the sample blanched without gum.

The slight increase in crude fibre content may be due to the ability of guar gum to reduce water accumulation (Featherstone, 2015). Similar results were obtained by Rodge *et al*. (2012) while studying the effect of hydrocolloid incorporation into bread; no significant change in crude fibre content could be found according to the study.

Table 4.7 Mean table for gum treated blanched cassava tubers, variety: M-4

Parameters	Control			B1			Bg1		
	Mean	±	SD	Mean	±	SD	Mean	±	SD
L*	71.70	±	0.09	63.39	±	0.23	63.01	±	0.01
a*	1.41	±	0.05	0.45	±	0.01	0.35	±	0.01
b*	18.13	±	0.43	19.77	±	0.18	20.01	±	0.02
Firmness	5.22	±	0.76	1.67	±	0.08	4.23	±	0.06
Toughness	15.17	±	3.50	3.00	±	1.25	5.60	±	0.10
Carbohydrate(%)	18.57	±	0.11	15.57	±	0.02	17.38	±	0.02
Crude fibre (%)	2.42	±	0.02	2.35	±	0.01	2.37	±	0.01

Table 4.8 Mean table for gum treated blanched cassava tubers, variety: Sree Jaya

Parameters	Control			B3			Bg2		
	Mean	±	SD	Mean	±	SD	Mean	±	SD
L*	73.00	±	0.10	58.80	±	0.01	58.40	±	0.01
a*	1.43	±	0.02	-1.25	±	0.01	-1.29	±	0.01
b*	17.89	±	0.01	20.40	±	0.01	20.94	±	0.06
Firmness	7.56	±	0.01	2.67	±	0.01	4.61	±	0.01
Toughness	14.39	±	0.04	4.34	±	0.01	6.14	±	0.05
Carbohydrate(%)	22.05	±	0.05	16.55	±	0.02	19.19	±	0.06
Crude fibre (%)	1.81	±	0.01	1.61	±	0.01	1.78	±	0.01

4.4 OPTIMISATION OF THERMAL PROCESSING

Calcium chloride brine with 0.4 per cent concentration was selected as the filler solution since calcium reduced the influence of heat and thereby increased the firmness of the sample (Stanley *et al*., 1995). Stanley *et al*. (1995) studied the effect of calcium on the firmness of canned beans and he observed increase in firmness compared with control sample. 0.4 per cent is the generally considered as the safe permissible limit for use in food (FDA, 2018).

4.4.1 Optimisation of time temperature combination of thermal processing

The thermal processing was conducted at 100˚C, 110˚C, 121˚C in combinations with process time.

T1 – M-4 thermally processed at 100˚C for 10 min with F_0 of 0.5

T2 – M-4 thermally processed at 100˚C for 20 min with F_0 of 1.1

T3 – M-4 thermally processed at 110˚C for 20 min with F_0 3.2

T4 – M-4 thermally processed at 110˚C for 40 min with F_0 6.1

T5 – M-4 thermally processed at 121˚C for 8 min with F_0 10.8

TV1 – Sree Jaya thermally processed at 100˚C for 10 min with F_0 0.6

TV2 – Sree Jaya thermally processed at 100˚C for 20 min with F_0 1.5

TV3 – Sree Jaya thermally processed at 110˚C for 10 min with F_0 1.1

TV4 – Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1

TV5 – Sree Jaya thermally processed at 121˚C for 2 minute with F_0 4

Thermally processed samples were stored at 30˚C for 48 h and the total plate count analyses were conducted to enumerate the microbial colonies in the thermally processed samples and the time temperature combinations were optimised accordingly. Further studies were conducted in the microbiologically safe samples alone.

The samples with no microbial count or microbial count less than 50 cfu/ml were selected (Table 4.9); 50 cfu/ml is the maximum permissible limit of bacterial count in thermally processed foods (PFA, 2002). Therefore T4, T5, TV4, TV5 were selected for further studies (Plate 4.3).

The samples other than thermally processed at 110˚C for 40 min and at 121˚C for 8 min in M-4 variety (T1, T2, T3) were discarded due to the microbial growth observed in the samples. The samples other than thermally processed at 110˚C for 20 min and at 121˚C for 2 min in Sree Jaya variety (TV1, TV2, TV3) were discarded due to the microbial growth observed in the samples.

Low acid foods needs to be thermally processed at temperatures above 100˚C (Berk, 2013); Cassava being a low acid food therefore requires higher thermal processing temperatures. The heat penetration characteristics of T4 are shown in the Fig. 4.19. T4 required 40 min at 110˚C to attain an F_0 value of 6.1. The microbial load in T4 was found to be nil. The heat penetration characteristics of T5 are shown in the Fig. 4.20. T5 was processed at 121˚C for 8 min with F_0 10.8. The microbial load in T5 was found to be nil. The heat penetration characteristics of TV4 are shown in the Fig. 4.21. TV4 required 20 min at 110˚C to attain an F_0 value of 2.1. The microbial load in TV4 was found to be nil. The heat penetration characteristics of TV5 are shown in the Fig. 4.22. TV5 was processed at 121˚C for 2 min with F_0 4. The microbial load in TV5 was found to be nil.

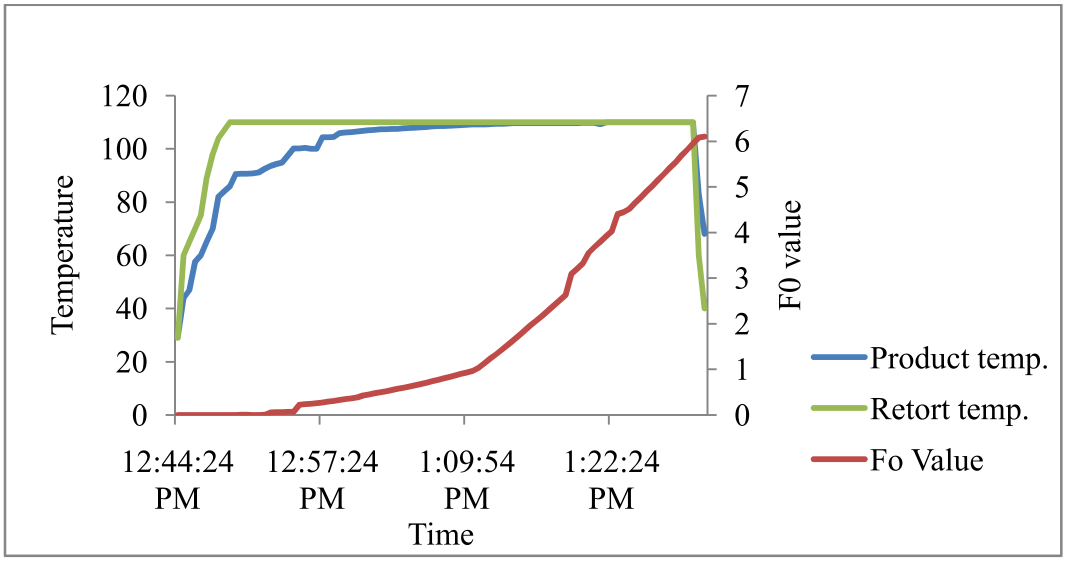


Figure 4.19 T4-Thermal processing at 110˚C for 40 minute with F_0 6.1

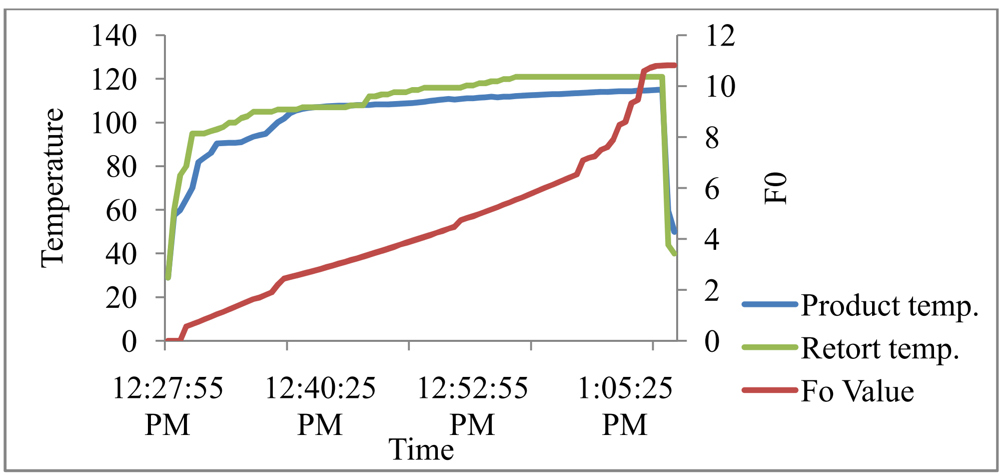


Figure 4.20 T5- Thermal processing at 121˚C for 8 min with F_0 10.8

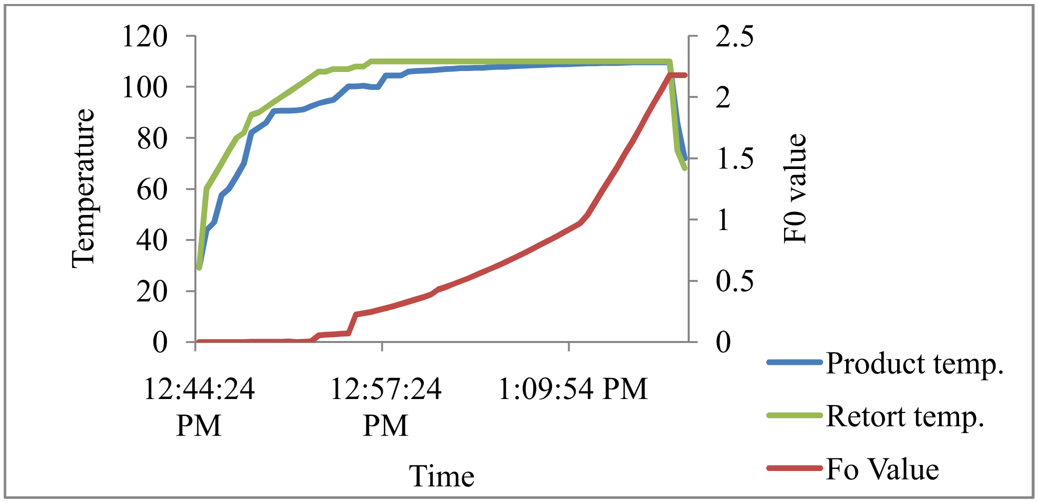


Figure 4.21 TV4-Thermal processing at 110˚C for 20 min with F_0 2.1

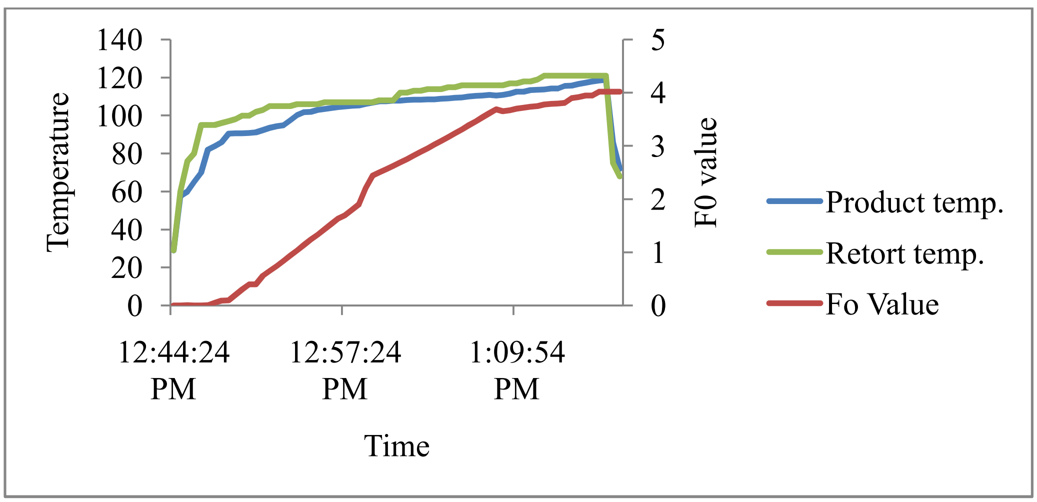


Figure 4.22 TV5 - Thermal processing at 121˚C for 2 min with F_0 4

Storage studies were conducted on samples T4, T5, TV4, TV5 and the optimum processing condition was selected.

Table 4.9 Microbial count of thermally processed samples

Treatment	TPC for bacteria	TPC for yeast and mould
T1	80 cfu/ml	Nil
T2	70 cfu/ml	Nil
T3	52 cfu/ml	Nil
T4	Nil	Nil
T5	Nil	Nil
TV1	83 cfu/ml	Nil
TV2	72 cfu/ml	Nil
TV3	54 cfu/ml	Nil
TV4	Nil	Nil
TV5	Nil	Nil

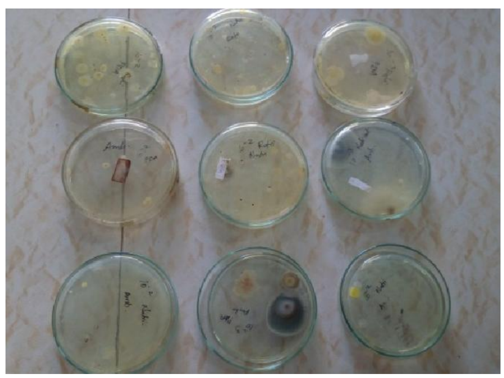


Plate 4.3 TPC analysis for microbial load

4.4.2 Quality Parameters of Retorted Samples on the 0th Day

The mean value of the quality parameters of retorted cassava on zeroth day is tabulated in the Table 4.10. Significant difference (p≤0.05) between optimally gum treated blanched samples and retorted samples were observed in the colour, texture, carbohydrate content and crude fibre content of both the varieties; ANOVA table for the same is tabulated in the Appendix V.

The L* value of T5 and T4 before retorting was 63.01 which reduced to 56.94 and 57.63 after retorting. The brightness of the sample was comparatively reduced due to thermal processing. The a* value indicative of greenness to redness reduced from 0.35 to -1.55 and -0.72 in T5 and T4, respectively after retorting. The b* value increased from 20.01 to 20.6 and 20.3 in T5 and T4, respectively. The increase in b* value indicated an increase in yellowness.

The L* value of TV5 and TV4 before retorting was 58.39 which reduced to 53 and 55.8 after retorting. The brightness of the sample was comparatively reduced due to thermal processing. The a* value indicative of greenness to redness reduced from -1.29 to -1.10 and -1.15 in TV5 and TV4 respectively after retorting. The change in a* value indicated a decrease in greenness of the sample. The b* value increased from 20.94 to 21.5 and 22.3 respectively in TV5 and TV4 respectively. The increase in b* value indicated an increase in yellowness. The change in colour values might be due to thermally induced non-enzymatic browning, which might be higher at higher temperatures (Basu and Shivhare, 2013; Imaizumi *et al*., 2017).

The texture parameters like firmness and toughness of the samples were observed and compared with the initial texture attributes; the initial firmness and toughness of T5 were 4.23 kg and 5.6 kg.s, respectively which reduced to 0.65 kg and 1.06 kg.s, respectively. In the case of T4 the initial value was same as T5 which reduced to 0.92 kg and 2.98 kg.s, respectively. The initial firmness and toughness of TV5 and TV4 reduced to 0.9 kg, 1.32 kg and 1.9 kg, 3.42 kg.s, respectively. The sample processed at lower temperature had lesser loss in texture compared with the sample processed at higher temperature. It might be due to temperature induced texture loss as a part of degradation of the cell wall due to breakdown of complex carbohydrates (Bushway *et al*. 1985).

The initial carbohydrate content of T4 and T5 before retorting was observed as 17.38 per cent; after retorting the carbohydrate content was 16.42 per cent and 15.87 per cent, respectively. The initial carbohydrate content in TV5 and TV4 was observed as 19.19 per cent which reduced to 17.01 per cent and 17.2 per cent, respectively. Excessive loss in carbohydrate content might be due amylose leaching and retrogradation at higher temperature processing (Gunaratne and Hoover, 2002).

The initial crude fibre content of T5 and T4 before retorting was observed as 2.37; after retorting the crude fibre content was 2.01 per cent and 2.18 per cent respectively. The initial crude fibre content in TV5 and TV4 was observed as 1.78 per cent which reduced to 1.64 per cent and 1.7 per cent. The decrease in crude fibre content might be due to moisture migration which might increase with increase in temperature (Wills *et al*. 1984).

Table 4.10 Mean values for thermally processed samples on 0th day

Parameters	T5	T4	TV5	TV4
	Mean	Mean	Mean	Mean
L*	56.94	57.63	53	55.8
a*	-1.55	-0.72	-1.10	-1.15
b*	20.6	20.3	21.5	22.3
Firmness	0.65	0.92	0.9	1.32
Toughness	1.06	2.98	1.90	3.42
Carbohydrate(%)	15.87	16.42	17.01	17.2
Crude fibre (%)	2.01	2.18	1.64	1.7

4.5 STORAGE STUDIES

A preliminary study on the storage life of retort processed cassava was conducted and it was observed that after three months storage at ambient conditions and six months at refrigerated conditions, the microbial load increased. Therefore the microbiologically safe samples were kept at ambient conditions for three months and at refrigerated conditions for six months. The changes in the quality attributes were studied throughout the storage period.

TS1 – M-4 thermally processed at 121˚C for 8 min with F_0 10.8 stored at ambient conditions

TS2 – M-4 thermally processed at 110˚C for 40 min with F_0 6.1 stored at ambient conditions

TS3 – Sree Jaya thermally processed at 121˚C for 2 min with F_0 4 stored at ambient conditions

TS4 - Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1 stored at ambient conditions

TR1 – M-4 thermally processed at 121˚C for 8 min with F_0 10.8 stored at refrigerated conditions

TR2 – M-4 thermally processed at 110˚C for 40 min with F_0 6.1 min stored at refrigerated conditions

TR3 – Sree Jaya thermally processed at 121˚C for 2 min with F_0 4 stored at refrigerated conditions

TR4 - Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1 stored at refrigerated conditions

4.5.1 Effect of Storage on Quality Parameters of Thermally Processed Cassava

The effect of storage on the quality parameters were analysed every month and are given below. The results were analysed statistically and the

ANOVA table for ambient storage and refrigerated storage are tabulated in the Appendix VI and VII, respectively.

4.5.1.1 Effect of storage parameters on colour of thermally processed cassava

The effect of ambient and refrigerated storage on L*, a*, b* values are shown in Figure 4.23, 4.24; 4.25, 4.26, 4.27 and 4.28. The results were analysed statistically and the variable was found to be significant at 5 per cent level ($p \leq 0.05$) (Appendix VI and VII).

The L* value of both the varieties showed a decrease in trend during the first month. In the second month L* value slightly increased and remained the same during the third month. The L* value had showed a decrease and then an increase compared with the zeroth day value.

At ambient conditions the L* value of TS1 was 56.94 which increased to 59.05 at the end of two months and slightly increased to 59.39 during the third month of storage; but at the end of one month of storage a decrease to 53.61 in the L* value was observed. In TS2, the L* value was 57.63 which reduced to 50.3 after the first 30 days then increased to 58.22 after 60 days and slightly increased to 58.26 at the end of third month. Similar trend has been observed in TS3 and TS4 samples. In TS3 the L* value was 53 on the zeroth day which increased to 54 at the end of third month. In TS4 the sample had an L* value of 55.8 on the zeroth day which reduced to 48.3 at the end of first month and then increased to 56.3 after three months.

In TR1 stored at refrigerated conditions the L* value showed a similar trend. The initial L* value of 56.94 increased to 57.5 at the end of six months. During the first month slight increase was seen to 57 which remained constant during the first two months. At the end of third month, the value slightly increased to 57.3 and then increased to 57.5 at the end of six months. Similar trend was observed in all the four samples.

The a* value was below zero on the zeroth day sample. During the three months of ambient storage a* value increased above 0 and reached near to a* value of raw sample. The a* value of TS1 increased from -1.55 to 1.58 at the end of three months of storage. The corresponding a* value of sample stored at refrigerated conditions at the end of six months was 1.29 only.

The b* value decreased with increase in storage period. Hence it is inferred that, yellowness of the sample reduced with the increase in storage time at ambient conditions. The b* value of TS1 was found to decrease from 20.6 to 17.5 at the end of three months of storage. Similar trend was observed in all the samples. In TR1 stored at refrigerated conditions the decrease from 20.6 was minimum and at the end of six months the value was 18.92.

TS2 had the highest L* value throughout the storage period in the case of M-4 variety. TS4 had the highest L* value throughout the storage period in the case of Sree Jaya variety.

The increase in L* value might be due to addition of guar gum during blanching since gums have an ability to bind moisture and prevent dehydration and inhibit maillard reaction (Yazdanseta *et al*., 2015).

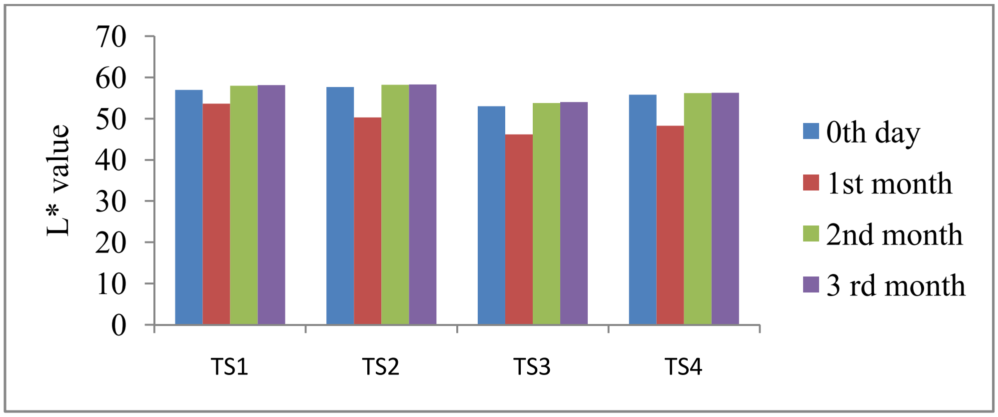


Figure 4.23 Changes in L*values during ambient storage

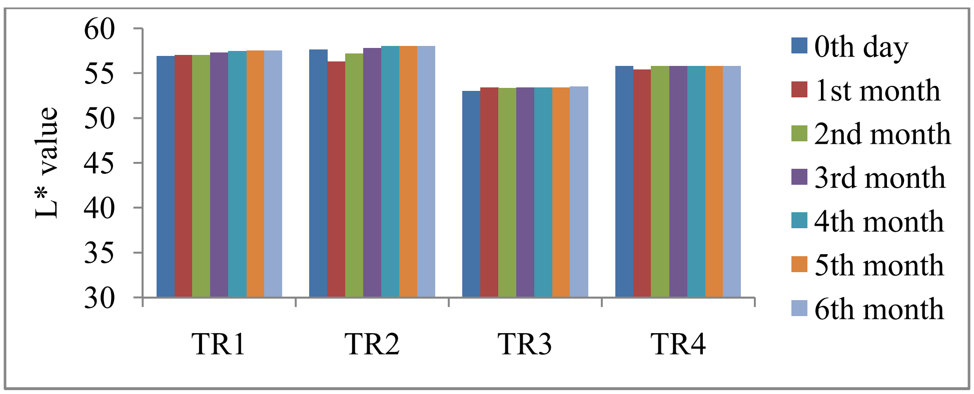


Figure 4.24 Changes in L* values during refrigerated storage

Figure 4.25 Changes in a* values during ambient storage

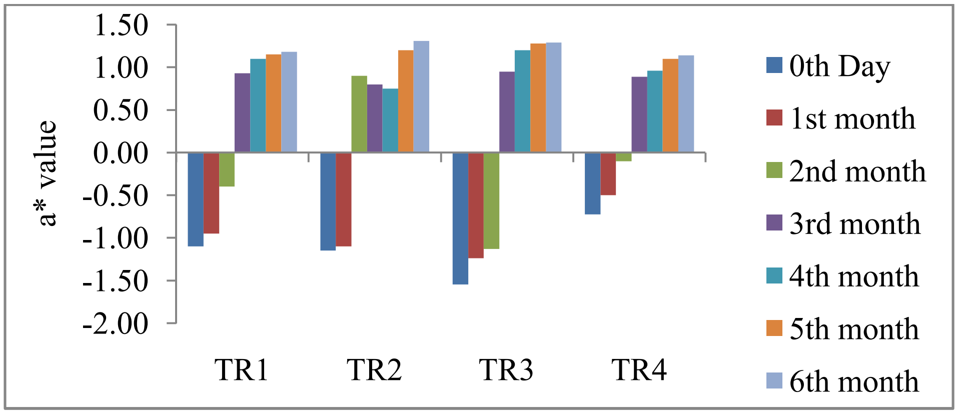


Figure 4.26 Changes in a* values during refrigerated storage

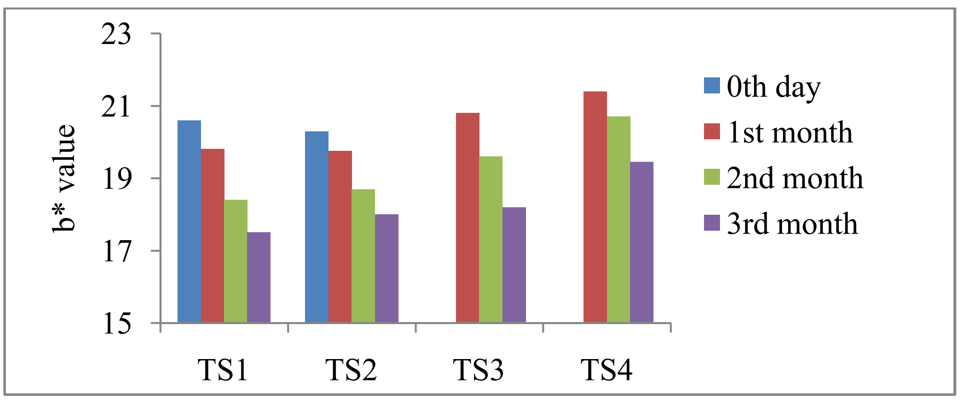


Figure 4.27 Changes in b* values during ambient storage

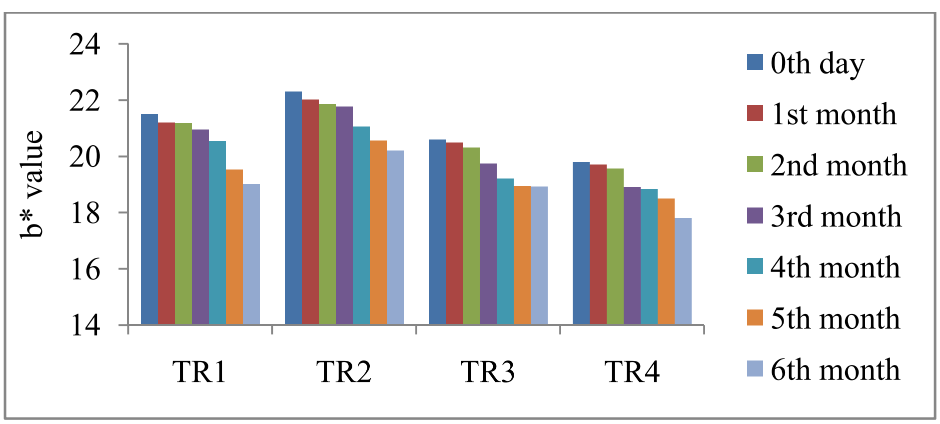


Figure 4.28 Changes in b* values during refrigerated storage

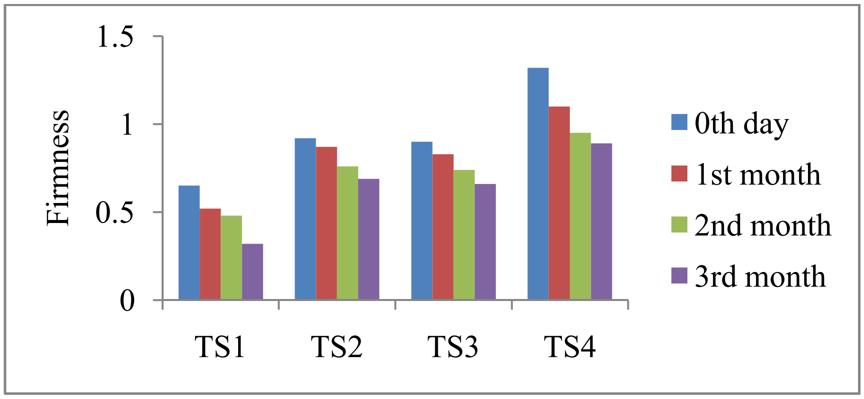


Figure 4.29 Changes in firmness during ambient storage

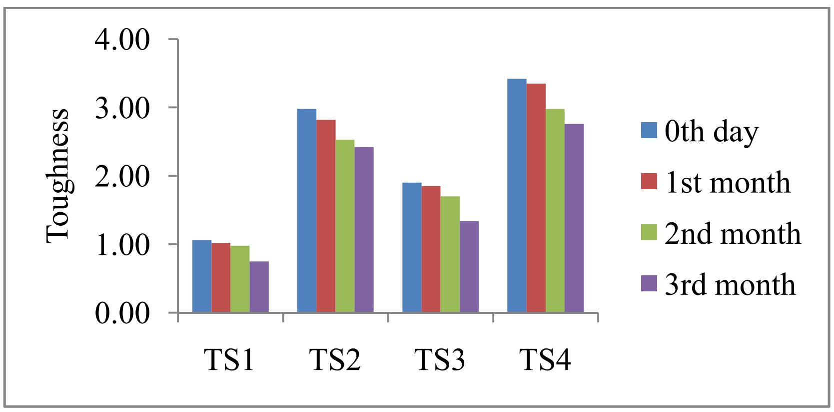


Figure 4.30 Changes in toughness during ambient storage

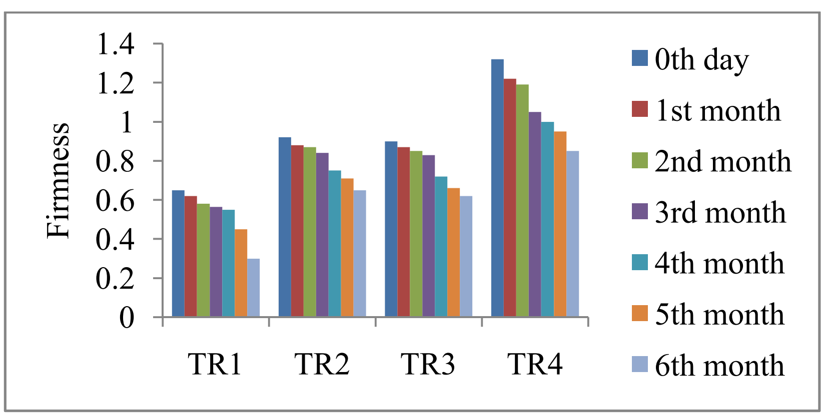


Figure 4.31 Changes in firmness during refrigerated storage

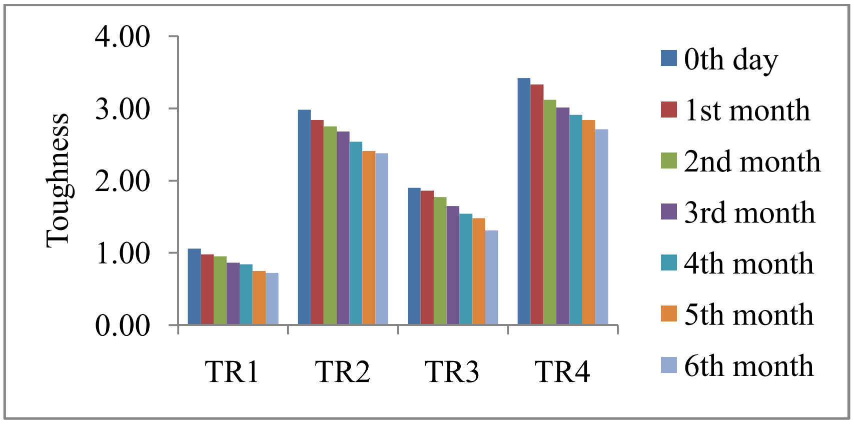


Figure 4.32 Changes in toughness during refrigerated storage

4.5.1.2 Effect of storage parameters on firmness and toughness of thermally processed cassava

The effect of ambient and refrigerated storage on firmness and toughness of retort processed cassava is shown in Figure 4.29, 4.31 and 4.30, 4.32, respectively. The results were analysed statistically and the variable was found to be significant at 5 per cent level ($p \leq 0.05$) (Appendix VI and VII).

The texture attributes, firmness and hardness, of cassava stored at ambient conditions and refrigerated conditions were analysed and it was observed that firmness and toughness reduced with the storage period. The decrease in texture attributes were more in ambient conditions compared with refrigerated conditions.

The sample TS1 had a firmness and toughness of 0.65 kg and 1.06 kg.s respectively on the zeroth day which reduced to 0.52 kg and 1.02 kg.s, respectively after one month ambient storage. The corresponding values after three months of ambient storage were 0.32 kg and 0.75 kg.s, respectively. In refrigerated storage, the firmness and toughness of TR1 reduced to 0.62 kg and 0.98 kg.s, respectively after one month of storage. In the second month the firmness and toughness again reduced to 0.58 kg and 0.954 kg.s. At the end of six months the firmness and toughness reached 0.30 kg and 0.72 kg.s, respectively.

Samples TS2, TS3 and TS4 followed a similar trend as in TS1. In TS2, the firmness reduced from 0.92 to 0.69 kg and the toughness reduced from 2.98 kg.s to 2.42 kg.s at the end of three months. In TS3, the toughness reduced from 1.9 kg.s to 1.34 kg.s and firmness reduced from 0.9 kg to 0.66 kg in three months. In TS4 the toughness and firmness reduced from 3.42 kg.s to 2.76 kg.s and 1.32 kg to 0.89 kg at the end of 90 days.

Samples TR2, TR3, TR4 followed a similar trend as in TR1. In TR2 the firmness reduced from 0.92 to 0.65 kg and the toughness reduced from 2.98 kg.s to 2.38 kg.s after six months of refrigerated storage. In TR3, the toughness reduced from 1.9 kg.s to 1.31 kg.s and the firmness reduced from 0.92 kg to 0.65 kg in six months. In TR4 the toughness and firmness reduced from 3.42 kg.s to 2.71 kg.s and 1.32 kg to 0.85 kg, respectively after six months of refrigerated storage.

In the case of M-4 variety, TS2 had the maximum value for the texture parameters throughout storage period at ambient conditions and TR2 had the maximum value for the texture parameters throughout storage period at refrigerated conditions. In Sree Jaya variety, TS4 and TR4 had the maximum value for texture parameters during the storage period at ambient and refrigerated conditions, respectively.

Similar results were observed by Catauro and Perchonok (2012) during storage of retort pouch processed apricot cobbler and rhubarb apple sauce. The reduction in firmness and becoming thinner over time might be due to moisture release from the tissues might have lead to the increase in free water in the sample.

4.5.1.3 Effect of storage parameters on carbohydrate content of thermally processed cassava

The effect of ambient and refrigerated storage on carbohydrate content is shown in Fig. 4.33 and 4.34. The results were analysed statistically and the variable was found to be significant at 5 per cent level ($p \leq 0.05$) (Appendix VI and VII).

The carbohydrate content of the samples decreased during the storage in ambient and refrigerated storage. The reduction of carbohydrate in ambient storage was more prominent compared to refrigerated storage. The carbohydrate content might have decreased due to the leaching of carbohydrates to the filler brine (Dinakaran *et al*., 2017; Gunaratne and Hoover, 2002).

Carbohydrate content of TS1 sample stored at ambient conditions were 15.87 per cent during the zeroth day, reduced to 14.4 per cent in three months where as in TR1, which was stored at refrigerated conditions reduced to 15.63 per cent. The reduction of carbohydrate content was less in refrigerated samples compared to ambient stored samples.

Similar trend has been observed in all other samples. In TS2, the carbohydrate content was reduced to 15.02 per cent during three months of ambient storage from 16.42 per cent on the zeroth day. In TR2, stored at refrigerated conditions the carbohydrate content reduced from 16.42 per cent to 16.38 per cent in six months. In TS3 the carbohydrate content decreased gradually from 17.01 per cent on the zeroth day to 15.5 per cent at the end of third month. In TR3, stored at refrigerated conditions, the carbohydrate content reduced to 16.55 per cent in six months. In TS4 stored at ambient conditions the carbohydrate content reduced from 17.2 per cent to 16.06 per cent in three months whereas in TR4 the carbohydrate content reduced from 17.2 to 17.08 per cent in six months. From the Figure, it is understood that carbohydrate content decreased gradually in refrigerated conditions.

In case of M-4 variety, TS2 had the maximum value for the carbohydrate content during storage period at ambient conditions and TR2 had the maximum value for carbohydrate content throughout storage period at refrigerated conditions. In case of Sree Jaya variety, TS4 and TR4 had the maximum value for carbohydrate content throughout the storage period at ambient and refrigerated conditions.

4.5.14 Effect of storage parameters on crude fibre content of thermally processed cassava

The effect of ambient and refrigerated storage on crude fibre content is shown in Fig. 4.35 and 4.36. Crude fibre content in the cassava samples reduced during storage but the change was less prominent in both refrigerated and ambient conditions. The reduction was comparatively more in the sample stored at ambient condition.

On zeroth day sample TS1 had crude fibre content of 2.01 per cent which reduced to 1.98 per cent at the end of first month where as in refrigerated storage it was reduced to 2 per cent. After two months of storage it was observed that the crude fibre content remained constant in the sample TR1 stored at refrigerated condition and slightly reduced to 1.94 per cent in the sample TS1 stored at ambient condition. At the end of three months crude fibre content of TS1 and TR1 reduced to 1.8 per cent and 1.98 per cent, respectively. At the end of fourth month in TR1 the crude fibre content reduced to 1.92 per cent and finally to 1.86 per cent at the end of six months.

A trend similar to TS1 was observed in TS2, TS3 and TS4. Also, samples TR2, TR3, TR4 showed similar trend as TR1. The crude fibre content of TS2, TS3 and TS4 samples placed at ambient storage for three months reduced from 2.18 to 2 per cent, 1.64 to 1.62 per cent and 1.7 to 1.65 per cent, respectively. The crude fibre content of TR2, TR3 and TR4 samples placed at refrigerated storage for six months reduced from 2.18 to 2.1 per cent, 1.64 to 1.6 per cent and 1.7 to 1.61 per cent, respectively.

In the case of M-4 variety, TS2 had the maximum value for crude fibre content throughout storage period at ambient conditions and TR2 had the maximum value for crude fibre content throughout storage period at refrigerated conditions. In the case of Sree Jaya variety, TS4 and TR4 had the maximum value for crude fibre content during the storage period at ambient and refrigerated conditions.

Bushway *et al*. (1985) reported a similar loss in crude fibre content in canned fiddlehead greens during storage. The reduction in crude fibre content might be due to hydrolysis of complex carbohydrates in the cell wall induced due to thermal processing.

4.5.1.6 Effect of storage parameters on pH of thermally processed cassava

The pH of both the samples of M-4 and Sree Jaya remained constant throughout the storage period.

In thermally processed foods the pH change is considered as a spoilage indicator (PFA, 2002). The pH of TS1, TS2, TR1, TR2 was 6.78 throughout the storage period whereas the pH of TS3, TS4, TR3, TR4 was 6.79 throughout the storage period.

4.5.1.7 Effect of storage parameters on the moisture content of thermally processed cassava

The effect of ambient and refrigerated storage on moisture content is shown in Fig. 4.37 and 4.38. It can be seen that the moisture content slightly increased in the cassava samples with the increase in the storage period. The results were analysed statistically and the variable was found to be significant at 5 per cent level ($p \leq 0.05$) (Appendix VI and VII).

In TS1 the moisture content increased from 75 per cent to 76.5 per cent in three months. In TS2 the moisture content increased from 75 per cent to 76.8 per cent in three months. In TS3 the moisture content increased from 75.2 per cent to 76.9 per cent in three months. In TS4 the moisture content increased from 75.4 per cent to 76.9 per cent in three months.

In TR1 the moisture content increased from 75 per cent to 76.4 per cent in six months. In TR2 the moisture content increased from 75 per cent to 76.3 per cent in six months. In TR3 the moisture content increased from 75.2 per cent to 76.2 per cent in six months. In TR4 the moisture content reduced from 75.4 per cent to 76.93 per cent in six months.

The slight increase in moisture content might be due to the presence of gum in the cassava samples, since guar gum has moisture retention properties (Rodge *et al*., 2012).

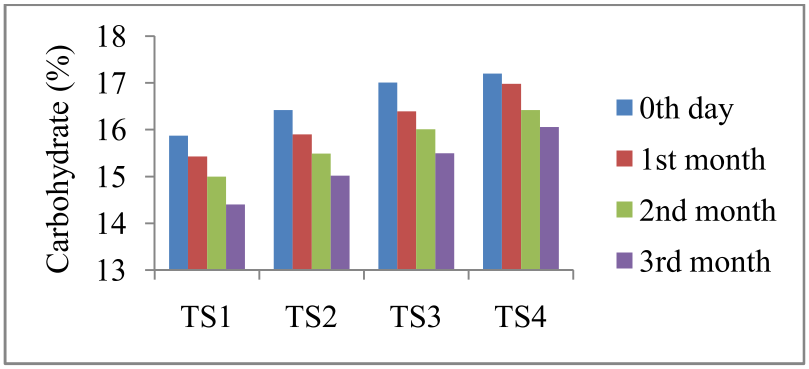


Figure 4.33 Changes in carbohydrate content during ambient storage

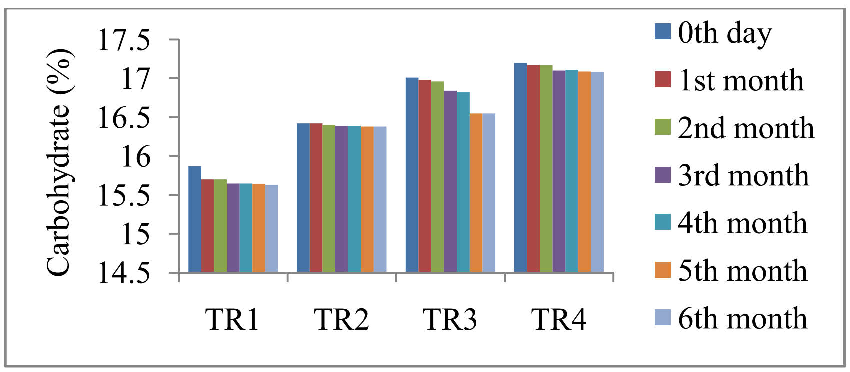


Figure 4.34 Changes in carbohydrate content during refrigerated storage

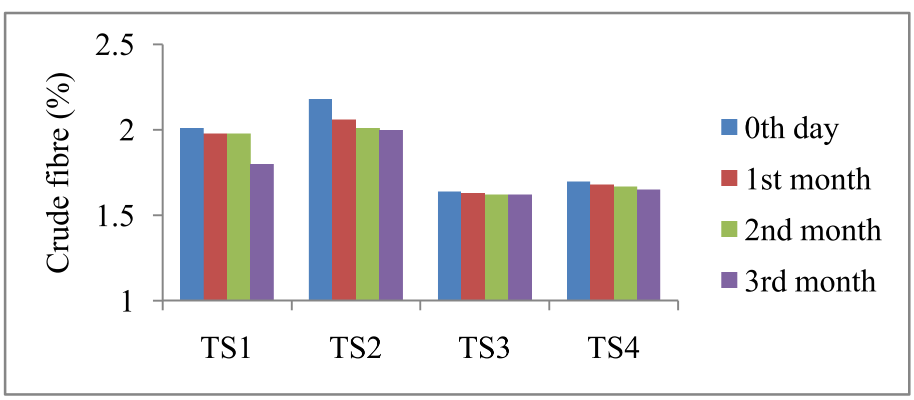


Figure 4.35 Changes in crude fibre content during ambient storage

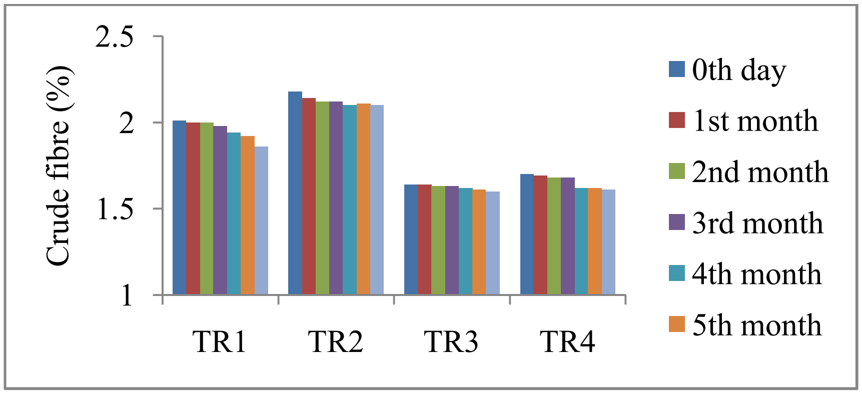


Figure 4.36 Changes in crude fibre content during refrigerated storage

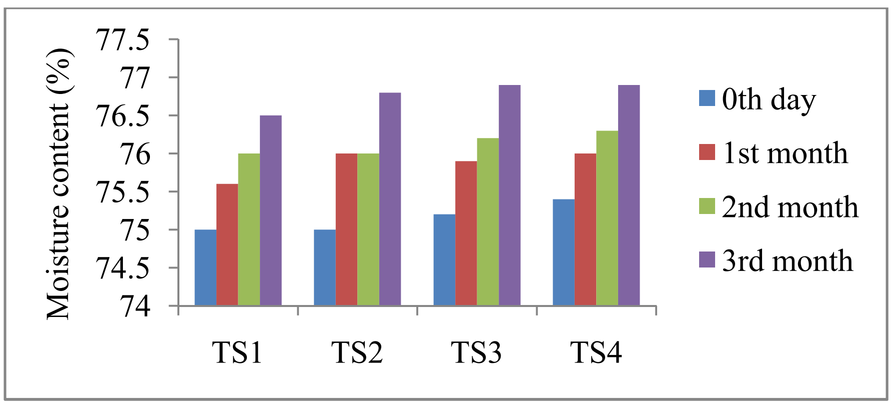


Figure 4.37 Changes in moisture content during ambient storage

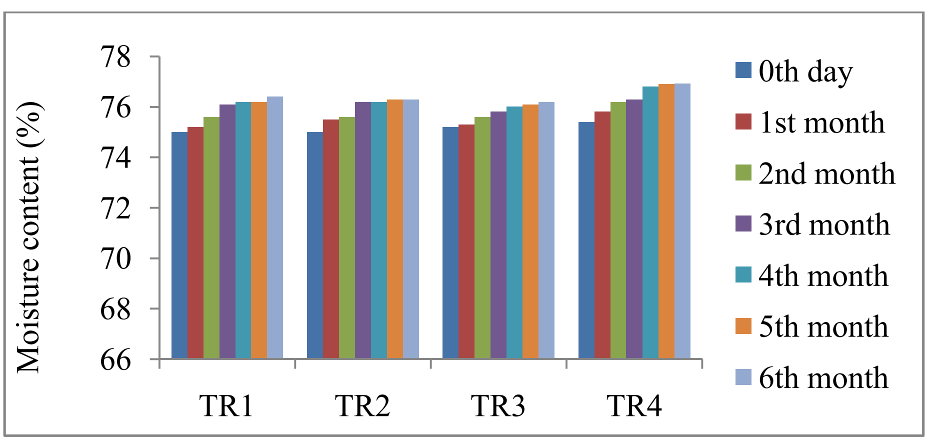


Figure 4.38 Changes in moisture content during refrigerated storage

4.6 MICROBIAL ANALYSIS

In all the samples stored at ambient conditions no microbial load was found till three months of storage. In the samples stored at refrigerated conditions also no microbial growth was observed throughout six months of storage (Plate 4.4).

Mohammedali *et al*. (2013) conducted microbial analysis in retort processed ready-to-drink traditional thari kanchi payasam and no microbial growth was found throughout the storage period.

Plate 4.4 TPC analysis during storage studies

4.7 SENSORY ANALYSIS

In the M-4 variety, TS2 and TR2 had the best sensory score whereas in the Sree Jaya variety, TS4 and TR4 had the best sensory score (Appendix VIII). The other samples had lost their texture due to the effect of high temperature processing. All the samples had acceptable score but the samples with the best score were selected as the optimised sample. Control had an overall acceptability score of 9; TS2 and TR2 (M-4) had the next best score of 8.9. The samples stored at ambient conditions had similar score as the sample stored at refrigerated conditions. The sample TS1 and TR1 had the lowest sensory scores of 5 and 5.3, respectively due to loss of texture and colour.

In Sree Jaya variety TR4 and TS4 had best score. The samples stored at ambient conditions had similar score as the sample stored at refrigerated conditions. TR4 and TS4 had the best score of 8.92 and 8.91. The sample TS3 had the lowest sensory score due to loss of texture and colour. The sensory score card is added in the Appendix VIII.

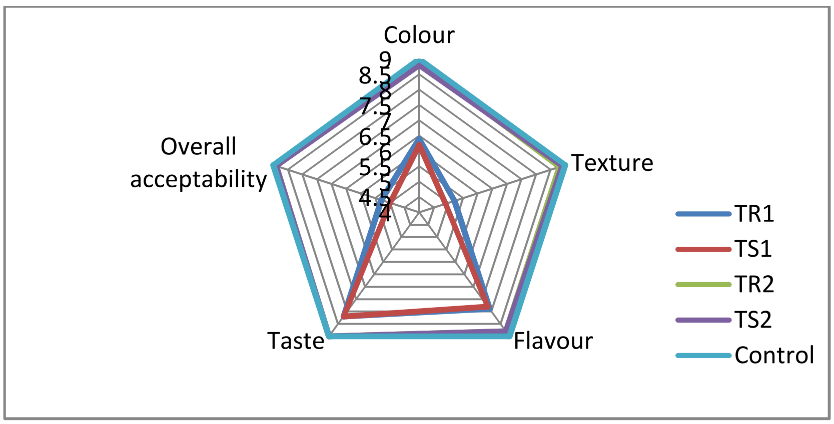


Figure 4.39 Sensory analysis of cassava tubers, variety: M-4

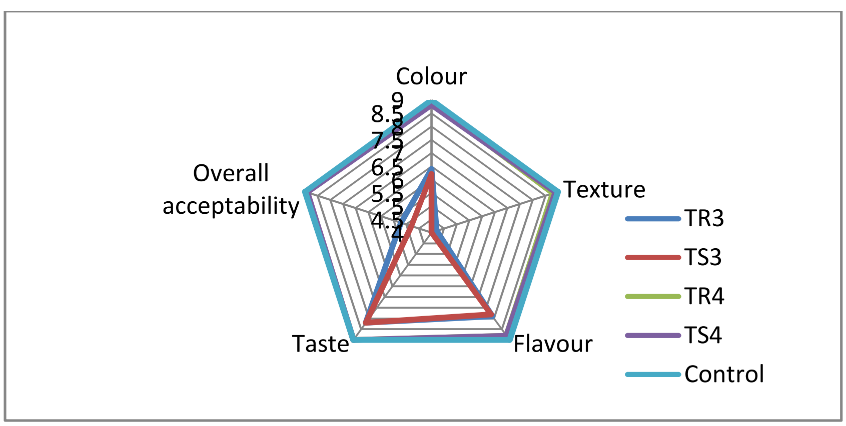


Figure 4.40 Sensory analysis of cassava tubers, variety: M-4

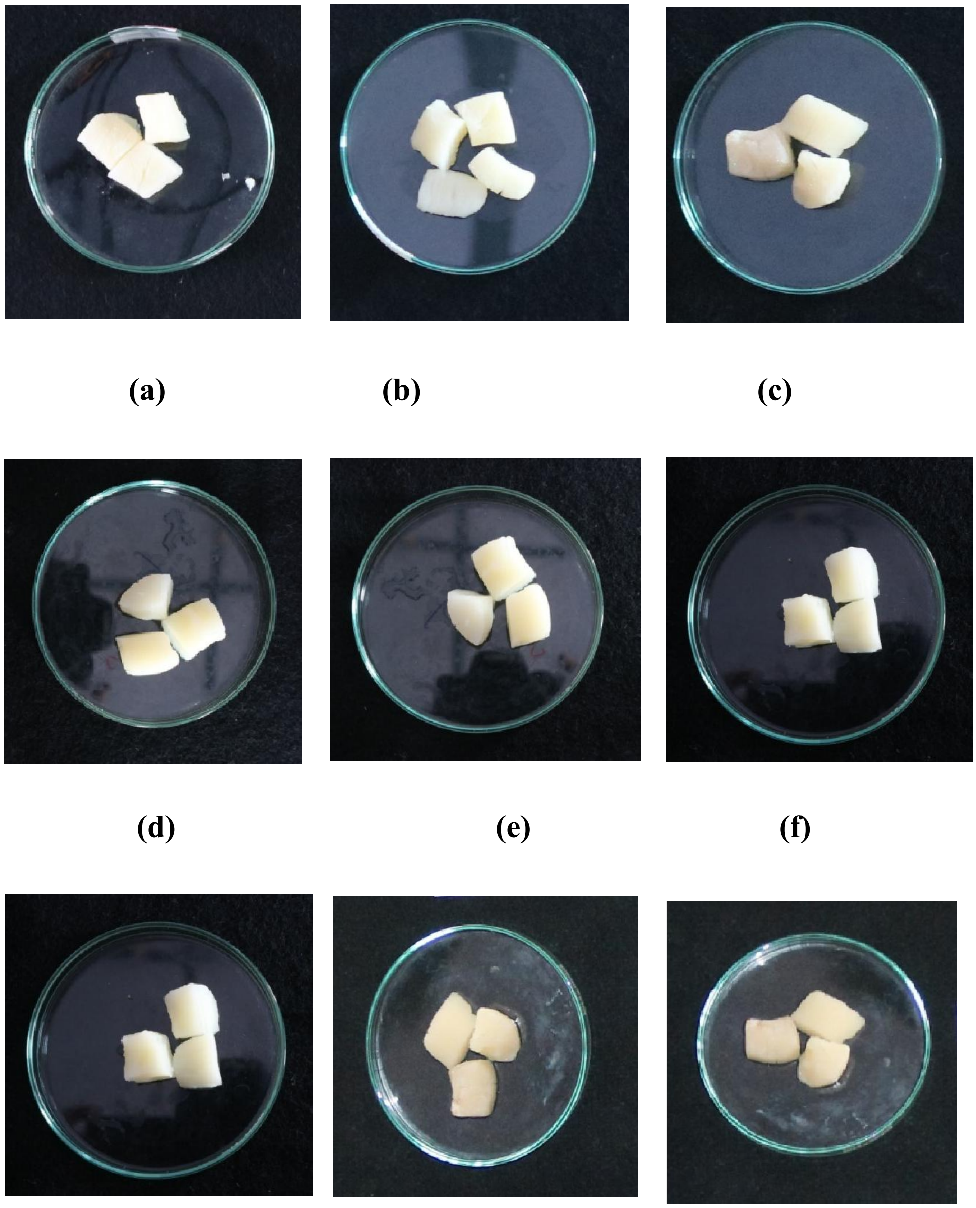
From the storage studies and the sensory analysis it can be concluded that Sree Jaya thermally processed at 110˚C for 20 min with F_0 2.1 and M-4 thermally processed at 110˚C for 40 min with F_0 6.1 are the best thermal processing treatments. The quality parameters and the sensory attributes of the processed cassava were best throughout the storage period. The shelf life studies of the optimised samples are shown in Plate 4.5 and 4.6. The optimised samples from sensory analysis are shown in Plate 4.7.

4.8 ENERGY VALUE

The energy value of 100 g of retort pouch processed cassava was estimated to be 72.44 kcal of energy. The calculation is presented in Appendix IX.

COST ANALYSIS

The cost of a retorted sample was estimated to be Rs. 19.20/250 g. The cost analysis is added in the Appendix X.



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

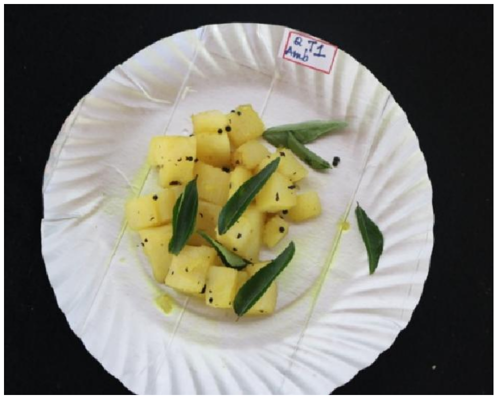
Plate 4.5 Shelf life study of optimised M-4 cassava (a) TS2- 1st month (b) TS2- 2nd month (c) TS2- 3rd month (d) TR2- 1st month (e) TR2- 2nd month (f) TR2- 3rd month (g) TR2- 4th month (h) TR2- 5th month (i) TR2- 6th month

(a) (b) (c)

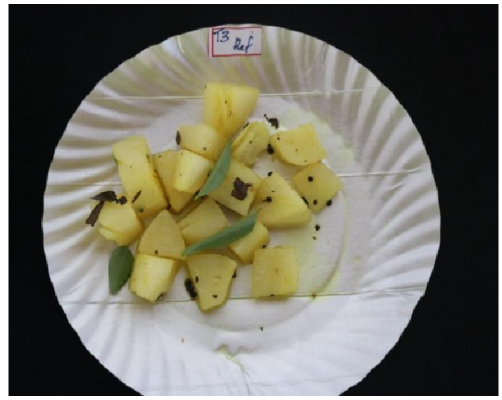
(d) (e (f)

(g) (h) (i)

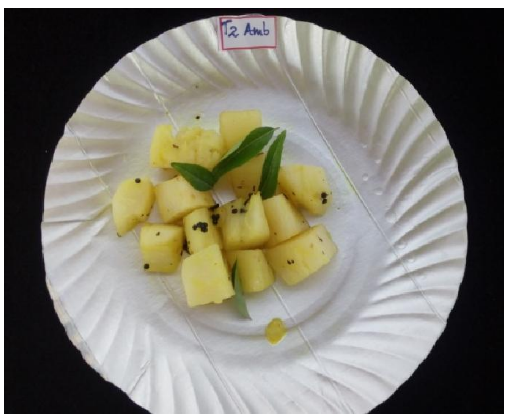
Plate 4.6 Shelf life study of optimised Sree Jaya cassava (a) TS4- 1st month (b) TS4- 2nd month (c) TS4- 3rd month (d) TR4- 1st month (e) TR4- 2nd month (f) TR4- 3rd month (g) TR4- 4th month (h) TR4- 5th month (i) TR4- 6th month



(a)



(b)



(c)

(d)

Plate 4.7 Optimised samples from sensory analysis (a) TS2 (b) TR2 (c) TS4 (d) TR4

CHAPTER V

SUMMARY AND CONCLUSION

At present, consumers are more concerned about the food they consume. They have grown into a health centric generation and have their vision on foods with lesser preservatives, which are more organic and natural. Therefore, newer technologies which can ensure increased shelf life of traditional products should gain momentum.

Cassava is one of the important food crop providing livelihoods and food security for millions of people in the tropical regions. Cassava has several health benefits which include the ability to help in healthy weight gain, increase blood circulation and red blood cell count, protect against birth defects and many more. But harvested cassava is highly perishable in nature. High moisture content of cassava, leads to early deterioration due to microbial attack and also makes it susceptible to desiccation and mechanical injury. This results in change in texture, colour, flavour and nutritive value, which renders it unsafe for human consumption. Therefore effort has to be put in so that cassava is made available to all the people year-round either in raw, preserved or processed manner.

Thermal processing in retort pouches is a widely accepted technology to preserve foods which provides a longer shelf life. Considering the above mentioned facts, thermal processing of cassava in retort pouches to produce ready to serve cassava was undertaken with the following objectives *viz.* to conduct the physico-chemical analysis of raw cassava, to optimise the process parameters of thermally processed cassava *viz.,* time-temperature combination and to conduct the shelf life studies and the quality evaluation of thermally processed cassava in retort pouch under ambient and refrigerated conditions.

The study was conducted on two varieties of cassava *viz.,* Sree Jaya and M-4. The physicochemical analysis of both the varieties were conducted and recorded. The blanching time at 100˚C was optimised based on the removal of hydrocyanic acid and retention of quality parameters during blanching. Quality improvement of raw cassava was done with the addition of 0.1 per cent guar gum during blanching process. Thermal processing was conducted at 100, 110 and 121˚C with various combinations of time. The retort processing treatments was optimised based on the quality evaluation and microbial analysis of the processed sample. Safe samples were stored at ambient conditions and refrigerated conditions for three and six months to conduct the shelf life studies. Microbial and quality analysis was conducted at every month to ensure the quality of the stored samples. Sensory analysis was conducted to find out the best thermal processing time-temperature combination. It was conducted at the end of three and six months for the pouches stored at ambient and refrigerated conditions, respectively. Cost analysis of the retorted samples was also conducted.

The blanching time for M-4 and Sree Jaya variety samples were optimised as 5 and 15 min, respectively with 0.1 per cent guar gum. The cyanide content of M-4 was reduced below the permissible limit of 50 ppm to 34.6 ppm after 5 min of blanching, whereas Sree Jaya took 15 min blanching time to remove cyanide below the permissible limit. The quality of blanched cassava was improved by the addition of guar gum. The L*, a*, b* values of gum blanched M-4 and Sree Jaya variety were found to be 63.01, 0.35, 20.01 and 58.40, -1.29, 20.94, respectively. The corresponding firmness and toughness values for both varieties were estimated to be 4.23 kg, 5.60 kg.s and 4.61 kg, 6.14 kg.s, respectively. The carbohydrate content for M-4 and Sree Jaya were observed as 17.38 and 19.19 per cent, respectively. The corresponding crude fibre content values for the samples were found as 2.37 and 1.78 per cent, respectively.

The thermal processing of cassava was conducted at 100˚C, 110˚C, 121˚C in combinations with different process time. The samples except thermally processed at 110˚C for 40 min and at 121˚C for 8 min with F_0 6.1and 10.8, respectively in M-4 variety and samples other than thermally processed at 110˚C for 20 min and at 121˚C for 2 min wit F_0 2.1 and 4, respectively in Sree Jaya variety were discarded due to the presence of microorganism found by microbial analysis.

In M-4 variety, the L* value of optimised sample stored at ambient conditions was 57.63 which increased to 58.26 at the end of third month. At refrigerated condition the L* value increased to 58.02. Similarly, the firmness and toughness values were reduced from 0.92 to 0.69 kg and 2.98 kg.s to 2.42 kg.s at the end of three months under ambient storage, respectively. The firmness and toughness values of samples stored at refrigerated conditions for six months were reduced from 0.92 to 0.65 kg and 2.98 kg.s to 2.38 kg.s, respectively. The carbohydrate content was reduced from 16.42 per cent to 15.02 per cent during the three months of ambient storage. At refrigerated conditions for six months storage, the carbohydrate content reduced from 16.42 per cent to 16.38 per cent. The crude fibre content of samples placed at ambient storage for three months reduced from 2.18 to 2 per cent. At refrigerated storage for six months, the crude fibre reduced from 2.18 to 2.1 per cent.

In Sree Jaya variety, the L* value of optimised sample stored at ambient conditions was 57.63 which increased to 58.26 at the end of third month. At refrigerated condition the L* value changed to 58.02. The firmness reduced from 1.32 kg to 0.89 kg and the toughness reduced from 3.42 kg.s to 2.76 kg.s at the end of three months of ambient storage. At refrigerated storage for six months, the firmness reduced from 1.32 kg to 0.89 kg and the toughness reduced from 3.42 kg.s to 2.76 kg.s. The carbohydrate content reduced from 17.2 per cent to 16.06 per cent during three months of ambient storage. At refrigerated conditions the carbohydrate content reduced from 17.2 per cent to 17.08 per cent in six months. The crude fibre content of samples placed at ambient storage for three months reduced from 1.7 to 1.65 per cent. At refrigerated storage for six months the crude fibre reduced from 1.7 to 1.61 per cent.

The optimised samples had an overall acceptability score of 8.9 in both ambient and refrigerated storage condition.

From the storage studies and the sensory analysis it can be concluded that Sree Jaya samples thermally processed at 110˚C for 20 min with F_0 2.1 and M-4 samples thermally processed at 110˚C for 40 min with F_0 6.1 are the best thermal processing treatments. The quality parameters and the sensory attributes of the processed cassava were best throughout the storage period. The shelf life of cassava tubers retorted at the optimised condition had a shelf life of three months at ambient condition and more than six months at refrigerated condition.

The cost of a retorted sample was estimated to be Rs. 19.20/100 g of cassava tuber.

CHAPTER VI

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APPENDIX I

ANOVA Table for Raw Cassava Tubers – M-4 and Sree Jaya Varieties

Quality parameters		Source of variation	SS	Df	MS	F	Sig.
Colour	L*	Between groups	2.509	1	2.509	269.303	0.000
		Within groups	0.037	4	0.009		
		Total	2.546	5			
	a*	Between groups	0.001	1	0.001	0.654	0.467
		Within groups	0.005	4	0.001		
		Total	0.006	5			
	b*	Between groups	0.086	1	0.086	0.917	0.393
		Within groups	0.377	4	0.094		
		Total	0.463	5			
Texture	Firmness	Between groups	8.181	1	8.181	926.813	0.000
		Within groups	0.035	4	0.009		
		Total	8.216	5			
	Toughness	Between groups	0.898	1	0.898	0.147	0.721
		Within groups	24.459	4	6.115		
		Total	23.357	5			
Carbohydrate		Between groups	23.721	1	23.721	3.242E3	0.000
		Within groups	0.029	4	0.007		
		Total	23.750	5			
Crude fibre		Between groups	5301.454	1	5411.707	0.980	0.387
		Within groups	21646.826	4	5411.707		
		Total	26948.280	5			
Cyanide content		Between groups	1442.434	1	1442.430	1.442E6	0.000
		Within groups	0.004	4	0.001		
		Total	1442.434	5			

APPENDIX II

ANOVA Tables for Blanched Cassava Tubers

ANOVA table for blanched M-4 cassava tubers

Quality parameters		Source of variation	SS	Df	MS	F	Sig.
Colour	L*	Between groups	526.024	3	175.341	4.589E3	0.000
		Within groups	0.306	8	0.038		
		Total	526.329	11			
	a*	Between groups	15.369	3	5.123	7.589E3	0.000
		Within groups	0.005	8	0.001		
		Total	15.374	11			
	b*	Between groups	9.937	3	3.312	48.668	0.000
		Within groups	0.544	8	0.068		
		Total	10.481	11			
Texture	Firmness	Between groups	45.218	3	15.073	1.378E3	0.000
		Within groups	0.087	8	0.011		
		Total	45.306	11			
	Toughness	Between groups	393.026	3	131.009	36.373	0.000
		Within groups	28.814	8	3.602		
		Total	421.840	11			
Ph		Between groups	0.000	3	0.000	0.923	0.472
		Within groups	0.001	8	0.000		
		Total	0.001	11			
Carbohydrate		Between groups	26.532	3	8.844	1.411E3	0.000
		Within groups	0.050	8	0.006		
		Total	26.582	11			
Crude fibre		Between groups	0.130	3	0.043	140.216	0.000
		Within groups	0.002	8	0.000		
		Total	0.132	11			

ANOVA table for blanched Sree Jaya

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Colour	L*	Between groups	322.446	3	107.482	4.202E4	0.000
		Within groups	0.020	8	0.003		
		Total	322.466	11			
	a*	Between groups	15.681	3	5.227	12.896	0.002
		Within groups	3.243	8	0.405		
		Total	18.924	11			
	b*	Between groups	11.565	3	3.855	2.435E4	0.000
		Within groups	0.001	8	0.000		
		Total	11.566	11			
Texture	Firmness	Between groups	41.343	3	13.781	2.062E5	0.000
		Within groups	0.001	8	0.000		
		Total	41.343	11			
	Toughness	Between groups	167.558	3	55.853	1.885E4	0.000
		Within groups	0.024	8	0.003		
		Total	167.582	11			
Ph		Between groups	0.000	3	0.000	0.923	0.472
		Within groups	0.001	8	0.000		
		Total	0.001	11			
Carbohydrate		Between groups	50.910	3	16.970	2.213E4	0.000
		Within groups	0.006	8	0.001		
		Total	50.916	11			
Crude fibre		Between groups	0.069	3	0.023	154.222	0.000
		Within groups	0.001	8	0.000		
		Total	0.071	11			

APPENDIX III

ANOVA for Cyanide Content of Cassava Tubers at Different Blanching Time

Blanching time	Source of variation	SS	df	MS	F	Sig.
Raw	Between groups	1442.430	1	1442.430	1.442E6	0.000
	Within groups	0.004	4	0.001		
	Total	1442.434	5			
Five min	Between groups	1693.440	1	1693.440	6.774E4	0.000
	Within groups	0.100	4	0.025		
	Total	1693.540	5			
Ten min	Between groups	870.733	1	870.733	6.874E5	0.000
	Within groups	0.005	4	0.001		
	Total	870.738	5			
Fifteen min	Between groups	475.794	1	475.794	9.422E4	0.000
	Within groups	0.020	4	0.005		
	Total	475.814	5			

APPENDIX IV

ANOVA Table for Guar Gum Blanched Cassava Tubers

ANOVA table for M-4 blanched with gum

Quality parameters		Source of variation	SS	Df	MS	F	Sig.
Colour	L*	Between groups	144.996	2	72.498	3.597E3	0.000
		Within groups	0.121	6	0.020		
		Total	145.117	8			
	a*	Between groups	2.055	2	1.028	1.340E3	0.000
		Within groups	0.005	6	0.001		
		Total	2.060	8			
	b*	Between groups	6.310	2	3.155	42.847	0.000
		Within groups	0.442	6	0.074		
		Total	6.752	8			
Texture	Firmness	Between groups	20.119	2	10.060	1.114E3	0.000
		Within groups	0.054	6	0.009		
		Total	20.173	8			
	Toughness	Between groups	246.399	2	123.19	26.805	0.001
		Within groups	27.577	6	4.596		
		Total	273.976	8			
Carbohydrate		Between groups	10.045	2	5.022	1.177E3	0.000
		Within groups	0.026	6	0.004		
		Total	10.070	8			
Crude fibre		Between groups	7242.51	2	3621.2	1.004	0.421
		Within groups	21646.8	6	3607.8		
		Total	28889.3	8			

ANOVA table for Sree Jaya blanched with gum

Quality parameters		Source of variation	SS	Df	MS	F	Sig.
Colour	L*	Between groups	414.959	2	207.479	6.185E4	0.000
		Within groups	0.020	6	0.003		
		Total	414.979	8			
	a*	Between groups	15.907	2	7.954	3.874E4	0.000
		Within groups	0.006	6	0.001		
		Total	15.914	8			
	b*	Between groups	14.636	2	7.318	7.535E3	0.000
		Within groups	0.001	6	0.000		
		Total	14.637	8			
Texture	Firmness	Between groups	36.336	2	18.168	2.329E5	0.000
		Within groups	0.000	6	0.000		
		Total	36.336	8			
	Toughness	Between groups	172.358	2	86.179	6.084E4	0.001
		Within groups	0.008	6	0.001		
		Total	172.366	8			
Carbohydrate		Between groups	45.453	2	22.727	1.060E4	0.000
		Within groups	0.013	6	0.002		
		Total	45.466	8			
Crude fibre		Between groups	7242.51	2	3621.2	1.004	0.421
		Within groups	21646.8	6	3607.8		
		Total	28889.3	8			

APPENDIX V

ANOVA Table for Thermally Processed Tubers

ANOVA table for TV4 on the 0th day

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Colour	l*	Between groups	10.088	1	10.088	3.026E5	0.000
		Within groups	0.000	4	0.000		
		Total	10.088	5			
	b*	Between groups	2.802	1	2.802	1.827E3	0.000
		Within groups	0.006	4	0.002		
		Total	2.808	5			
	a*	Between groups	0.031	1	0.031	462.250	0.000
		Within groups	0.000	4	0.000		
		Total	0.031	5			
Texture	Firmness	Between groups	16.269	1	16.269	2.440E5	0.000
		Within groups	0.000	4	0.000		
		Total	16.269	5			
	Toughness	Between groups	11.125	1	11.125	7.853E3	0.000
		Within groups	0.006	4	0.001		
		Total	11.130	5			
Carbohydrate		Between groups	5.920	1	5.920	3.172E3	0.000
		Within groups	0.007	4	0.002		
		Total	5.928	5			
Crude fibre		Between groups	0.008	1	0.008	115.200	0.002
		Within groups	0.000	3	0.000		
		Total	0.008	4			

ANOVA table for TV5 on 0th day

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Colour	l*	Between groups	43.632	1	43.632	1.309E6	0.000
		Within groups	0.000	4	0.000		
		Total	43.632	5			
	b*	Between groups	0.482	1	0.482	314.130	0.000
		Within groups	0.006	4	0.002		
		Total	0.488	5			
	a*	Between groups	0.054	1	0.054	1.076E3	0.000
		Within groups	0.000	4	0.000		
		Total	0.054	5			
Texture	Firmness	Between groups	20.635	1	20.635	4.086E5	0.000
		Within groups	0.000	4	0.000		
		Total	20.635	5			
	Toughness	Between groups	26.903	1	26.903	1.905E4	0.000
		Within groups	.006	4	0.001		
		Total	26.908	5			
Carbohydrate		Between groups	7.126	1	7.126	3.852E3	0.000
		Within groups	0.007	4	0.002		
		Total	7.134	5			
Crude fibre		Between groups	0.029	1	0.029	533.944	0.000
		Within groups	0.000	4	0.000		
		Total	0.0029	5			

ANOVA table for T4 on 0th day

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Colour	l*	Between groups	43.400	1	43.400	8.594E5	0.000
		Within groups	0.000	4	0.000		
		Total	43.400	5			
	a*	Between groups	1.718	1	1.718	3.425E4	0.000
		Within groups	0.000	4	0.000		
		Total	1.719	5			
	b*	Between groups	0.126	1	0.126	946.125	0.000
		Within groups	0.001	4	0.000		
		Total	0.127	5			
Texture	Firmness	Between groups	16.454	1	16.454	9.866E3	0.000
		Within groups	0.007	4	0.002		
		Total	16.461	5			
	Toughness	Between groups	10.294	1	10.294	2.059E3	0.000
		Within groups	0.020	4	0.005		
		Total	10.314	5			
Carbohydrate		Between groups	1.372	1	1.372	1.174E4	0.000
		Within groups	0.000	4	0.000		
		Total	1.372	5			
Crude fibre		Between groups	0.054	1	0.054	1.061E3	0.000
		Within groups	0.000	4	0.000		
		Total	0.054	5			

ANOVA table for T5 on 0^{th} day

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Colour	l*	Between groups	55.237	1	55.237	1.080E6	0.000
		Within groups	0.000	4	0.000		
		Total	55.237	5			
	a*	Between groups	5.423	1	5.423	1.060E5	0.000
		Within groups	0.000	4	0.000		
		Total	5.423	5			
	b*	Between groups	0.522	1	0.522	4.431E3	0.000
		Within groups	0.000	4	0.000		
		Total	0.523	5			
Texture	Firmness	Between groups	19.235	1	19.235	1.153E4	0.000
		Within groups	0.007	4	0.002		
		Total	19.242	5			
	Toughness	Between groups	30.881	1	30.881	6.170E3	0.000
		Within groups	0.020	4	0.005		
		Total	30.901	5			
Carbohydrate		Between groups	3.396	1	3.396	2.862E4	0.000
		Within groups	0.000	4	0.000		
		Total	3.397	5			
Crude fibre		Between groups	0.192	1	0.192	3.697E3	0.000
		Within groups	0.000	4	0.000		
		Total	0.192	5			

APPENDIX VI

Ambient Storage Studies

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
L*	Zero	Between groups	35.713	3	11.904	2.497E3	0.000
		Within groups	0.038	8	0.005		
		Total	35.752	11			
	One	Between groups	86.989	3	28.996	440.050	0.000
		Within groups	0.527	8	0.066		
		Total	87.516	11			
	Two	Between groups	55.318	3	18.439	205.222	0.000
		Within groups	0.719	8	0.090		
		Total	56.037	11			
	Three	Between groups	43.411	3	14.470	995.463	0.000
		Within groups	0.116	8	0.015		
		Total	43.527	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
a*	Zero	Between groups	1.003	3	0.334	1.672E3	0.000
		Within groups	0.002	8	0.000		
		Total	1.005	11			
	One	Between groups	6.748	3	2.249	4.354E3	0.000
		Within groups	0.004	8	0.001		
		Total	6.752	11			
	Two	Between groups	0.645	3	0.215	560.957	0.000
		Within groups	0.003	8	0.000		
		Total	0.648	11			
	Three	Between groups	1.663	3	0.554	7.262	0.000
		Within groups	0.611	8	0.076		
		Total	2.274	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
b*	Zero	Between groups	7.370	3	2.457	1.340E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.371	11			
	One	Between groups	5.841	3	1.947	6.148E3	0.000
		Within groups	0.003	8	0.000		
		Total	5.843	11			
	Two	Between groups	12.608	3	4.203	49.472	0.000
		Within groups	0.680	8	0.085		
		Total	13.288	11			
	Three	Between groups	6.063	3	2.021	7.823E3	0.000
		Within groups	0.002	8	0.000		
		Total	6.065	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Firmness	Zero	Between groups	0.688	3	0.229	2.294E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.689	11			
	One	Between groups	0.509	3	0.170	1.273E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.510	11			
	Two	Between groups	0.321	3	0.107	1.069E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.321	11			
	Three	Between groups	0.507	3	0.169	1.689E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.507	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
	Zero	Between groups	10.133	3	3.378	3.378E4	0.000
Toughness		Within groups	0.001	8	0.000		
		Total	10.134	11			
	One	Between groups	9.586	3	3.195	3.835E4	0.000
		Within groups	0.001	8	0.000		
		Total	9.587	11			
	Two	Between groups	7.094	3	2.365	3.547E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.094	11			
	Three	Between groups	7.857	3	2.619	2.619E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.857	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
	Zero	Between groups	3.295	3	1.098	1.098E4	0.000
Carbohydrate		Within groups	0.001	8	0.000		
		Total	3.296	11			
	One	Between groups	3.962	3	1.321	1.321E4	0.000
		Within groups	0.001	8	0.000		
		Total	3.963	11			
	Two	Between groups	3.363	3	1.121	2.038E3	0.000
		Within groups	0.004	8	0.001		
		Total	3.368	11			
	Three	Between groups	4.447	3	1.482	1.482E4	0.000
		Within groups	0.001	8	0.000		
		Total	4.447	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
	Zero	Between groups	0.573	3	0.191	1.432E3	0.000
Crude fibre		Within groups	0.001	8	0.000		
		Total	0.574	11			
	One	Between groups	0.380	3	0.127	217.314	0.000
		Within groups	0.005	8	0.001		
		Total	0.385	11			
	Two	Between groups	0.364	3	0.121	1.213E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.365	11			
	Three	Between groups	0.272	3	0.091	906.750	0.000
		Within groups	0.001	8	0.000		
		Total	0.273	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
	Zero	Between groups	0.339	3	0.113	452.122	0.000
Moisture content		Within groups	0.002	8	0.000		
		Total	0.341	11			
	One	Between groups	0.351	3	0.117	359.889	0.000
		Within groups	0.003	8	0.000		
		Total	0.353	11			
	Two	Between groups	0.262	3	0.087	40.875	0.000
		Within groups	0.017	8	0.002		
		Total	0.279	11			
	Three	Between groups	0.312	3	0.104	545.512	0.000
		Within groups	0.001	7	0.000		
		Total	0.313	10			

APPENDIX VII

Refrigerated Storage Studies

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
L*	Zero	Between groups	35.423	3	11.808	2.256E3	0.000
		Within groups	0.042	8	0.005		
		Total	35.465	11			
	One	Between groups	33.575	3	11.192	4.087E4	0.000
		Within groups	0.002	7	0.000		
		Total	33.577	10			
	Two	Between groups	22.237	3	7.412	6.589E3	0.000
		Within groups	0.009	8	0.001		
		Total	22.246	11			
	Three	Between groups	29.372	3	9.791	5.389E3	0.000
		Within groups	0.015	8	0.002		
		Total	29.386	11			
	Four	Between groups	34.527	3	11.509	6.905E4	0.000
		Within groups	0.001	8	0.000		
		Total	34.528	11			
	Five	Between groups	37.846	3	12.615	3.604E4	0.000
		Within groups	0.003	8	0.000		
		Total	37.849	11			
	Six	Between groups	38.785	3	12.928	3.694E4	0.000
		Within groups	0.003	8	0.000		
		Total	38.788	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
a*	Zero	Between groups	1.038	3	0.346	1.730E3	0.000
		Within groups	0.002	8	0.000		
		Total	1.040	11			
	One	Between groups	0.886	3	0.295	285.645	0.000
		Within groups	0.008	8	0.001		
		Total	0.894	11			
	Two	Between groups	6.472	3	2.157	1.618E4	0.000
		Within groups	0.001	8	0.000		
		Total	6.473	11			
	Three	Between groups	0.028	3	0.009	70.563	0.000
		Within groups	0.001	8	0.000		
		Total	0.029	11			
	Four	Between groups	0.348	3	0.116	994.381	0.000
		Within groups	0.001	8	0.000		
		Total	0.349	11			
	Five	Between groups	0.054	3	0.018	217.700	0.000
		Within groups	0.001	8	0.000		
		Total	0.055	11			
	Six	Between groups	0.067	3	0.022	222.750	0.000
		Within groups	0.001	8	0.000		
		Total	0.068	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
b*	Zero	Between groups	10.624	3	3.541	1.288E4	0.000
		Within groups	0.002	8	0.000		
		Total	10.626	11			
	One	Between groups	8.784	3	2.928	2.196E4	0.000
		Within groups	0.001	8	0.000		
		Total	8.785	11			
	Two	Between groups	8.937	3	2.979	2.979E4	0.000
		Within groups	0.001	8	0.000		
		Total	8.937	11			
	Three	Between groups	14.517	3	4.839	4.839E4	0.000
		Within groups	0.001	8	0.000		
		Total	14.518	11			
	Four	Between groups	10.036	3	3.345	3.345E4	0.000
		Within groups	0.001	8	0.000		
		Total	10.037	11			
	Five	Between groups	7.155	3	2.385	2.862E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.155	11			
	Six	Between groups	8.729	3	2.910	2.910E4	0.000
		Within groups	0.001	8	0.000		
		Total	8.730	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Firmness	Zero	Between groups	0.695	3	0.232	2.780E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.696	11			
	One	Between groups	0.542	3	0.181	2.166E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.542	11			
	Two	Between groups	0.561	3	0.187	2.244E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.562	11			
	Three	Between groups	0.361	3	0.120	1.610E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.361	11			
	Four	Between groups	0.320	3	0.107	2.132E3	0.000
		Within groups	0.000	8	0.000		
		Total	0.320	11			
	Five	Between groups	0.389	3	0.130	2.594E3	0.000
		Within groups	0.000	8	0.000		
		Total	0.390	11			
	Six	Between groups	0.452	3	0.151	1.506E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.453	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Toughness	Zero	Between groups	10.232	3	3.411	5.116E4	0.000
		Within groups	0.001	8	0.000		
		Total	10.233	11			
	One	Between groups	9.776	3	3.259	4.888E4	0.000
		Within groups	0.001	8	0.000		
		Total	9.777	11			
	Two	Between groups	8.661	3	2.887	9.214E4	0.000
		Within groups	0.000	8	0.000		
		Total	8.662	11			
	Three	Between groups	8.670	3	2.890	4.661E4	0.000
		Within groups	0.000	8	0.000		
		Total	8.670	11			
	Four	Between groups	7.997	3	2.666	5.332E4	0.000
		Within groups	0.000	8	0.000		
		Total	7.998	11			
	Five	Between groups	7.927	3	2.642	3.171E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.928	11			
	Six	Between groups	7.672	3	2.557	2.557E4	0.000
		Within groups	0.001	8	0.000		
		Total	7.673	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Crude fibre	Zero	Between groups	0.579	3	0.193	2.315E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.579	11			
	One	Between groups	0.532	3	0.177	2.130E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.533	11			
	Two	Between groups	0.528	3	0.176	1.507E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.528	11			
	Three	Between groups	0.508	3	0.169	3.389E3	0.000
		Within groups	0.000	8	0.000		
		Total	0.509	11			
	Four	Between groups	0.534	3	0.178	1.186E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.535	11			
	Five	Between groups	0.538	3	0.179	2.153E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.539	11			
	Six	Between groups	0.524	3	0.175	1.164E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.525	11			

Quality parameter		Source of variation	SS	Df	MS	F	Sig.
Moisture content	Zero	Between groups	0.199	3	0.066	6.906	0.000
		Within groups	0.077	8	0.010		
		Total	0.276	11			
	One	Between groups	0.619	3	0.206	235.743	0.000
		Within groups	0.007	8	0.001		
		Total	0.626	11			
	Two	Between groups	0.778	3	0.259	1.296E3	0.000
		Within groups	0.002	8	0.000		
		Total	0.779	11			
	Three	Between groups	0.407	3	0.136	121.602	0.000
		Within groups	0.009	8	0.001		
		Total	0.416	11			
	Four	Between groups	0.920	3	0.307	95.059	0.000
		Within groups	0.026	8	0.003		
		Total	0.945	11			
	Five	Between groups	1.157	3	0.386	841.473	0.000
		Within groups	0.004	8	0.000		
		Total	1.161	11			
	Six	Between groups	0.947	3	0.316	2.367E3	0.000
		Within groups	0.001	8	0.000		
		Total	0.948	11			

APPENDIX VIII

Sensory Score Cards

Sensory scores of M-4

Parameter	TR1	TS1	TR2	TS2	Control
Colour	6.4	6.2	8.9	8.8	9
Texture	5.2	4.9	8.8	8.9	9
Flavour	7.9	7.8	8.8	8.8	9
Taste	8.2	8.2	9	9	9
Overall acceptibility	5.3	5	8.9	8.9	9

Sensory scores of Sree Jaya

Parameter	TR3	TS3	TR4	TS4	Control
Colour	6.4	6.2	8.9	8.8	9
Texture	4.2	4	8.8	8.9	9
Flavour	7.9	7.8	8.8	8.8	9
Taste	8.2	8.2	9	9	9
Overall acceptibility	5.2	4.8	8.92	8.91	9

APPENDIX IX

Energy Value

Carbohydrate	=	4 x 16
Fat	=	9 x 0.36
Protein	=	4 x 1.3
Total energy/ 100 g	=	72.44 kilo calorie

APPENDIX X

Cost Analysis

Number of working day / annum (A) = 300

Number of shift / day = 2

Number of working hour / shift = 8

Number of working hour / day = 16

Salvage value for machineries = 10 % of original cost

Interest on investment (Ri) = 10 % of original cost

Repair and maintenance for machineries cost based on type of equipment used = 2-10 % of original

Life span of the unit (n) = 15 years

Cost of the retort and hydraulic sealer (c) = Rs. 5.6 lakhs /-

Cost of the induction stove = Rs. 2500/-

1. Fixed cost

A) Fixed cost of the retort and sealer unit $= \frac{Ri \times (1+Ri)^n}{(1+Ri)^n+1} \text{x c}$

$= \frac{0.10 \times (1+0.10)^{15}}{(1+0.10)^{15}+1} \text{x } 5{,}60{,}000$

= Rs. 45184/-

B) Fixed cost of the induction stove $= \frac{0.10 \times (1+0.10)^{15}}{(1+0.10)^{15}+1} \text{x} 2500$

= Rs. 202/-

C) Fixed cost of floor area 6 m^2, water charge and installation charge

= Rs. 9000/-

Total fixed cost / year = A+B+C

= 45184+202+9000

= Rs. 54348/-

2. Variable cost / year

a) Repair and maintenance of retort and sealer = 2% of initial cost of the retort and sealer

= 0.02x5,60,000

= Rs. 11200/-

b) Repair and maintenance of induction stove = 2% of initial cost of the induction stove

= 0.02x2500

= 50

Total repair and maintenance cost = a+b

= 11200+50

= Rs. 11250/-

3. Cost of energy

Total power consumption	= 40 kWh/day
Cost of1 kWh	= Rs.4.00
Electricity consumption charges/ year	= No. of days x energy/ day x rate
	= 40x4x300
	= Rs. 48000/-

4. Labour charges

Cust of labour @ Rs. 350/shift	= Rs. 350/-
Labour charge / day	= Rs. 700/-
Cost of labour / year	= Rs. 2,10,000/-

5. Cost of raw material

Cost of cassava	= Rs. 35/kg
No. of pouches filled by 1kg cassava	= 8 pouches
No. of batches possible in a day	= 5 batches
No. of pouches required in a day	= 20x5
	=100
Quantity of guar gum required in a year	= 7x300 g

	= 2.1 kg
Quantity of $CaCl_2$ required in a year	= 50x300 g
	= 15 kg
i. Cost of retort pouches required / year	= 4x100x300
	= Rs. 120000/-
ii. Cost of cassava required/year	= 300x100x 35/8
	= Rs. 131250/-
iii. Cost of guar gum and $CaCl_2$ required / year	= 90x2.1+ 35x15
	= 189+525
	= Rs. 714
Total cost of raw material/year	= i+ii+iii
	= Rs. 251964
Total cost of production/year	= 1+2+3+4+5
	= Rs. 575562/-
Cost of production of one pouch of cassava	= 575562/(300x100)
	= Rs. 19.20/ 100 g

DEVELOPMENT AND QUALITY EVALUATION OF THERMALLY PROCESSED CASSAVA IN RETORT POUCH

By

RASMI JANARDHANAN

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ABSTRACT OF THESIS

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ABSTRACT

Cassava (*Manihot esculenta Crantz*), popularly known in India as tapioca, is one of the important food crops providing livelihoods and food security for millions of people in the tropical regions. High moisture content of cassava, leads to early deterioration due to microbial attack and also makes it susceptible to desiccation and mechanical injury. Therefore effort has to be put in so that cassava is made available to all the people year-round either in raw, preserved or processed manner. Therefore, an investigation has been taken up to develop and optmise a process protocol, which could contribute to cassava based industries. The study was conducted on two varieties of cassava namely, Sree Jaya and M-4. The physicochemical analysis of both the varieties were conducted and recorded. The blanching time at 100˚C was optimized and quality improvement with addition of 0.1 per cent guar gum was conducted. The blanching time for M-4 was optimised as 5 minutes in 0.1 per cent guar gum and for Sree Jaya the blanching time was optmised as 15 minutes in 0.1 per cent guar gum. Calcium chloride brine with 0.4 per cent concentration was selected as the filler solution. Thermal processing was conducted at 100, 110, 121˚C with different time combinations. The retort pouch processing parameters were optimised and the shelf life studies of the microbiologically safe samples were conducted for six months at refrigerated condition and three months at ambient conditions. From the storage studies and the sensory analysis it was concluded that Sree Jaya thermally processed at 110˚C for 20 minutes with F_0 2.1 and M-4 thermally processed at 110˚C for 40 minutes with F_0 6.1 are the best thermal processing treatments. The quality parameters and the sensory attributes of the processed cassava were best throughout the storage period. The cost of one pouch of 100 g was estimated to be Rs.19.20/- only. The optimised treatment resulted in a product which resembled the fresh sample, available to the consumers in a ready to eat form throughout the year.