STUDIES ON PROCESSING OF WOOD APPLE (*Feronia limonia* L. Swingle) PULP FOR VALUE ADDITION

KOUSTUBHA M. GOWDA

DEPARTMENT OF POST HARVEST TECHNOLOGY
KITTUR RANI CHANNAMMA COLLEGE OF HORTICULTURE,
ARABHAVI - 591 218
UNIVERSITY OF HORTICULTURAL SCIENCES,
BAGALKOT - 587 102

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KOUSTUBHA M. GOWDA
UHS15PGM574

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON PROCESSING OF WOOD APPLE (*Feronia limonia* L. Swingle) PULP FOR VALUE ADDITION"** submitted by **KOUSTUBHA M GOWDA** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **DEPARTMENT OF POST HARVEST TECHNOLOGY** of the University of Horticultural Sciences, Bagalkot is a record of research work done by her during the period of her study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place : ARABHAVI
Date : JUNE, 2017

(**Dr. LAXMAN KUKANOOR**)
Professor and Head
Department of Post Harvest Technology
K.R.C. College of Horticulture, Arabhavi

Approved by
Chairman: ______________________________
(Dr. LAXMAN KUKANOOR)

Members: 1. ______________________________
(Dr. K. RAMACHANDRA NAIK)

2. ______________________________
(Dr. E. RAJASHEKHAR)

3. ______________________________
(Dr. SRINIVAS N.)

4. ______________________________
(Mr. VEERESH M. HIREMATH)

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JUNE 2017 **(KOUSTUBHA M GOWDA)**

Affectionately Dedicated To

My Parents

CONTENTS

LIST OF ABBREVIATIONS

1.	%	Per cent
2.	@	At the rate of
3.	/	Per
4.	Anon	Anonymous
5.	^{0}B	Degree brix
6.	*et al*	Et alia (and others)
7.	^{0}C	Degree celsius
8.	CFU	Colony forming unit
9.	cm	Centimeter
10.	mm	Millimeter
11.	g	Gram
12.	Hr	Hour
13.	Kg	Kilogram
14.	Mg	Milligram
15.	Ml	Millilitre
16.	TSS	Total soluble solids
17.	RS	Reducing sugars
18.	NRS	Non-reducing sugars
19.	TS	Total sugars
20.	Min	Minutes

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1. INTRODUCTION

India is the centre of origin for many tropical fruit tree species, most of which are not commercially cultivated but provide a significant source of livelihood support for many rural communities. Many tropical fruits are labeled as “underutilized species”, which are characterized by the fact that they are locally abundant, but restricted in their geographical dispersion and have a high use value. One of the underutilized fruit species that is of importance in India is wood apple (*Feronia limonia* L. Swingle), which belongs to Rutaceae family. The name *Feronia* is very ancient and has been derived after Roman god *Fero.* In India, it is known by several names like elephant apple, curd apple, monkey fruit, kavat, kathbel, Kotha, Vilanga, Kapith and Vela marum (Mazumder *et al.,* 2006).

The wood apple is native to India and Srilanka which is common in wild dry plains (Veeraghavathatham *et al.,* 1996). In India it is grown in Maharashtra, Madhya Pradesh, Uttar Pradesh, Chhattisgarh, Bihar, Jharkhand and Karnataka. It can be planted under all conditions of soil and climate (Anon, 1956). The tree is very hardy, tolerant to drought and salinity and thrives better in deep, well drained soils of dry forests. It prefers slightly acidic soil but can be grown on a variety of soils. Its cultivation as a tree is very rare, but fruits of naturally occurring trees in community lands, forests and on road sides are used for chutney and pickle making (Minh, 2015). The fruits are majorly classified into two forms, one with large, sweetish fruits; one with small acid fruits. Some of the promising genotypes of wood apple include CISH WA-4, CISH WA-10 and CISH WA-16.

Wood apple is a climacteric fruit which are consumed as a good source of juice during its harvesting (October- January) season due to their low cost and thirst quenching ability. The fruit takes eleven months after fruit set to ripen on the tree. At maturity, grip of fruit stalk is loosened and the fruit is detached from the tree without any effort. Harvesting is done individually from the tree to obtain good quality fruits. A minor crack or impact on the rind causes spoilage during storage (Vidhya and Narain, 2011).

Importance of wood apple fruit lies in its curative properties, which makes the tree as one of the useful medicinal plants of India. Its medicinal properties are dealt in

Charaka Samhita and *Sushrutha Samhita*, two early medicinal treaties in Sanskrit (Kirtikar and Basu, 1935). It has great demand in the native system of Ayurvedic medicine. The fruits and leaves are used in herbal preparations. The fruit is used in India as a liver and cardiac tonic, when unripe as astringent means of halting diarrhea and dysentery (Singh *et al.*, 2000), effective treatment for hiccups, sore throat and diseases of gums. The pulp is used for curing bite and stings of venomous insects (Kirtikar and Basu, 1935). Due to its high religious, cultural, nutritional and medicinal values, this is one of the fruit awarded with "Shree" title. In Sanskrit language, its name is "Shree Phalam" or "Amrit Phal".

Wood apple has high nutritional value. The pulp is pleasant and sweet, contains 2.66 per cent pectin, 64.2 per cent moisture, 7.1 per cent protein, 3.7 per cent fat, 1.9 per cent minerals, 50 per cent fibre, 18.1 per cent carbohydrates, 0.13 per cent calcium, 0.11 per cent phosphorous and 0.048 per cent iron (Roy and Mazumder, 1988). Average weight of fruit is 350 g with pulp weight of 224 g. Wood apple fruits have high content of both acidity and pectin, hence the most suited for jelly making (Singh *et al.*, 1999 and Hayes, 1970).

The fruit has hard shell, sticky texture and numerous seeds which make it difficult to eat by hand. The scooped out pulp though sticky is blended with or without sugar/jaggery, or as a beverage after blending it with other ingredients. The Srilankan people Simhalese prepare a popular drink known as dimbulkiri (wood apple milk) by mixing ripened wood apple pulp with coconut pulp and palm sugar (Morton, 1981). The pulp is also suitable for making food products such as juice, nectar, jam, fruit bar, wine, chutneys, sherbet, pulp powder *etc.* The ripe fruit is used as a dessert and source of beverage, cream and jellies (Adikaram *et al.*, 1989). The ripe fruit pulp makes excellent chutney and is also consumed as fresh along with sugar (Veeraghavathatham *et al.,* 1996).

A fruit with such nutritional values and immense health benefits indicates its potentiality for processing commercially into valuable products (Chopra and Singh, 2001). Many of wood apple products are new to consumers, sincere efforts need to be made to introduce wood apple products in the market and to evaluate consumer acceptance and economic viability of augmenting the use of higher yielding nutritious fruits to the best possible extent but will also give a fillip to the establishment of wood apple processing industry. Since the consumers are the ultimate say, in the selection of any food, study of acceptability and shelf life are important.

Srivatsava and Vatsya (1986) investigated that the wood apple beverage produces cooling effect in the same way as Bael fruit. Extraction of pulp from wood apple is the major bottle neck in beverage industry mainly due to its compact, fibrous and mucilaginous flesh with numerous seeds. Further, starch-degradation enzymes for fruit juice clarification and later, pectinolytic enzymes represent the first enzymatic products that are successfully used in fruit juice production. The enzymes thus are important as processing aids for production of high quality juices and concentrates (Albrect, 1996).

Fruit bar is a nutritious product, has a chewy texture, similar to dried raisins and is a good source of dietary fibre and natural sugar (Vidhya and Narain, 2011). Fruit bar or slab or leather is prepared by dehydration of fruit pulp with or without acid, sugar and other ingredients. Dried fruit provide a nutritious way to satisfy a sweet tooth. Fruit bars offer tremendous advantage owing to simplicity and lower inherent cost in the production with the better consumer acceptance.

Therefore, the present study was undertaken with following objectives to exploit the excellent and delightful pulp characters having potential nutritional and medicinal value of wood apple fruits by converting them into value added product such as fruit bar, which would help to overcome market glut and thereby assure economic prices to the fruits.

1. To standardize the method of extraction of wood apple pulp using pectinase enzyme.
2. To standardize the protocol for the preparation of wood apple fruit bar.
3. To study the changes in quality of wood apple pulp and fruit bar during storage.

2. REVIEW OF LITERATURE

Wood apple is an under exploited fruit which is known for its delightful pulp characters having exceptional medicinal values. This fruit is not popular as a dessert fruit because fruit has hard shell containing mucilaginous pulp with numerous seeds. Therefore in order to explore the possibilities of utilizing the fruit for processing, an attempt has been made to find out easy pulp extraction methods, protocol for standardization of wood apple fruit bar and to study their changes in quality during storage.

Literature reveals that there is limited work on the various aspects of wood apple particularly on processing and preservation of wood apple pulp and their value added products such as fruit bar and their storage stability. Hence, the available literature is reviewed here under this chapter covering not only on wood apple fruit, but also on other commonly growing fruits of India.

2.1 Wood apple

Wood apple fruits generally ripen during November to March. Well grown wood apple tree yields 400-800 fruits during the season and an average fruit weight is about 350 g (Vaidehi *et al.*, 1977).

It is a small to moderate size, deciduous and glabrous tree with thorny branches, growing to a height of 10 meter and 0.6-1.6 meter in girth, trunk is short cylindrical with symmetrical crown of foliage. Leaves measure 3-4 inches in length with small ovate leaflets. Flowers are large, round fruits having hard woody pericarp. The fruit consists of 43 per cent edible portion and 57 per cent of inedible portion. Seeds are numerous, small and compressed. The pulp is pleasant and sweet. (Singh *et al.*, 2000)

Fruits are rich in pectin, minerals and vitamins. Ripened wood apple fruit pulp is highly valued for its therapeutic values in Ayurveda. The fruits and seeds are used in herbal preparations. It is rich in natural acids such as oxalic, tannic, mallic and citric acid. It is a good source of calcium, phosphorus, iron and vitamins A, B and C (Roy and Singh, 2001).

The fruits are considered as a tonic, antiscorbutic and taken as such or in the form of a sauce (Garg, 2003). Fruit is much used in India as a liver and cardiac tonic and for effective treatment for high cough, sore throat and gum diseases. Wood apples also have hypoglycemic activity, antitumor, larvicidal and antimicrobial activity and hepatoprotective activity (Vidhya and Narain, 2011). In addition to this they have anti-inflammatory, antipyretic, analgesic anti-diabetic and antioxidant activity (Ahamed *et al.*, 2008; Patel *et al.*, 2012).

Wood apple is useful in curing scurvy and in relieving flatulence. Mashed seedless pulp of the raw fruit is beneficial in the treatment of dysentery, diarrhea and piles. Wood apple in the form of chutneys and sherbet is useful in treating hiccups (Ratnayake *et al.,* 2009). Wood apple fruit contains flavonoids, glycosides, saponins and tannins. There are reports that some coumarins and tyramine derivatives were also isolated from the fruits of *Limonia* (Ilango and Chitra, 2009).

The wood apple seed protein concentrate (SPC) is found to be a good source of essential amino acids leucine, phenyl alanine, valine, isoleucine and threonine (Rao *et al.* 2011).

2.2 Chemical composition of wood apple fruits

Wood apple has got high medicinal value. Every part of the fruit *i.e.* pulp, seed and oil has got its medicinal property (Ramakrishna *et al.*, 2010).

Anonymous (1956) reported that, ripe fruits contain sour-sweet, aromatic pulp which has about 2.3 per cent acidity and 7.2 per cent sugars. The pulp from ripe fruit contains moisture (74%), protein (8.0%), fat (1.45%), carbohydrates (7.45%), ash (5.0%), calcium (0.17%), phosphorous (0.08%), iron (0.07%) and tannins (1.03%).

The pulp in ripened fruit is about 70 per cent of total weight and seeds are embedded in the pulp. It contains about 70 per cent moisture, 7.3 per cent protein, 0.6 per cent fat, 1.9 per cent mineral matter, 2.3 per cent acidity, 7.2 per cent sugars, 0.07 per cent iron, 0.08 per cent phosphorus and it is a rich source of riboflavin (77 mg/100 mg) and calcium (0.17%). The pectin content of the pulp is 3 to 5 per cent (Chundawat, 2003).

The pulp from ripe fruit contains moisture (64.2 g), protein (7.1 g), fat (0.3 g), carbohydrates (17.0 g), vitamin-C (3 mg), total minerals (0.3 g), calcium (4 mg), phosphorous (9 mg), iron (0.5 mg), magnesium (41 mg), copper (0.21 mg), manganese (0.18 mg), zinc (0.46 mg), vitamin B_1 (0.04 mg), vitamin B_2 (0.17 mg), Vitamin B_6 (0.8 mg) and 74 calories of energy value (Shukla and Singh, 2008).

Jayakumar and Geetha (2012) reported that pulp from ripe fruit contains moisture (74.0%), protein (8.00%), fat (1.45%), carbohydrates (7.45%), ash (5.00%), calcium (0.17%), phosphorous (0.08%), iron (0.07%) and tannins (1.03%).

2.3 Juice or pulp extraction methods

The method of extraction of pulp/ juice varies with structure and composition of fruit. Generally crushing and pressing are the methods to extract juices from fresh fruits. Some fruits require heat treatment for easy release of juices (Srivatsava and Sanjeevkumar, 2014).

Extraction of wood apple pulp was found difficult when added water less than one part of flesh. Addition of water at the ratio of 1:2 (pulp: water) and heating of the mixture to 100^0C helped in dissolving the mucilage uniformly to provide homogenous pulp. Thermal application enhanced the juice recovery, TSS and acid content in pulp (Chopra and Singh, 2001).

Different methods of pulp extraction *viz.*, cold water extraction, hot water extraction, cold and hot water enzymatic extraction were tried for wood apple pulp extraction. The maximum pulp recovery was obtained by soaking wood apple pulp + combination of pectinase and cellulase enzyme @ 0.125 per cent each for 2 hr. The enzymatic treatment of wood apple pulp resulted in maximum TSS, acidity, ascorbic acid and total sugars as compared to other methods of extraction (Chandana, 2016).

Shresta (2000) opined that the bael pulp extracted by passing through the sieve without addition of water resulted in very sticky pulp. The pulp so obtained is unfit for handling and nearly 10 per cent loss of pulp due to mucilage content is observed during extraction. Incorporation of water and application of heat results in dilution of mucilage considerably and make the complete extraction of juice.

Bael pulp was extracted successfully by addition of water to pulp in the proportion of 1:1 and 2:1 and clear juice was obtained by centrifugation of pulp at 4000 rpm for 10 min (Ghosh and Gangopadhyay, 2002)

2.4 Pectinase enzyme in fruit juice extraction

The use of enzymes has been an essential part of the entire technology of fruit processing industries. Starch degrading enzymes for fruit juice clarification and later, pectinolytic enzymes represent the first enzymatic products that were successfully used in fruit processing industries. The importance of enzymes as a processing aid for high quality fruit juice and concentrate has not decreased since then (Albrecht, 1996)

Pectinolytic enzymes hydrolyze the pectic substances present in fruit, resulting in juice that has much lower amount of pectin. With the addition of pectinases the viscosity of the fruit juice drops, the press ability of the pulp improves, the jelly structure disintegrates and the fruit juice is easily obtained with higher yields (Tapre and Jain, 2014).

Pectolytic enzymes are used for the fruit processing industry to increase yields, improve liquification, clarification and filterability of juices, maceration and extraction of plant tissues releasing flavour, enzymes, proteins, polysaccharides, starch and agar. The pectin enzymes assist in pectin hydrolysis, which causes a reduction in pulp viscosity and a significant increase in juice yield (Pilnik and Voragen, 1993).

Nagaraju (2002) reported that, ber pulp treated with pectinase-B enzyme at the rate of 8 g per Kg pulp for 12 hours gave the maximum juice recovery (74.71%) with better quality parameters as compared to untreated control (56.81%).

The effect of pectinase enzymes on juice recovery and certain quality parameters in ber var. "Umran" were studied by Devaraju *et al.* (2002). The results revealed that incorporation of enzyme pectinase III (0.1 g per kg pulp) for four hours improved the juice yield and quality parameters like TSS, ascorbic acid and total sugars as compared to the control.

Lakkond *et al.* (2003) studied the effect of pectinase enzyme on juice recovery and quality parameters in sapota and reported an improved juice yield (73.15 %), physico-chemical and sensory qualities of the juice over control at 0.0075 per cent incorporation of pectinase-B.

Patil *et al.* (2004) studied the effect of pectinase enzymes on juice recovery in banana, var. Robusta. The results revealed that incorporation of enzyme pectinase A to the banana pulp @ 6.00 g per kg pulp for six hours improved the juice yield (86.86%) and quality parameters like TSS (21.96%), titratable acidity (0.49%) and total sugars (14.15%) as compared to control (50.96%, 21.92%,0.46% and 13.2% respectively). Treatment of fruit pulps with pectinase also showed an increase in fruit juice volume from banana, grapes and apples (Kaur *et al.*, 2004)

The maximum recovery (84.00%) of clarified guava juice was reported in pulp treated with pectinase-A enzyme at 8 g per kg pulp for 10 hours. The highest TSS (10.58^0B), titratable acidity (0.711%), minimum pectin content (0.123%) and maximum level of reducing sugar (6.54%), non-reducing (1.32%) and total sugars (7.92%) were noticed in pectinase-B at 1.00 g per kg pulp for 10 hours (Manikanta, 2005).

The optimum yield of orange juice (97%) was obtained at 1 per cent pectinase enzyme. Turbidity and viscosity decreased with increasing concentration of pectinase enzyme. This is because pectinase degrades the polysaccharides material in the orange juice into smaller fractions, thus facilitating filtration and reduction in viscosity and turbidity (Kareem and Adebowale, 2007).

Due to slimy nature of kiwi fruit pulp, the extraction of juices from kiwi fruits was found difficult. To overcome this problem a combination of enzymes (pectinase 0.025 g/kg + amylase 0.025 g/kg + mash enzyme 0.05 g/kg) were used to macerate the pulp (2h at 50^0C) and thus to facilitate juice extraction. The enzyme treatment enhanced the juice recovery from kiwi fruit pulp (78.46%) as compared to control (58.44%) (Vaidya *et al.*, 2009)

Vijayanand *et al.* (2010) studied the clarification of litchi pulp at different pectinase concentrations and found that treatment with pectinase enzyme facilitated the removal of insoluble solids and extraction of juice.

Norjana and Noor (2011) treated durian juice with different pectinase concentrations under different incubation time. Greater yield of juice was obtained when the amount of enzyme (0.05%) used was higher with longer incubation time (3 hours). The results indicated that juice yield increased by 35 per cent when the pectinase enzyme was used.

The effect of two cell wall degrading enzymes, namely pectinase and viscozyme, on the nutraceutical composition of *Zizyphus* juice was investigated by Koley *et al.* (2011). Enzyme assisted processing significantly improved the juice yield, total soluble solids, total phenolics and total antioxidant activity (AOX). Results indicated that enzyme-assisted processing can significantly improve the functional properties of the *Zizyphus* juice.

Joshi *et al.* (2011) reported that enzymatic treatment of plum, peach, pear and apricot juice at 2.5 per cent concentration resulted in significant increase in recovery of juice from 52-72 per cent in plums, 38-63 per cent in peach, 60-72 per cent in pear and 50-80 per cent in apricot. In case of bael fruit, enzymatic extraction resulted in 17.5 per cent increase in juice yield at an enzyme concentration of 20 mg/100 g pulp, incubation time of 425 min and temperature of 47^0C (Singh *et al.*, 2012).

Sherpa *et al.* (2014) optimized type and concentrations of commercial enzyme for the treatment of the plum pulp to improve the juice yield with colour enhancement. Pectinase enzyme at a concentration 10 units/ml was found to give juice yield upto 86.33 per cent.

Ahmed *et al.* (2014) reported increase in yield of pectinase enzyme treated guava (80%), jackfruit (79%), pineapple juices (81%). This is due to the partial or complete degradation of the cell wall and middle-lamina pectins, other polysaccharides and cell substances thus increasing press capacity which resulted in increased juice yield and dry matter content of the product with the increased enzyme concentration and incubation time. The vitamin C content of enzymatically extracted juice decreased as ascorbic acid is a heat liable vitamin and cannot withstand the heat treatment as it was applied at the time of enzyme inactivation.

2.4.1 Effect of pH, time and temperature on enzyme activity

Enzymatic degradation of the biomaterial depends upon the type of enzyme, incubation time, incubation temperature, enzyme concentration, agitation, pH and use of different enzyme combinations (Sharma *et al.,* 2014).

Baumann (1981) observed that temperature has a significant effect on the activity of pectic enzymes. There was a close relationship between temperature and time during enzyme treatment of fruit juices. As temperature increases, the rate of pectin degradation increased and the time of enzyme treatment decreased.

Sharma and Joshi (2016) optimized the conditions for juice extraction from wood apple pulp and found out that combined pre treatment (Steaming and enzyme) *i.e.* 6 min of steaming, 30 mg/100 g enzymatic concentration, 6 hrs of incubation time at 40^0C incubation temperature obtained maximum juice recovery (82.36 %) and TSS content (5.3^0B) from wood apple pulp.

Among different extraction methods, wood apple pulp treated in hot water + combination of pectinase and cellulase enzyme @ 0.125 per cent for 2 hours resulted in maximum recovery of juice with higher physico chemical and sensory characterisitics (Chandana, 2016).

According to Roy and Singh (1979) the fruit pulp from bael was successfully extracted by addition of equal quantity of water (with seeds and fibre) by adjusting the pH to 4.3 by adding citric acid and heating to a temperature of 80^0C for one minute and then passing through a pulper. Finally, seeds and fibre were separated by straining the hot mass through muslin cloth.

Singh *et al.* (2012) studied the effect of incubation time (97.5-652.5 min), incubation temperature ($28.18\text{-}61.82^0$C) and pectinase concentration (0.64-7.36 mg/25 g bael pulp) on the juice yield, viscosity and clarity of the juice obtained from bael fruit. The recommended enzymatic treatment conditions were incubation time (425 min), incubation temperature (47^0C), and pectinase concentration (5.0 mg/ 25 g bael pulp) and the juice yield, viscosity and clarity under these conditions were 84.5 per cent, 1.35 cps and 22.43 per cent, respectively.

Kumar and Muzaffar (2015) studied on the effect of different process parameters on extraction of pulp from tamarind fruit and found that the tamarind pulp soaked in water at 2.5:1 for 31 min at incubation temperature of 38^0C resulted in higher pulp yield.

The commercial pectinase was tested for the increase in yield, viscosity reduction and clarification of banana juice. The clear juice yields of 55 and 60 per cent was obtained at 0.01 per cent of enzyme treatment for 20 min at 45°C whereas untreated pulp yield was less than 5 per cent under same conditions (Viquez *et al.,* 1981). Enzymatic concentration of 2 per cent, incubated at 50^0C for 2hrs resulted in a serum yield of 65 per cent in mango pulp (Gupta and Girish, 1988).

An enzyme concentration of 0.5 per cent incubated at 45^0C for 5 hours was found optimum to liquefy apricot and plum pulps to obtain maximum juice yield of 59 per cent from mango pulp (Chauhan *et al.* 2001).

Sin *et al.* (2006) optimized conditions for enzymatic clarification of sapodilla juice. Sapodilla juice was treated with pectinase enzyme at different incubation times (30-120 min), temperature (30-50^0C) and enzyme concentration (0.03-0.10%). The recommended enzyme clarification condition was 0.1 per cent enzyme concentration at 40^0C for 120 min.

Vandhana *et al.* (2006) studied the effect of enzyme concentration and incubation temperature on yield of carrot juice and observed a sharp increase in yield up to certain point and then decreased.

Tadakittisarn *et al.* (2007) reported that the optimum conditions for enzymatic juice extraction of banana variety 'Gross Michael' was found to be 0.15 per cent of pectinase enzyme incubated at 50^0C for 120 min. Thompson (2003) observed that the 0.1 per cent pectinase enzyme concentration incubated at 40^0C for 120 minutes was found to be optimum for clarification of sapota juice.

Vaidya *et al*. (2009) reported that kiwi fruits treated with pectinase 0.025 g/kg + amylase 0.025 g/kg + mash enzyme 0.05 g/kg and incubated for 2h at 50^0C resulted in enhancement of juice recovery (78.46%) compared to control (58.44%).

Suresh and Viruthagiri (2010) reported that incubation temperature of 40^0C and 5 pH was found to be optimum conditions for the maximum growth of pectinase producing *Aspergillus niger.*

Ndiaye *et al.* (2011) optimized the processing conditions for natural cloudy mango juice using pectinoloytic enzymes and celluloytic enzymes and found that pectinase and cellulase enzyme of 30μL and 22μL concentration respectively, incubated at 45^0C, for 43 min at pH of 5, was found to be optimum condition for processing cloudy mango juices.

The optimum conditions for clarification of guava juice was found to be incubation temperature 45^0C, incubation time 7.23 hr and enzyme concentration 0.70 mg per 100 g of guava pulp which resulted in ascorbic acid content of 77.71 mg/100 g, clarity of 34.54 per cent transmittance, viscosity of 1.24 cps and colour (L value) 23.33(Kaur *et al.*, 2011).

Kothari *et al.* (2013) treated apple juice by crude extracts of Pectinase, Cellulase and Amylase produced in laboratory for clarification of apple juices. Enzymes at different pH, temperatures and time as individual enzyme and as a mixture of enzymes were evaluated. Enzymes showed activity in acidic pH range between 3 to 6 and the temperature range 30 to 60^0C. Mixture of enzyme showed maximum activity at pH 5.0 and temperature at 40^0C.

Minh (2014) studied on enzymatic pectinase application in extraction and purification of juice turbidity from red rose apple and found that pectinex 3XL of 0.03 per cent concentration incubated at 40^0C for 80 min was found optimum for juice clarification.

Maximum apple juice yield can be obtained by treating cellulase enzyme, incubating at pH-4 and temperature 50^0C whereas, by treating pectinase enzyme, incubating at pH-5 and temperature 45-50^0C on yield of apple juice (Srivatsava and Tyagi, 2013).

Saini *et al.* (2015) worked on the novel pectinase producing fungal strain for juice clarification and extraction and reported that orange peel was proved to be best substrate with 24 hr of incubation with 5 ml inoculums at 4 pH.

2.5 Storage stability of pulp

Fruit juices/pulp are pasteurized in order to achieve a reduction of microbes and to inactivate undesirable enzymes. The most popular way to achieve these goals is by thermal pasteurization. This process is traditionally accomplished by rapid heating and cooling of the puree to help preserve quality factors (Fender, 2005).

It is known that conventional heat pasteurization can effectively reduce the number of pathogens such as *E. coli* O157:H7, *Salmonella* sp., *Listeria monocytogenes* and *Cryptosporidium parvum* and suitable for all types of juices (Tandon, *et al.* 2007).

Tendon *et al.* (1983) investigated on chemical composition of stored guava pulp in PVC containers. Guava pulp from two *cv*. (Alahabad safeda and Lucknow 49) was stored at room temperature for 60 days. It was observed that during storage reducing sugar increased, ascorbic acid and tannins decreased. Juice prepared from stored pulp was of good quality.

Kolera *et al.* (1991) conducted experiment on 12 months stored pulps from four commercial mango cultivars and papaya blends were used for preparation of beverages, which was preserved for one year in glass bottles under ambient condition (20-36^{0}C). Titratable acidity and TSS did not change on storage. The yellowness index (Y.I.) remained stable during storage. The Y.I. of mango was higher than papaya.

Spanos and Wrolstad (1992) reported that the total phenol concentration reduced up to 50 per cent in thermally pasteurized apple juice at 80^{0}C for 15 minutes. Fender, 2005 suggested that enzymatic and thermal treatments applied during juice making may affect phenolic composition. According to the study of Lee and Coates (1999), slight visual differences after thermal pasteurization of red grape juice were reported.

Kute *et al.* (2000) worked on preservation of sapota pulp and reported a continuous decrease in sensory quality scores for colour, appearance, taste and flavor during storage. The ascorbic acid content was found to decrease during storage period and it was reported to be more under ambient conditions than at cold temperatures.

Hussain *et al.* (2003) evaluated on the physico-chemical, microbiological and sensory evaluation of mango pulp storage for 150 days at ambient conditions with chemical preservatives and pasteurization. The stored samples were found to be normal even after 270 days. No microbial load was found up to 90 days of storage period. It was observed that the pasteurized mango pulp could be stored for extended period of time without any major changes in chemical composition and sensory characteristics.

Ladaniya (2008) observed that physicochemical, organoleptic and microbial changes in Nagpur mandarin orange juice pasteurized (90±2°C) without any preservative can be stored for up to 180 days under ambient (30±5°C) conditions.

Pareek *et al.* (2011) studied on influence of juice extraction methods and pasteurization temperature and time on quality of mandarin. Juice extracted with screw type juice extractor and processed at 65^{0}C for 15 min maintained better quality characteristics like total soluble solids, acidity, ascorbic acid, sugars and non-enzymatic browning during 6 months storage.

Shinde *et al.* (2015) studied on the microbial contamination of pasteurized mango pulp stored under different temperatures. The microbial load of the product showed an increasing trend irrespective of the temperatures. However it was more pronounced in higher temperature compared to lower temperature. The pasteurized mango pulp stored under ambient conditions was found safer up to 3 months of storage.

Kundu *et al.* (2015) studied on the effect of different storage conditions on quality of plum pulp. The maximum total soluble solids (11.39%) and acidity (1.79%) were found in the pulp stored at room temperature, while minimum was observed in pulp stored at frozen temperature (11.13% and 1.74% respectively). The maximum ascorbic acid (8.02 mg/100 g) content was found in pulp stored at frozen temperature and it decreased progressively with the increase in storage period. The maximum total sugars (8.66%) were recorded in pulp stored at room temperature but no effect was recorded on reducing sugars. No significant changes in total and reducing sugars were observed up to 90^{th} day of storage. However, in later storage periods it increased significantly. No microbial load and browning were observed up to 120 days of storage.

Swetha *et al.* (2016) studied on effect of combination of chemical preservatives and pasteurization on custard apple pulp storage and observed that with the advancement of storage period under ambient conditions a gradual increase in chemical constituents such as TSS (26.54-27.33^{0}B), reducing sugar (15.73-15.99%) and total sugar (19.06-19.40%) was observed whereas, ascorbic acid (9.38-7.95 mg/100 g), titratable acidity (0.69-0.50%) and non-reducing sugar (41.72-36.32%) decreased. Kavya (2014) reported that the custard apple pulp pasteurized at 90^{0}C for 25 min was superior in sensory attributes.

2.6 Fruit bar

Fruit bars are confectionery product prepared by mixing fruit pulp with calculated amount of sugar and other ingredients, which is then spread on trays and dried until the moisture content is reduced to required level. The dried sheet is cut into suitable sizes and packed (Nanjundaswamy *et al.*, 1976). It is a nutritious product, having a chewy texture, similar to dried raisins and is a good source of dietary fibre and natural sugar (Vidhya and Narain, 2011). It is an age old traditional fruit product acceptable by all age groups (Nanjundaswamy *et al.*, 1976; Rao and Roy, 1980).

Ready to eat food bars provide nutrition as snacks, meal supplements or meal substitutes. The ingredients are selected and processed for desired food bar in the form of cylindrical or rectangular shapes, finally processed and packaged to provide portable convenience in handling and eating. They have great potential in supplying nutrients to military persons, mountaineers and astronauts, besides growing children (Kalsi, 1998).

Mathur *et al.* (1972) reported that fruit bars are well established products and being commercially prepared in India. Most type of fruits is suitable for this type of processing. Many researches has been done on the quality improvement of papaya leather (Cherian and Cherian; 2003), Manimegalai (2001) in jackfruit bar, Singh *et al.* (2004) in mango leather and Jain and Nema (2007) in guava leather

2.5.1 Preparation of fruit bar

Kalamgh and Unde (1996) developed wood apple khoa bar and wood apple milk powder bar. The bar was prepared by heating the mixture of pulp and sugar for half and hr. At this stage, khoa or milk powder was added at the ratio of 4:1 and further heated to mix the ingredients thoroughly. It was moulded, cooled, sealed and packed in plastic polyethylene wrappers and stored in a cool place. They were highly acceptable during organoleptic evaluation.

Sakate (2000) observed that 20 per cent wood apple pulp with 45 per cent sugar produced desirable wood apple burfi with improved sensory quality and low cost production.

Vidhya and Narain (2011) prepared fruit bar from ripe wood apple pulp with addition of 100 per cent sugar, 20 per cent milk powder, 10 per cent of hydrogenated fat, 1tsp citric acid and 1 pinch of salt. The TSS of mixture was raised to 71.5^0 B, poured in a greased tray and cooled at room temperature. It was then cut into equal pieces and packed in butter paper and stored under room temperature for 90 days.

Bhatt and Jha (2015) prepared wood apple mango bar. Pulp-water blends (1:2) of wood apple was prepared and heated at 100^0C, cooled and sieved. For the preparation of wood apple mango bar, mango pulp was mixed with extracted wood apple pulp in different proportions of 10, 30, 50 and 70 per cent and mixture was blended manually. It was then heated for 10-15 min and sucrose was added at 30 per cent and heated at 80^0C which was then poured into trays and dried in an oven at 65-70^0C for 24 hours, cooled, cut into pieces, packed in aluminum foil and polythene and stored at room temperature.

Rakesh *et al.* (2015) formulated the process for preparation of bael slab. It was prepared by addition of 200-300 ml water/ kg of pulp followed by agitation and heating of pulp up to 30^0C. It was then sieved and sugar, citric acid and KMS was added so that the pulp contains 35^0B TSS, 0.5 per cent titratable acidity and 0.07 per cent KMS. The treated pulp was boiled and spread on aluminum trays smeared with butter and dried at 55-60^0C for 15-16 hr to achieve the moisture content of 14.5 per cent. Cut slabs were then wrapped in butter paper and packed in polythene bags.

Khalil *et al.* (1984) fortified date bars with skim milk powder and yeast protein in different proportions and the fortified bars showed higher amount of protein, fat, fibre, ash and minerals than that of control or unfortified bars. Sensory evaluation scores showed that all the bars were equally acceptable.

Irwandi and Cheman (1996) prepared durian leather. The results based on sensory evaluation showed that the most acceptable formulation was an ingredient combination of 10 per cent glucose syrup solid, 5 per cent sucrose, 2.67 per cent hydrogenated palm oil and 0.45 per cent soy-lecithin added into durian aril for the preparation of durian leather.

Premalatha and Manimegalai (1996) prepared jackfruit leather by using pulp, sugar and citric acid. The mixture was heated to about 60^0 C and dried in sunlight by spreading in trays. The dried leather was cut in to pieces and wrapped in butter paper. The jackfruit leather was found to be highly acceptable and scored more than 95 per cent for all quality attributes.

Chauhan *et al.* (1997) developed protein enriched mango fruit bar. The mango pulp was supplemented with skim milk powder, soy slurry and sucrose at levels of 4.5 per cent each resulted in mango leather with the highest acceptability.

Good quality fruit leather samples from mango, guava, papaya and fig were obtained from the treatment standardized by mixing the pulp thoroughly with sugar 20^0brix, liquid glucose 5.0 per cent, pectin 0.2 per cent and emulsifying agent 0.5 per cent to the pulp (Naikare *et al.*, 1998).

Mir and Nath (2000) fortified mango bar with protein using different proportions of cane sugar, citric acid, soy protein concentrate and coconut powder. Addition of citric acid to mango pulp reduced sugar to acid ratio. Color of bar improved upon addition of citric acid up to 0.6 per cent. The product with 1 per cent citric acid was found to be sticky. The bar prepared by adjusting TSS of mango pulp to 30^0Brix with cane sugar powder, 0.6 per cent citric acid and 2.0 per cent dry coconut powder or 4.5 per cent soy protein concentrate was found to be acceptable.

Jack fruit bar was prepared from pulped jack fruit bulbs. Acidity and TSS were adjusted to 0.4 per cent and 50^0 brix, mixture spread evenly on a tray to a thickness of 1.0 cm and dried at 50 ± 2^0C for 12 hours by using cabinet dryer (Manimegalai *et al.*, 2001).

According to Ekanayake and Bandhara (2002) 15% sugar level for banana leather was found the best, having satisfactory texture and palatability and tray load of 7.5 mm thickness was found suitable.

Gujral and Khanna (2002) studied on effects of addition of soy protein concentrate, skim milk powder and sucrose at different levels on drying rate, colour, texture and sensory properties of mango leather. Mango leather containing 4.5 per cent skim milk powder and 4.5 per cent sucrose each exhibited the highest acceptability scores.

Rao and Das (2003) standardized fuzzy logic based optimization of ingredients for production of mango bar. Ingredients selected for formulation of mango bar were commercial sucrose, milk powder and maltodextrin.

Kushwaha and Verma (2003) standardized fortified papaya fruit bar by raising TSS of extracted pulp from 9^0 brix to 30^0 brix by adding different proportions of cane sugar, gram flour and skimmed milk powder. Fortified papaya fruit bar prepared by adding pulp (82%), sugar (13.6%), pectin (0.6%), citric acid (0.7%) and skimmed milk powder (3.25%) was found to be the best.

Huang and Hsieh (2005) prepared pear fruit leather by drying the mixture of pear juice concentrate, pectin corn syrup and water at 70°C for 8 hr. Lee and Hsieh (2008) prepared strawberry fruit leathers by blending strawberry puree, corn syrup, pectin and citric acid in a ratio of 200:40:2:1.

Prasad (2009) fortified mango and banana bar with protein using roasted skim milk powder (SMP) and roasted bengal gram flour (RBF). The results indicated 5 per cent level of SMP and RBF in mango and banana bar, respectively gave ideal sensory attributes. The fortified bars were found to be richer in protein and minerals in comparison to plain bars and had superior overall acceptability (OAA) having score of 8.5 and 8.1 in comparison to plain mango and banana bar with the sensory OAA score of 7.8 and 7.5 respectively.

Mishra *et al.* (2010) standardized the product and process for development of amla bar. The bar prepared from 125 g amla pulp, 100 g sugar, glucose (12%), skim milk powder (8%), pectin (8%) and sodium alginate (2%) was of superior quality in terms of overall acceptability.

Sharma *et al.* (2011) reported that the wild apricot fruit bar prepared by using wild apricot pulp + 60 per cent sugar + 0.3 per cent pectin and packed in aluminum laminated pouches was found to be highly acceptable. Result showed decrease in total sugar, ascorbic acid content during 6 months of storage.

Kumar *et al.* (2012) observed that the protein content of sapota-papaya bar increased gradually from 1.17 per cent to 1.85 per cent with increasing amount of skim milk powder whereas, protein content of fruit bars without addition of skim milk powder was found to be 0.87 per cent.

Rehman *et al.* (2012) optimized the ingredients for preparation of apricot-date bars using date paste, dried apricot paste, skim milk powder, roasted gram flour, peanuts and sodium chloride in different proportions.

Rahman (2012) conducted a study to investigate the use of three levels of sucrose (5, 10 and 15%) in drying rate and development of good quality tamarind leathers. The results revealed that tamarind leather containing 15 per cent sucrose showed the best quality performance than other levels of sucrose.

Take *et al.* (2012) fortified sapota-papaya bar with protein using skim milk powder and reported that it can be successfully prepared by using sapota pulp (50%) + papaya pulp (50%) + Sugar (50%) + skim milk powder (6%) + Pectin (2.5%) + Citric acid (1%) + Maltodextrin (1%). The amount of energy obtained by consuming 100 g of sapota papaya bar fortified with 6 per cent SMP was higher (346.06 kcal) than that of control sample (342.96 kcal).

Kuchi *et al.* (2014) evaluated on the standardization of recipe for preparation of guava jelly bar. Among different treatment combinations, the recipe with 50 per cent sugar, 0.3 per cent citric acid and 0.5 per cent pectin added to pulp extract recorded highest organoleptic score.

Bafna and Marimalai (2014) developed the procedure for making kokum fruit bar. The optimum ingredients level was found to be pulp, sugar, milk powder; 50 g, 40 g and 9.39 g respectively. The values of texture, overall acceptability score and calcium content were found to be 8.29, 8.68, 91.73 mg/100 g respectively, at optimum ingredients level.

Take *et al.* (2014) optimized a procedure for making papaya bar. Papaya pulp were first blended in different proportions to standardize parameters like pectin and skim milk powder concentration and then mixture was dried in mechanical dehydrator at 55±2ºCfor 8-10h. According to organoleptic qualities, fortified bar was found to be excellent followed by nutritional qualities particularly protein, fat, crude fibre and calorie content increased with increasing SMP (0-6%) in fruit bar.

2.7 Storage stability of fruit bars

Vidhya and Narain (2011) formulated and evaluated wood apple bar and assessed its quality attributes. Significant gain in total sugar content (0.89%) and reducing sugar content (1.53%) and reduction in titratable acidity (1.66%), vitamin C content (57.7%), calcium (12.5%) and phosphorous (10.7%) content was observed during storage for 3 months under ambient conditions. The microbial load was under the limit at the end of storage period.

Bhatt and Jha (2015) reported significant changes in moisture, protein, carbohydrate, vitamin C, acidity, pH, TSS, total sugar, reducing sugar and non-reducing sugar whereas, non-significant changes were noticed in fat and total ash during six months of storage of wood apple mango fruit bar. A slight decrease in colour, flavour, taste, body and texture and chewiness and overall acceptability was observed with storage.

Gahilod *et al.* (1982) observed a reduction in reducing sugars, ascorbic acid and carotenoid contents and increase in acidity and non enzymatic browning in mango leather packed in polythene bags stored for 70 days at 10±1^{0}C.

Nadanasabapathi *et al.* (1993) evaluated the indigenously available packaging materials such as paper/aluminum foil/low density polyethylene of 40, 20 and 12 micron, metalized polyester/high density-low density polyethylene and nylon/ionomer for packing ready to eat commercially available mango bar. Aluminum foil based materials were found necessary for long term storage of mango bar supplied to armed forces.

Man and Taufik (1995) observed a decrease in colour and texture values of jackfruit leather during storage of two months. Sensory evaluation showed that the jackfruit leather was acceptable after two months of storage at both ambient temperature and at 8^0C.

Aruna *et al.* (1999) studied on physicochemical and microbiological changes during storage of papaya fruit bar for 9 months at room temperature (25-45°C). The prepared bar had 82.93ºBrix initially, which decreased to 81.53^0Brix on 9 months storage. The pectin content of fruit bar decreased in non-significant manner as the period of storage increased. The moisture content, total sugars, non-reducing sugars, vitamin C and ß-carotene decreased drastically on storage.

Krishnaveni *et al.* (1999) studied the storage stability of jack fruit pulp combination with soy protein packed in butter paper (BP), polypropylene (PP) and metalized polyester polyethylene pouches (MPP) stored at room temperature. The moisture content of jackfruit sheet was reduced from 17.07 to 16.02, 16.64 to 15.51 and 16.28 to 15.09 per cent and increase in acidity and reducing sugars respectively from 1.75 to 2.04, 1.35 to 1.62, 1.07 to 1.35, 29.45 to 34.92, 17.70 to 23.60 and 10.08 to 15.02 per cent respectively, at 500 ppm level of sulphur dioxide. Good retention of carotenoids at lower temperature (40^0C) during the storage period of 90 days.

Manimegalai *et al.* (2001) observed reduction in vitamin C, beta carotene and total sugar content in jack fruit bar irrespective of packaging materials used. Kumar and Manimegalai (2002) reported an increase in acidity, TSS, and reducing sugar and decrease in pH, total sugar and ascorbic acid in sapota bar at the end of 180 days of ambient storage.

Kumar *et al.* (2007) prepared guava leather from Allahabad safeda variety of guava and stored at ambient and low temperature (10±1°C). It was observed that guava leather can be stored upto three months at room temperature but quality was not found to be comparable with the leather stored under low temperature.

Sandhu *et al.* (2008) observed that the papaya leather remained highly acceptable after storage in polythene bags or aluminium foil for up to 1 month under ambient conditions, but was only slightly liked after 3 months of storage. Reducing sugars and non-enzymatic browning increased and ascorbic acid, beta-carotene, titratable acidity, total sugars and water activity decreased during storage whereas, no significant changes in pH, pectin and ash contents were observed during storage

Kuchi *et al.* (2014) conducted storage studies in guava jelly bar in both ambient and refrigerated conditions for two months. Physico-chemical characteristics like total sugars and TSS increased while acidity, pectin content, ascorbic acid, and organoleptic scores decreased in jelly bar stored under ambient conditions while changes were negligible for jelly bar stored in refrigerated storage. Jelly bar packed in laminated aluminium foil and stored in refrigerated condition has better quality till consumption.

Safdar *et al.*, 2014 studied on the quality aspects of guava leather packed in vegetable parchment paper, polythene sheet and aluminum foil, stored under refrigerated temperature for 240 days. A gradual increase in total soluble solids (TSS), acidity and total sugar was observed during storage whereas moisture, brix/acid ratio, pH and ascorbic acid were decreased. It was found that the changes were more pronounced in samples packed in polyethylene sheet and least in aluminum foil. Sensory evaluation results revealed that aluminum foil packed samples were ranked highest and more acceptable than others.

Akhtar *et al.* (2014) developed an apple-date bar and evaluated physicochemical, sensory quality and shelf life of developed fruit bar. The moisture content of fresh fruit bar was in between 27.92-30.14 per cent. No microbial detection in developed fresh fruit bar was observed. The developed fresh fruit bar was well acceptable by panelists. During storage, pH and moisture content decreased, while total plate count increased consistently.

2.7.1 Sensory quality of fruit bars on storage

Man and Taufik (1995) observed a decrease in colour and texture values of jackfruit leather during storage of two months. Sensory evaluation showed that jackfruit leather was acceptable even after two months of storage at both ambient temperature and at 8^0C.

The organoleptic quality of osmotically dehydrated papaya stored at 8^0C was unchanged and little changes in colour, flavour and texture at room temperature (27^0C) and at elevated temperature (37^0C) were observed by Ahmed and Chaudhary (1995).

Aruna *et al.* (1999) observed a significant difference in colour and appearance of papaya fruit bars during storage and organoleptic scores decreased 29.02 (initially) to 24.93, 24.93, 22.13 and 19.80 when stored at 5^0C - 8^0C, 9-24^0C, 25-34^0C and 35-45^0C, respectively.

Overall organoleptic score of guava bar reduced from 8.33 to 7.13 after 3 months of storage (Sandhu *et al.*, 2001). The freshly prepared jackfruit bar samples had firm texture, which changed to mild to moderate hardness during 6 months of storage (Manimegalai *et al.*, 2001).

Sensory score studies in relation to period of storage by Babalola *et al.* (2002) showed that the guava leather gave better result in overall acceptability at initial, one and two months of storage at 8^0C. It also gave better sensory qualities in fruitiness, smell, chewiness, toughness, colour, and overall acceptability. At the end of storage, decreasing trend in organoleptic score values of protein enriched mango bars was observed (highly acceptable to acceptable) by Shanthi *et al.* (2003).

Jain and Nema (2007) reported that the organoleptic quality (*i.e.* colour, flavour, taste, texture and overall acceptability) of guava leather decreased gradually with increase in quantity of sugar added. Mean value of moisture content increased significantly with increase in sugar content of leather whereas, the acidity and ascorbic acid content decreased significantly with increase in sugar content in guava leather.

3. MATERIAL AND METHODS

An investigation on "Studies on processing of wood apple pulp for value addition" was carried out in the Department of Post Harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during 2016-17. The details of the material and methods adopted during the investigation are presented here under.

3.1 Location and climatic conditions

Arabhavi is situated in Northern Dry Zone-3 of region-2 of agro climatic zone of Karnataka. It lies at 16°12' N latitude and 75°45' E longitude, at an altitude of 640 m from mean sea level. The average annual rainfall at Arabhavi is about 530 mm and it is distributed over a period of seven months from May to November. The mean maximum temperature goes up to 36.4°C (May) and mean minimum temperature drops down to 20.90°C (February). The relative humidity varies between 57.6 per cent (April) and 81.4 per cent (December).

3.2 Materials

Wood apple fruits used in the present experiment were procured from a single tree located in farmer field in Kadabhalli village, Nagamangala taluk, Mandhya district at fully ripe edible stage during the season (December and January). Fruits of uniform size, shape and maturity were utilized for this study. The Milk powder and Hydrogenated fat were obtained from the local market of Gokak, Belagavi district.

3.3 Experiment-I: Standardization of wood apple pulp extraction method using pectinase enzyme

The design of the experiment was completely randomized design (CRD) with ten treatments and three replications.

Treatment details

T_1 - Incubation temperature 45°C + pH 4.5

T_2 - Incubation temperature 45°C + pH 5.0

T_3 -Incubation temperature 45°C + pH 5.5

T_4 - Incubation temperature 50°C + pH 4.5

T_5 - Incubation temperature 50°C + pH 5.0

T_6 - Incubation temperature 50°C + pH 5.5

T_7 - Incubation temperature 55°C + pH 4.5

T_8 - Incubation temperature 55°C + pH 5.0

T_9 - Incubation temperature 55°C + pH 5.5

T_{10} - Control (Incubation at ambient condition of 25°C temperature and 33% RH with existing pH of 4.10)

3.3.1 Methodology for extraction of wood apple pulp

Sorting and grading is essential to get suitable quality of fruit which was done by hand. Fresh, fully ripe and sound wood apple fruits were used for extraction of pulp. The fruits were opened by breaking against the hard surface and by hammering. The pulp along with the seeds and fiber were separated with the help of stainless steel spoon from the hard shell. The scooped pulp was homogenized by blending manually and the weight of the homogenized pulp was recorded. For each replication, 500 g of homogenized pulp was used.

In case of all the 10 treatments, wood apple pulp was soaked in two parts of normal water and homogenized by hand crushing. Afterwards the pectinase enzyme was added at the concentration of 0.25 per cent to all the treatments. Then the pH of the pulp was adjusted to the required pH (4.5, 5.0 and 5.5) as mentioned in the treatment details using pH meter with sodium bicarbonate buffer. The pH adjusted pulp was incubated for 2 hours at different temperature (45, 50 and 55°C) as mentioned

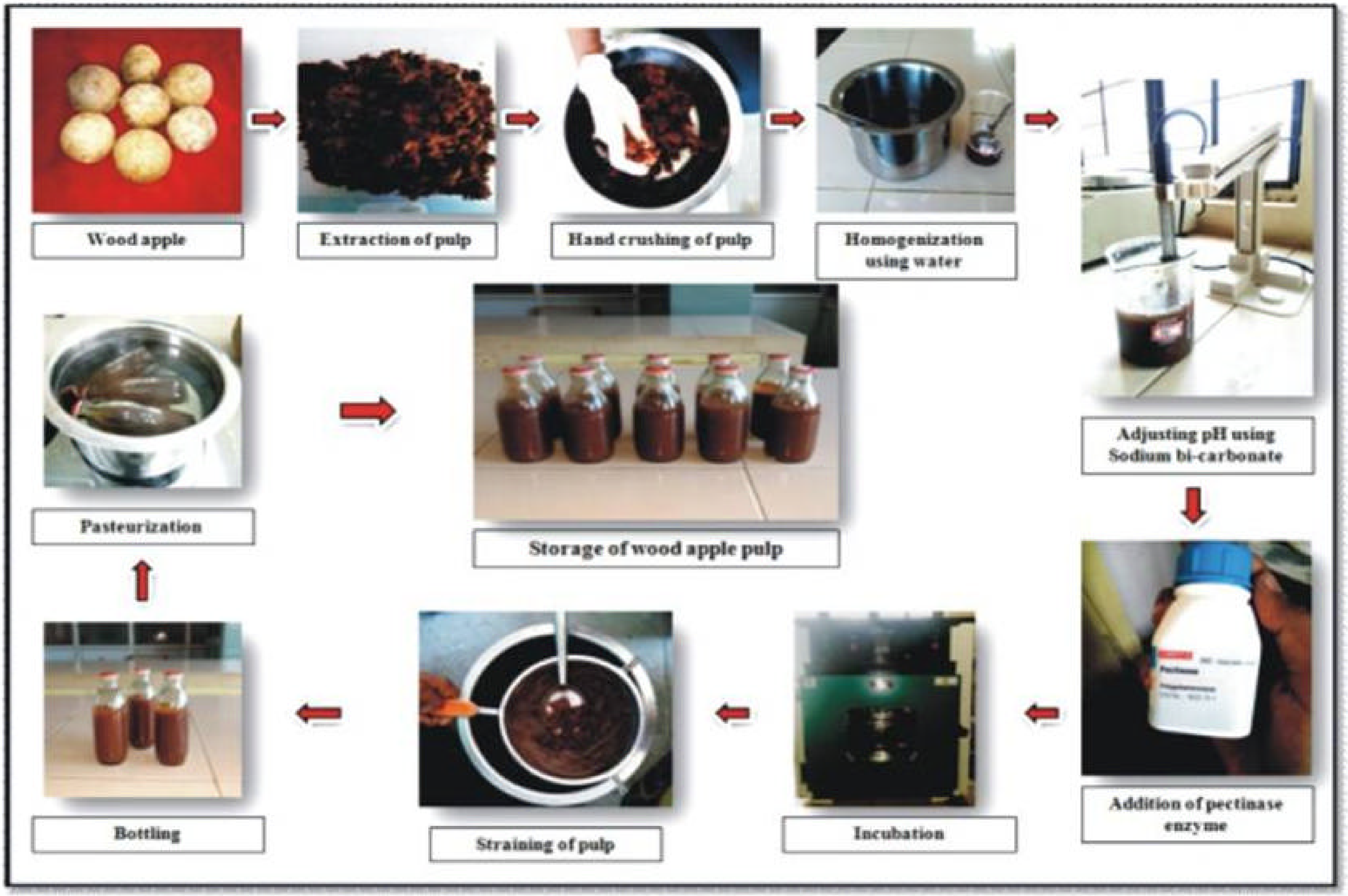

Plate 1: Flowchart for extraction of wood apple pulp using pectinase enzyme

in the treatment details in an incubator. In case of T_{10} (Control), the extracted pulp after homogenization was mixed with the pectinase enzyme at 0.25 per cent concentration and incubated at ambient conditions (Temperature of 25^0C and RH of 33% with existing pH of 4.10).

At the end of treatment period, the pulp was extracted by passing through a strainer and the extract was heated at 90^0C for 5 min to inactivate enzymes. The extracted pulp was then filled in clean sterilized glass bottles and corked tightly. These bottles were pasteurized at 90^0C for 25 min and kept for 3 months of storage studies under ambient conditions (25-28^0C temperature and 33-35% RH) for the estimation of physico-chemical and sensory quality parameters.

3.3.2 Observations recorded

The following parameters were recorded immediately after extraction and at monthly intervals during the storage period of 3 months.

3.3.2.1 Pulp recovery (%)

The pulp recovery percentage was calculated by using the following formula

$$\text{Pulp recovery (\%)} = \frac{\text{Weight of flesh taken for pulp extraction (g)} - \text{Left out pulp after extraction (g)}}{\text{Weight of flesh taken for pulp extraction (g)}} \times 100$$

3.3.2.2 Total Soluble Solids (^{0}B)

The Total Soluble Solids of wood apple pulp was measured by using an ‘Erma’ hand refractometer and expressed as degree brix after making necessary corrections.

3.3.2.3 Titratable acidity (%)

A known volume of sample (5 ml/5 g) was taken and macerated with distilled water, filtered through muslin cloth and volume was made up to 100 ml with distilled water. From this 5 ml of aliquot was taken and titrated against standard NaOH (0.1N) using phenolphthalein indicator. The appearance of light pink colour indicated the end point. The value was expressed in terms of citric acid as percentage titratable acidity as citric acid (Anon., 1984).

Plate 2: Wood apple pulp extracted with different treatments

$$\text{Acidity (\%)} = \frac{\text{Titre value x N. of NaOH x Vol. made up x Eq. weight of citric acid}}{\text{Vol. of aliquot x Vol. of sample taken x 1000}} \times 100$$

3.3.2.4 pH

The pH of wood apple pulp was determined by using digital pH meter (Model: Analog research, USA). The pH meter was first calibrated using standard buffer solutions.

3.3.2.5 Ascorbic acid (mg/100 ml)

Ascorbic acid content was estimated titrimetrically using 2, 6- dichlorophenol indophenol dye as per the modified procedure of AOAC (Anon., 1984). Five ml of fresh pulp was taken and diluted to a known volume with four per cent oxalic acid. In case of fruit bar it is first grinded using pestle and mortar and then it is diluted with four per cent oxalic acid. This was filtered through muslin cloth to get a clear juice and then volume was made to 100 ml using four per cent oxalic acid. Five ml of aliquot was titrated against dye solution till the pink colour appeared. The ascorbic acid content was expressed as mg per 100 ml of pulp/ fruit bar.

$$\text{Ascorbic acid (mg/ 100 g)} = \frac{\text{Ascorbic acid in standard (mg) x Total sample volume x } V_2}{\text{ml of aliquot x Weight of sample x } TV_1} \times 100$$

Where,

TV_1= Titre value of standard and TV_2= Titre value of sample

3.3.2.6 Pectin (%)

Fifty grams of sample was taken into a 1000 ml beaker, 400 ml of water was added and boiled for one hour. The evaporated water is replaced and then cooled and filtered. 300 ml distilled water is added to 100 ml of filtrate along with 10 ml 1N NaOH solution and kept overnight. 25 ml 1N $CaCl_2$ was added and kept for an hour and filtered through whatmans No. 4 filter paper and the filterate was dried in oven and weighed and expressed as calcium pectate.

$$\text{Pectin (\%)} = \frac{\text{Weight of calcium pectate}}{\text{Weight of sample}} \times 100$$

3.3.2.7 Sugars

The sugar content of the samples was obtained from representative samples under each treatment and were estimated and expressed as per cent on volume basis.

3.3.2.7.1 Reducing sugars (%)

Reducing sugars in samples was estimated as per the Dinitro-salicylic acid method (Miller, 1972). The values obtained were expressed as per cent.

3.3.2.7.2 Total sugars (%)

The total sugars present in the products were estimated by the same method as in case of reducing sugars after inversion of the non- reducing sugars using dilute hydrochloric acid (Anon., 1984). One ml of evaporated extract was taken and kept in boiling water till the alcohol completely evaporated and allowed it to cool. Then phenolphthalein indicator was added followed by 1 N sodium hydroxide till the solution turned pink. Again 0.1 N Hydrochloric acid was added to discolour the solution. Then Dinitro-salicylic acid (DNSA) method for reducing sugar was followed. The results were expressed in terms of per cent.

3.3.2.7.3 Non-reducing Sugars (%)

The per cent non-reducing sugars was obtained by subtracting the values of reducing sugar from that of total sugar and multiplied by a correction factor 0.95

Non reducing sugars (%) = [Total sugars (%) - Reducing sugars (%)] x 0.95

3.3.2.8 Organoleptic evaluation

Organoleptic evaluation of wood apple pulp was done at initial and monthly intervals *i.e.,* 1, 2 and 3 months after storage (MAS).

The organolpeptic characters like colour and appearance, flavor, taste, mouth feel and overall acceptability was evaluated by a panel of semi-trained judges consisting of teachers and post-graduate students of Kittur Rani College of Horticulture, Arabhavi on a nine point hedonic scale using the score card mentioned in Appendix I. The mean score given by panelists were used for statistical analysis (Ranganna, 1997).

Score		Colour and appearance	Flavour	Mouth feel/ Texture	Taste	Overall acceptability
9	Like extremely					
8	Like very much					
7	Like moderately					
6	Like slightly					
5	Neither like or dislike					
4	Dislike slightly					
3	Dislike moderately					
2	Dislike very much					
1	Dislike extremely					

3.3.2.9 Microbial load (CFU/ml)

The microbial count of wood apple pulp was taken at monthly intervals during storage period of 3 month as per the method of Harrigan and McCance (1966).

3.3.2.9.1 Preparation of sample

Sample was prepared by taking 10 ml of representative sample from each treatment and it was mixed with 90 ml of sterilized distilled water in a conical flask.

3.3.2.9.2 Dilution

A serial dilution technique was carried out to estimate the microbial load in the samples. One ml of sample was transferred to the test tube containing nine ml of distilled water and shaken vigorously with sterilized glass rod to have thorough suspension. Dilutions prepared for microbial count was 10^{-1}, 10^{-2}, 10^{-3},10^{-4} and 10^{-5}. The dilution of 10^{-3} and 10^{-5} was used for total fungal and bacterial count. Nutrient agar media was used for enumerating the total bacterial count in wood apple pulp whereas potato dextrose agar medium was used for estimating the total fungal colony.

3.3.2.9.3 Enumeration

The media was sterilized in the autoclave at 121^0C for 20 minutes. In each sterilized petri dish, 1 ml of respective aliquot was transferred; 25 ml of medium was poured in duplicate plates. After solidification the plates were kept upside down position and incubated at 37^0C for four days. The colonies were counted and the total count was expressed as CFU per gram of wood apple pulp and fruit bar.

3.3.2.10 Statistical analysis

The data recorded on the physico-chemical and organoleptic (sensory) parameters of wood apple pulp were subjected to statistical analysis in Completely Randomized Design (CRD). The interpretation of the data was carried out in accordance with Panse and Sukhatme (1985). The level of significance used in the F test was $p=0.01$ for both the experiments. Critical difference values were calculated whenever ‘F’ test was significant.

3.4 Experiment-II: Standardization of protocol for preparation of wood apple fruit bar

The design of the experiment was completely randomized design (CRD) with eight treatments and three replications.

Treatment details:

Treatments	Pulp (g)	Sugar (g)	Milk powder (g)	Hydrogenated fat (g)	Citric acid (%)
T_1	1000	750	200	100	0.25
T_2	1000	750	200	100	0.50
T_3	1000	750	200	200	0.25
T_4	1000	750	200	200	0.50
T_5	1000	1000	200	100	0.25
T_6	1000	1000	200	100	0.50
T_7	1000	1000	200	200	0.25
T_8	1000	1000	200	200	0.50

3.4.1 Methodology for the preparation of wood apple fruit bar:

3.4.1.1 Preparation of pulp from fresh wood apple fruits

The pulp was extracted from the fully ripe wood apple fruits. The extracted pulp was mixed with the water (1:1) and homogenized by hand crushing. It was then passed through the strainer to separate seeds and fibre. This pulp was homogenized again using blender to make fine pulp which provides good texture to fruit bar.

3.4.1.2 Preparation of fruit bars from wood apple pulp

For the development of a good quality fruit bar, the pulp prepared from wood apple fruits were boiled for 10 minutes with continuous stirring. It was then mixed with powdered cane sugar, milk powder, hydrogenated fat and citric acid in different combinations as mentioned in the treatment details. The citric acid was added near to the end point. The prepared pulp was then spread evenly on the trays to a thickness of 10 mm. These trays were loaded into easy drier and were maintained at 65±2^{0}C for 12 hours.

After drying to optimum moisture content, the dried sheets were cut into bars of equal size of 7x3.5cm and packed in aluminum foils and kept under refrigerated condition for 3 months for storage studies. Organoleptic evaluation was conducted among semi trained panelists to determine the best treatment. The following flow chart shows the procedure involved in the preparation of fruit bars.

Selection of fully ripe fruits
|
Breaking of hard shell
|
Scooping of pulp
|
Preparation of pulp
|
Boiling for 10 min
|
Addition of sugar
|
Continuous boiling with stirring
|
Addition of milk powder
|
Addition of hydrogenated fat
|
Addition of Citric acid
|
End point 68.5^{0}B
|
Poured in the greased trays and dried at 65±2^{0}C for 12 hours
|
Cut into equal pieces and packed in aluminum foils
|
Stored at refrigerated condition (4^{0}C and 85% RH)

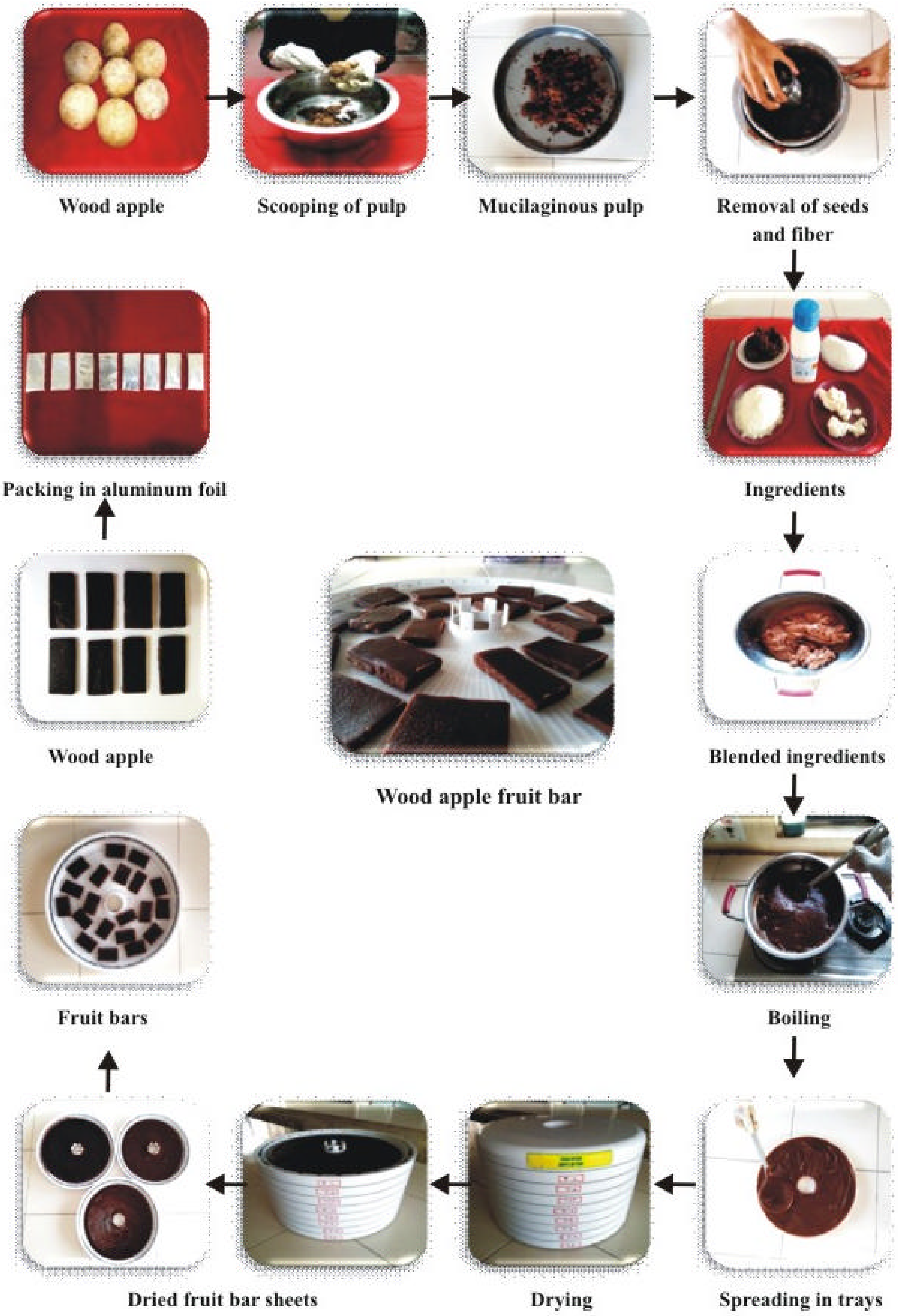

Plate 3: Flow chart for preparation of wood apple fruit bar

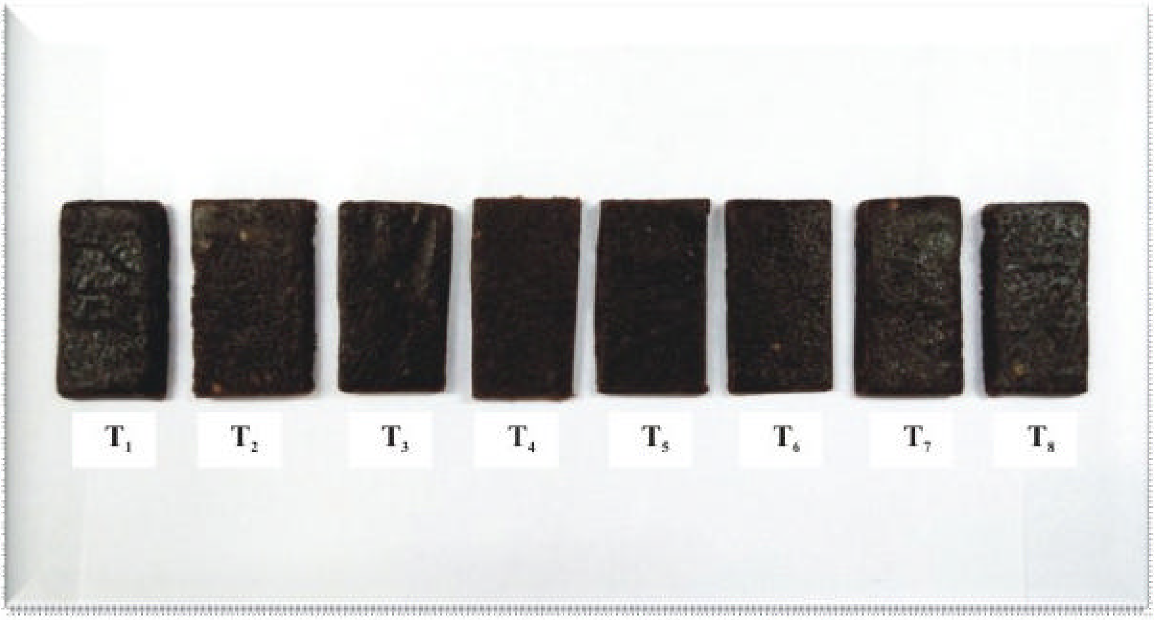

Plate 4: Wood apple fruit bars prepared with different treatments

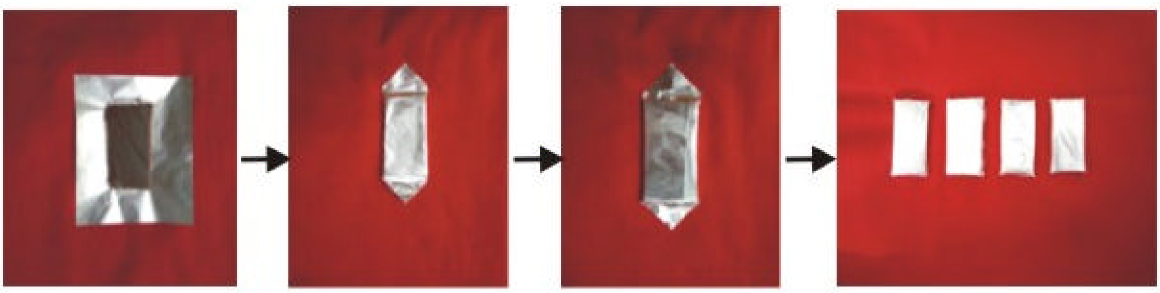

Plate 5: Packing of wood apple fruit bars in aluminum foil

3.4.2 Observations recorded

The following physico-chemical parameters of wood apple fruit bars were recorded immediately after preparation and at monthly intervals up to 3 months of storage.

3.4.2.1 Moisture content (%)

Moisture content of the wood apple fruit bar was determined using moisture analyzer (Model: P1019319, A & D Company Limited, Japan). Two grams of sample was taken for moisture analysis and was determined on the per cent basis.

3.4.2.2 Total Soluble Solids (^{0}B)

The Total Soluble Solids of wood apple fruit bar was measured as mentioned in 3.3.2.2

3.4.2.3 Titratable acidity (%)

Titratable acidity was estimated as presented in 3.3.2.3

3.4.2.4 pH

The pH of the wood apple fruit bar was measured as mentioned in 3.3.2.4

3.4.2.5 Ascorbic acid (mg/100 ml)

Ascorbic acid content was estimated as mentioned in 3.3.2.5

3.4.2.6 Pectin (%)

Pectin content was estimated as mentioned in 3.3.2.6

3.4.2.7 Sugars

Sugar content was estimated as mentioned in 3.3.2.7

3.4.2.7.1 Reducing sugars (%)

Reducing sugars in samples was estimated as mentioned in 3.3.2.7.1

3.4.2.7.2 Total sugars (%)

The total sugars content present in the products were estimated as mentioned in 3.3.2.7.2

3.4.2.7.3 Non-reducing Sugars (%)

The per cent non-reducing sugars were estimated as mentioned in 3.3.2.7.3

3.4.2.8 Calcium and Phosphorous (mg/100 g)

Calcium and phosphorous content of wood apple fruit bar was estimated as per the procedure given in AOAC (Anon, 1984).

3.4.2.8.1 Calcium

The samples were prepared using dry ash method. Twenty to 100 ml of ash solution obtained by dry ashing was diluted with 20-50 ml water. 10 ml of saturated ammonium oxalate solution and 2 drops of methyl red indicator was added to it. It was made slightly alkaline by addition of dilute ammonia and then slightly acid by with few drops of acetic acid until faint pink color (5 pH). The solution was heated, allowed to stand at room temperature overnight and then filtered through whatman filter paper No.42 and then washed with water. The point of filter paper was broken and precipitate was washed first using hot dilute H_2SO_4 and then with hot water. The solution was titrated against 0.01N $KMnO_4$ till permanent pink color appears. Then the filter paper is added to solution and again titrated. Calcium content is determined using below formula.

$$\text{Calcium (mg/100 g)} = \frac{\text{Titre value x Total volume of ash solution}}{\text{Vol. taken for estimation x Wt. of sample taken for ashing}} \times 100$$

3.4.2.8.2 Phosphorus

Five ml of ash solution was taken and 5 ml of molybdate reagent was added to it and mixed. Then 2 ml of aminonaphtholsulphonic acid was added to it and volume was made up to 50 ml. The blank was prepared similarly using water in place of sample. The sample was allowed to stand for 10 min and then color was measured at 650 nm setting blank at 100% transmission. For standard curve, ten ml of standard potassium phosphate was diluted to 50 ml with water. 5 to 40 ml of these aliquot was taken and 5 ml of molybdate reagent was added to it and mixed well. Then 2 ml of aminonaphtholsulphonic acid was added and volume made up to 50 ml. The color of each sample was measured and the plot of concentration against absorbance was prepared.

$$\text{Phosphorous (mg/100 g)} = \frac{\text{mg of phosphorus in aliquot of ash solution taken for estimation x Total volume of ash solution}}{\text{Vol. taken for estimation x Wt. of sample taken for ashing}} \times 100$$

3.4.2.9 Organoleptic evaluation

Organoleptic evaluation of wood apple fruit bar was carried out in 9 point hedonic scale as mentioned in 3.3.2.8.

3.4.2.10 Microbial load (CFU/ml)

The microbial count of wood apple fruit bar was done as mentioned in 3.3.2.9.

3.4.2.11 Statistical analysis

The statistical analysis of wood apple fruit bar was done as mentioned in 3.3.2.10.

4. EXPERIMENTAL RESULTS

The results on the investigation of "Studies on processing of wood apple pulp for value addition" was conducted at the Department of Post Harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during 2016-17 are presented in this chapter.

4.1 Experiment-I: Standardization of wood apple pulp extraction method using pectinase enzyme

4.1.1 Preparation and preservation of wood apple pulp

4.1.1.1 Pulp recovery (%)

The data pertaining to pulp recovery percentage as influenced by different treatments are presented in Table 1 and depicted in Fig. 1. The data revealed significant differences among the treatments. Significantly maximum pulp recovery percentage was recorded in T_2 (81.60%) which was statistically on par with T_1 (80.85%) while, minimum percentage was recorded in T_{10} (65.12%).

4.1.1.2 Total soluble solids (^{0}B)

The data on changes in total soluble solids of wood apple pulp with respect to different treatments and storage period are presented in Table 1. The perusal of the data indicates significant differences among the treatments and total soluble solids were found to increase during the storage.

At initial stage, maximum total soluble solids was recorded in T_2 (6.23^{0}B) which was on par with T_1 (6.15^{0}B), T_5 (6.05^{0}B) and T_4 (6.00^{0}B) while, it was recorded minimum in T_{10} (5.20^{0}B). After 1, 2 and 3 months of storage, the highest total soluble solids was observed in T_2 (6.41, 6.64 and 6.88^{0}B) whereas, lowest total soluble solids was observed in T_{10} (5.31, 5.49 and 5.70 ^{0}B) respectively.

4.1.1.3 Titratable acidity (%)

The titratable acidity was expressed in terms of citric acid percentage of wood apple pulp. The observations on titratable acidity as influenced by different treatments

Table 1: Effect of different treatments on pulp recovery and changes in total soluble solids of wood apple pulp during storage period

Treatments	Pulp recovery (%)	Total soluble solids (^{0}B)			
		Months after storage			
		Initial	1	2	3
T_1- Incubation temperature 45^{0}C + pH 4.5	80.85	6.15	6.28	6.49	6.63
T_2- Incubation temperature 45^{0}C + pH 5.0	81.60	6.23	6.41	6.64	6.88
T_3- Incubation temperature 45^{0}C + pH 5.5	72.32	5.80	5.89	6.11	*
T_4- Incubation temperature 50^{0}C + pH 4.5	78.16	6.00	6.12	6.29	6.47
T_5- Incubation temperature 50^{0}C + pH 5.0	78.80	6.05	6.16	6.30	6.51
T_6- Incubation temperature 50^{0}C + pH 5.5	71.00	5.80	5.93	6.08	*
T_7- Incubation temperature 55^{0}C + pH 4.5	68.60	5.60	5.71	5.94	6.13
T_8- Incubation temperature 55^{0}C + pH 5.0	67.83	5.53	5.65	5.85	*
T_9- Incubation temperature 55^{0}C + pH 5.5	67.00	5.50	5.63	5.85	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	65.12	5.20	5.31	5.49	5.70
Mean	**74.89**	**5.90**	**6.01**	**6.19**	**6.39**
S.Em±	0.92	0.05	0.02	0.05	0.03
C.D. @ 1%	3.72	0.21	0.11	0.19	0.14

*Sample spoiled

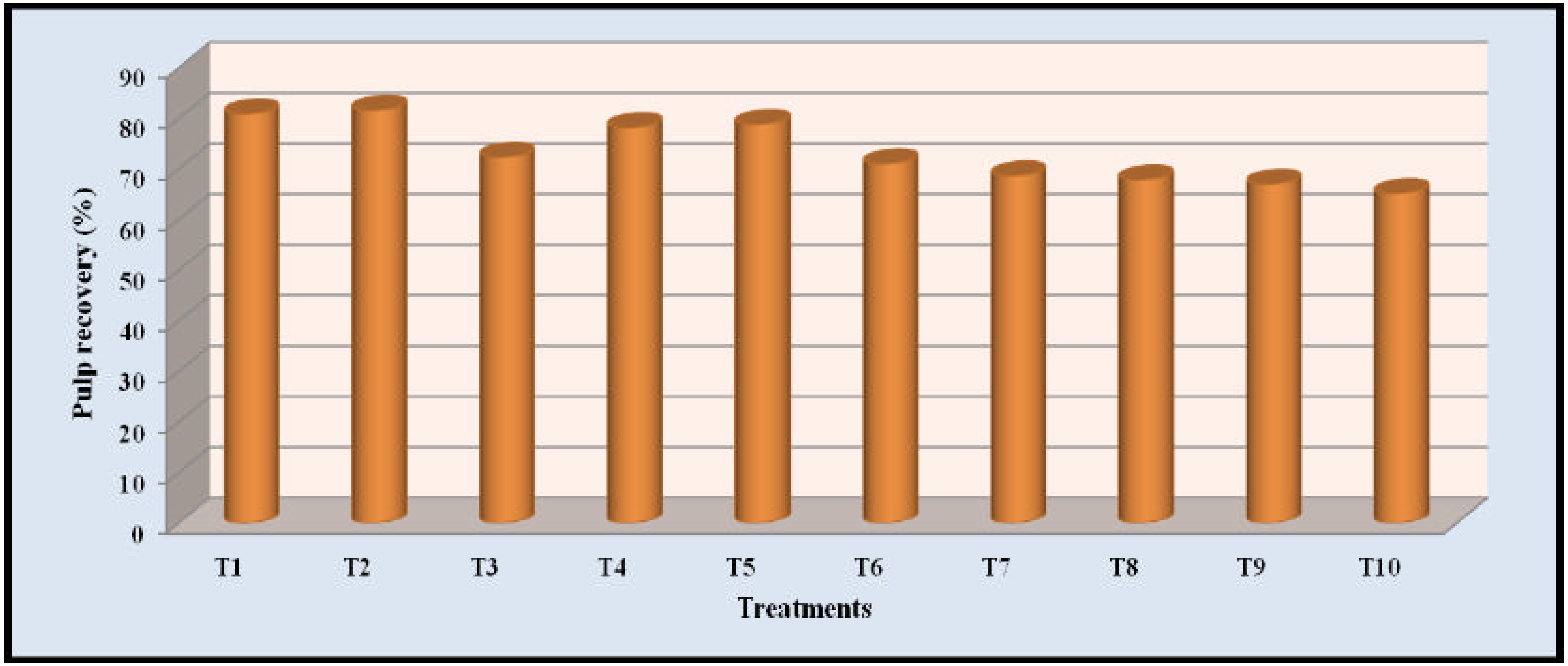

Fig. 1: Effect of different treatments on wood apple pulp recovery

T_1- Incubation temperature 45^{0}C+ pH 4.5
T_2- Incubation temperature 45^{0}C+ pH 5.0
T_3- Incubation temperature 45^{0}C+ pH 5.5
T_4- Incubation temperature 50^{0}C+ pH 4.5
T_5- Incubation temperature 50^{0}C+ pH 5.0
T_6- Incubation temperature 50^{0}C+ pH 5.5
T_7- Incubation temperature 55^{0}C+ pH 4.5
T_8- Incubation temperature 55^{0}C+ pH 5.0
T_9- Incubation temperature 55^{0}C+ pH 5.5
T_{10}- Control (Incubation at ambient temperature with existing pH

and storage period are presented in Table 2. It was evident from the table that the titratable acidity exhibited decreasing trend with the advancement of storage period irrespective of treatments.

Significantly, highest per cent of titratable acidity was noticed in T_{10} (1.83, 1.76, 1.68 and 1.53%) which was on par with T_1 (1.78, 1.73 and 1.67%), T_4 (1.77, 1.73 and 1.65%) and T_7 (1.75, 1.69 and 1.65%) while, minimum per cent was observed in T_9 (1.40, 1.33 and 1.30%) at initial, 1 and 2 months after storage respectively. Further at the end of storage period, significantly highest per cent of titratable acidity was recorded in T_1 (1.62%) which was on par with T_7 (1.59%) and T_4 (1.58%) while, lowest per cent of titratable acidity was recorded in T_5 (1.41%).

4.1.1.4 pH

The changes in the pH of the wood apple pulp as influenced by different treatments and storage period are presented in Table 2. The pH of wood apple pulp increased as the storage period progressed in all the treatments. The data revealed that there were significant differences among the treatments and during the storage period.

At initial stage, 1 and 2 months after storage, minimum pH was registered in T_{10} (4.10, 4.13 and 4.18) while, maximum pH was observed in T_9 (5.50, 5.55 and 5.62) which was on par with T_6 (5.47, 5.54 and 5.61) and T_3 (5.46, 5.53 and 5.59) respectively. However, after 3 months of storage period significantly minimum pH was in recorded in T_{10} (4.28) whereas, maximum pH was recorded in T_5 (5.21).

4.1.1.5 Ascorbic acid (mg/100 g)

The data pertaining to retention of ascorbic acid content of wood apple pulp as influenced by different treatments and storage period are presented in Table 3 and depicted in Fig. 2. The mean ascorbic acid content over the different storage period of observations indicated that the ascorbic acid content gradually decreased with the advancement of storage period from 2.85 to 2.62 mg/100 g for 3 months.

The maximum retention of ascorbic acid content during initial and throughout the storage period was observed in T_{10} (3.46, 3.35, 3.28 and 3.13 mg/100 g). The minimum content was recorded in T_9 (2.25, 2.19 and 2.05 mg/100 g) at initial, 1 and 2 months after storage. Further, at the end of storage period after 3 months, it was recorded minimum in case of T_7 (1.96 mg/100 g).

Table 2: Changes in titratable acidity and pH of wood apple pulp as influenced by treatments and storage period

Treatments	Titratable acidity (%)				pH			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1- Incubation temperature 45^0C + pH 4.5	1.78	1.73	1.67	1.62	4.48	4.52	4.57	4.62
T_2- Incubation temperature 45^0C + pH 5.0	1.62	1.56	1.54	1.43	5.00	5.03	5.07	5.12
T_3- Incubation temperature 45^0C + pH 5.5	1.46	1.45	1.36	*	5.46	5.53	5.59	*
T_4- Incubation temperature 50^0C + pH 4.5	1.77	1.73	1.65	1.58	4.45	4.49	4.57	4.62
T_5- Incubation temperature 50^0C + pH 5.0	1.62	1.53	1.48	1.41	5.00	5.06	5.14	5.21
T_6- Incubation temperature 50^0C + pH 5.5	1.49	1.43	1.36	*	5.47	5.54	5.61	*
T_7- Incubation temperature 55^0C + pH 4.5	1.75	1.69	1.65	1.59	4.50	4.55	4.59	4.65
T_8- Incubation temperature 55^0C + pH 5.0	1.58	1.54	1.49	*	4.95	4.98	5.03	*
T_9- Incubation temperature 55^0C + pH 5.5	1.40	1.33	1.30	*	5.50	5.55	5.62	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	1.83	1.76	1.68	1.53	4.10	4.13	4.18	4.28
Mean	**1.63**	**1.57**	**1.51**	**1.50**	**4.89**	**4.93**	**4.99**	**-**
S.Em±	0.03	0.02	0.03	0.04	0.03	0.02	0.02	0.02
C.D. @ 1%	0.14	0.11	0.14	0.15	0.14	0.12	0.11	0.11

*Sample spoiled

Table 3: Changes in ascorbic acid and pectin content of wood apple pulp as influenced by treatments and storage period

Treatments	Ascorbic acid (mg/100 g)				Pectin (%)			
	Months after storage							
	Initial	**1**	**2**	**3**	**Initial**	**1**	**2**	**3**
T_1- Incubation temperature 45^0C + pH 4.5	3.23	3.18	3.06	2.90	0.45	0.43	0.42	0.41
T_2- Incubation temperature 45^0C + pH 5.0	3.28	3.21	3.09	2.93	0.43	0.42	0.40	0.39
T_3- Incubation temperature 45^0C + pH 5.5	3.18	3.09	2.93	*	0.67	0.67	0.66	*
T_4- Incubation temperature 50^0C + pH 4.5	2.82	2.75	2.61	2.45	0.55	0.54	0.50	0.49
T_5- Incubation temperature 50^0C + pH 5.0	2.85	2.76	2.62	2.48	0.55	0.55	0.53	0.51
T_6- Incubation temperature 50^0C + pH 5.5	2.75	2.63	2.53	*	0.70	0.69	0.64	*
T_7- Incubation temperature 55^0C + pH 4.5	2.33	2.25	2.12	1.96	0.80	0.79	0.73	0.72
T_8- Incubation temperature 55^0C + pH 5.0	2.33	2.20	2.09	*	0.82	0.80	0.77	*
T_9- Incubation temperature 55^0C + pH 5.5	2.25	2.19	2.05	*	0.80	0.79	0.77	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	3.46	3.35	3.28	3.13	0.89	0.87	0.87	0.86
Mean	**2.85**	**2.76**	**2.65**	**2.62**	**0.66**	**0.65**	**0.62**	**0.57**
S.Em±	0.05	0.03	0.03	0.02	0.03	0.04	0.03	0.02
C.D. @ 1%	0.20	0.13	0.14	0.11	0.14	0.16	0.13	0.12

*Sample spoiled

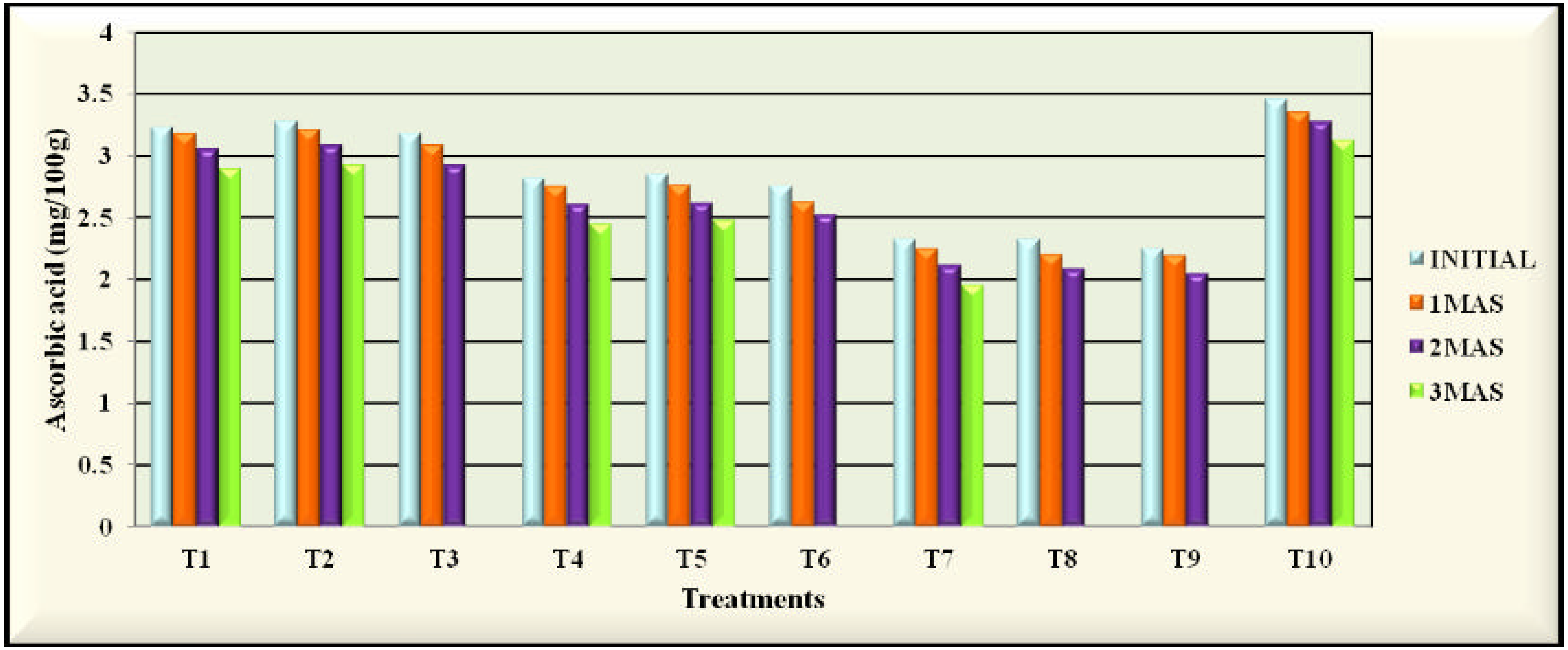

Fig. 2: Changes in ascorbic acid content of wood apple pulp as influenced by treatments and storage period

T_1 - Incubation temperature 45^0C+ pH 4.5

T_2 - Incubation temperature 45^0C+ pH 5.0

T_3 - Incubation temperature 45^0C+ pH 5.5

T_4 - Incubation temperature 50^0C+ pH 4.5

T_5 - Incubation temperature 50^0C+ pH 5.0

T_6 - Incubation temperature 50^0C+ pH 5.5

T_7 - Incubation temperature 55^0C+ pH 4.5

T_8 - Incubation temperature 55^0C+ pH 5.0

T_9 - Incubation temperature 55^0C+ pH 5.5

T_{10} - Control (Incubation at ambient temperature with existing pH

4.1.1.6 Pectin (%)

The pectin content of wood apple pulp as influenced by different treatments and storage period are presented in Table 3 and depicted in Fig. 3. There was a significant variation among the treatments and during the storage period.

Significantly minimum pectin content was recorded in T_2 (0.43, 0.42, 0.40 and 0.39%) which was on par with T_1 (0.45, 0.43, 0.42 and 0.41%) whereas, maximum pectin content was recorded in T_{10} (0.89, 0.87, 0.87 and 0.79%) respectively at initial, 1, 2 and 3 months after storage.

4.1.1.7 Reducing sugars (%)

The data regarding reducing sugars percentage of wood apple pulp as influenced by different treatments showed an increasing trend throughout the storage period irrespective of treatments (Table 4). Significantly, maximum reducing sugars content was recorded in T_2 (3.55, 3.64, 3.83 and 3.95%) whereas, minimum reducing sugars content was recorded in T_{10} (2.73, 2.84, 2.91 and 3.04%) respectively at 0, 1, 2 and 3 months after storage.

4.1.1.8 Non-reducing sugars (%)

The results on non-reducing sugars content of wood apple pulp are presented in Table 4. The mean values of 1.30 per cent, 1.25 per cent, 1.23 per cent and 1.22 per cent indicated a decreasing trend in non-reducing sugars content with the advancement of storage period up to 3 months. Maximum percentage of non-reducing sugars was recorded in T_1 (1.61, 1.58, 1.55 and 1.52%) and T_5 (1.61, 1.57, 1.56 and 1.52%) while, minimum percentage was observed in case of T_{10} (1.11, 1.02. 1.02 and 0.99%) at 0, 1, 2 and 3 months after storage respectively.

4.1.1.9 Total sugars (%)

The observations on percentage of total sugars content as influenced by different treatments are presented in Table 4. The total sugars content of wood apple pulp increased as storage period advances. Significantly highest total sugars was

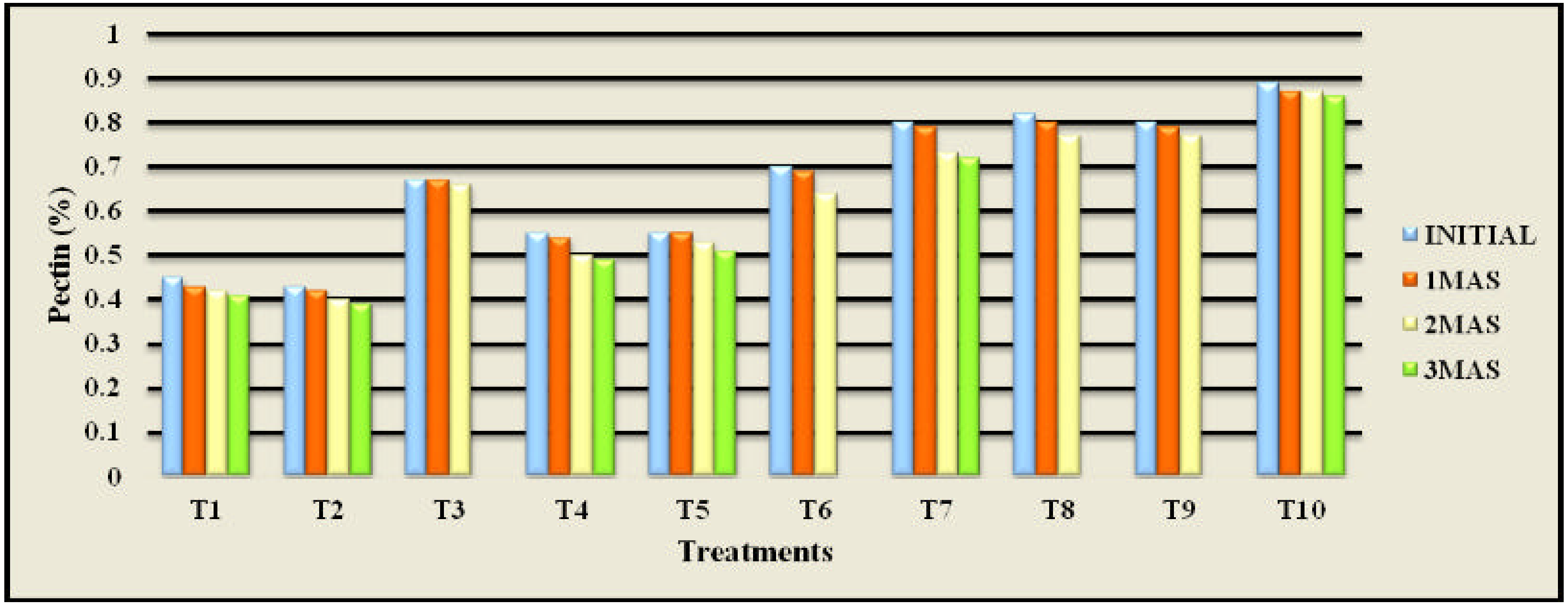

Fig. 3: Changes in pectin content (%) of wood apple pulp as influenced by treatments and storage period

T_1- Incubation temperature 45 ^{0}C+ pH 4.5

T_2- Incubation temperature 45 ^{0}C+ pH 5.0

T_3- Incubation temperature 45 ^{0}C+ pH 5.5

T_4- Incubation temperature 50 ^{0}C+ pH 4.5

T_5- Incubation temperature 50 ^{0}C+ pH 5.0

T_6- Incubation temperature 50 ^{0}C+ pH 5.5

T_7- Incubation temperature 55 ^{0}C+ pH 4.5

T_8- Incubation temperature 55 ^{0}C+ pH 5.0

T_9- Incubation temperature 55 ^{0}C+ pH 5.5

T_{10}- Control (Incubation at ambient temperature with existing pH

Table 4: Changes in reducing sugars, non-reducing sugars and total sugars of wood apple pulp as influenced by treatments and storage period

Treatments	Reducing sugars (%)				Non-reducing sugars (%)				Total sugars (%)			
	Months after storage											
	Initial	1	2	3	Initial	1	2	3	Initial	1	2	3
T_1- Incubation temperature 45^0C + pH 4.5	3.35	3.43	3.59	3.69	1.61	1.58	1.55	1.52	5.05	5.10	5.23	5.29
T_2- Incubation temperature 45^0C + pH 5.0	3.55	3.64	3.83	3.95	1.49	1.46	1.39	1.33	5.12	5.18	5.30	5.36
T_3- Incubation temperature 45^0C + pH 5.5	3.24	3.31	3.39	*	1.23	1.22	1.21	*	4.54	4.60	4.67	*
T_4- Incubation temperature 50^0C + pH 4.5	3.35	3.42	3.61	3.73	1.42	1.43	1.35	1.33	4.85	4.93	5.04	5.13
T_5- Incubation temperature 50^0C + pH 5.0	3.22	3.30	3.36	3.48	1.61	1.57	1.56	1.52	4.92	4.96	5.01	5.09
T_6- Incubation temperature 50^0C + pH 5.5	3.27	3.39	3.51	*	1.14	1.06	1.05	*	4.48	4.51	4.62	*
T_7- Incubation temperature 55^0C + pH 4.5	3.00	3.08	3.25	3.36	1.23	1.20	1.12	1.10	4.30	4.35	4.43	4.52
T_8- Incubation temperature 55^0C + pH 5.0	3.06	3.16	3.21	*	1.03	1.00	1.08	*	4.15	4.22	4.35	*
T_9- Incubation temperature 55^0C + pH 5.5	2.95	3.11	3.26	*	1.14	1.03	1.02	*	4.15	4.20	4.34	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	2.73	2.84	2.91	3.04	1.11	1.02	1.02	0.99	3.90	3.92	3.99	4.09
Mean	3.17	3.26	3.39	3.53	1.30	1.25	1.23	1.22	4.56	4.59	4.69	4.91
S.Em±	0.03	0.03	0.03	0.03	0.05	0.03	0.04	0.02	0.05	0.04	0.03	0.03
C.D. @ 1%	0.16	0.13	0.13	0.14	0.20	0.13	0.16	0.12	0.20	0.15	0.14	0.14

*Sample spoiled

recorded in T_2 (5.12, 5.18, 5.30 and 5.36%) which was on par with T_1 (5.05, 5.10, 5.23 and 5.29%) whereas, minimum total sugar content was recorded in T_{10} (3.90, 3.92, 3.99 and 4.09%) at 0, 1, 2 and 3 months after storage respectively.

4.1.1.10 Organoleptic evaluation

Organoleptic evaluation of wood apple pulp involving various treatments was carried out to assess its consumer acceptability by a panel of semi-trained judges.

The mean value of data indicates decrease in colour and appearance values during the storage period irrespective of the treatments (Table 5). Highest score for colour and appearance was observed in T_1 (8.00, 7.88, 7.67 and 7.50) and T_2 (8.00, 7.88, 7.60 and 7.40) while, lowest score was recorded in T_7 (6.00, 5.88, 5.67 and 5.33) at 0, 1, 2 and 3 months after storage respectively.

The maximum score for flavour (Table 5) was observed in T_4 (8.50, 8.37, 8.00 and 7.50) and T_1 (8.50, 8.33, 7.88 and 7.50) whereas, minimum score was recorded in T_{10} (7.60, 6.80, 6.67 and 6.63) at initial, 1, 2 and 3 months after storage period respectively.

At initial, 1, 2 and 3 months after storage, significantly maximum score for taste (Table 5) was recorded in T_2 (8.50, 8.33, 8.20 and 7.87) followed by T_5 (8.50, 8.30, 8.00 and 7.60) whereas, minimum score was recorded in T_9 (7.00, 6.88 and 6.50) and T_{10} (7.00, 6.88, 6.66 and 6.33) respectively.

Significantly maximum score for mouth feel (Table 6) at initial and at 1, 2 and 3 months after storage was observed for T_1 (8.16, 8.00, 7.87 and 7.50) followed by T_2 (8.16, 7.90, 7.80 and 7.37), T_4 (8.00, 7.87, 7.66 and 7.30) and T_5 (8.00, 7.83, 7.16 and 7.00) while, the minimum scores was recorded in T_{10} (6.50, 6.33, 6.16 and 6.00).

The overall acceptability score (Table 6 and Fig. 4) was found maximum in T_1 (8.50, 8.33, 8.16 and 7.88) followed by T_2 (8.50, 8.27, 8.00 and 7.80) whereas, it was found minimum in case of T_{10} (6.88, 6.66, 6.50 and 6.16) at 0, 1, 2 and 3 months after storage respectively.

Table 5: Changes in colour and appearance, flavour and taste of wood apple pulp as influenced by treatments and storage period (9 point hedonic scale)

Treatments	Colour and appearance				Flavour				Taste			
	Months after storage											
	Initial	1	2	3	Initial	1	2	3	Initial	1	2	3
T_1- Incubation temperature 45^0C + pH 4.5	8.00	7.88	7.67	7.50	8.50	8.33	7.88	7.50	8.00	7.76	7.43	7.00
T_2- Incubation temperature 45^0C + pH 5.0	8.00	7.88	7.60	7.40	8.33	8.20	7.66	7.47	8.50	8.33	8.20	7.87
T_3- Incubation temperature 45^0C + pH 5.5	7.88	7.67	7.50	*	7.50	7.30	7.00	*	7.50	7.33	6.88	*
T_4- Incubation temperature 50^0C + pH 4.5	7.50	7.30	7.00	6.88	8.50	8.37	8.00	7.50	8.00	7.88	7.50	7.30
T_5- Incubation temperature 50^0C + pH 5.0	7.50	7.33	7.16	6.88	8.33	8.16	7.88	7.16	8.50	8.30	8.00	7.60
T_6- Incubation temperature 50^0C + pH 5.5	7.16	7.00	6.80	*	7.16	7.00	6.66	*	7.67	7.50	7.16	*
T_7- Incubation temperature 55^0C + pH 4.5	6.00	5.88	5.67	5.33	7.50	7.33	7.00	6.88	7.50	7.50	7.33	7.00
T_8- Incubation temperature 55^0C + pH 5.0	7.00	6.67	6.50	*	7.00	6.88	6.50	*	7.50	7.33	7.00	*
T_9- Incubation temperature 55^0C + pH 5.5	7.00	6.80	6.60	*	7.00	6.80	6.67	*	7.00	6.88	6.50	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	7.88	7.66	7.50	7.33	7.00	6.80	6.67	6.33	7.00	6.88	6.66	6.33
Mean	**7.45**	**7.23**	**6.85**	**5.61**	**7.83**	**7.62**	**7.28**	**7.14**	**7.85**	**7.62**	**7.37**	**6.29**
S.Em±	0.08	0.07	0.07	0.07	0.07	0.08	0.09	0.07	0.10	0.10	0.08	0.07
C.D. @ 1%	0.34	0.29	0.32	0.30	0.32	0.34	0.36	0.30	0.43	0.41	0.34	0.43

*Sample spoiled

Table 6: Changes in mouth feel and overall acceptability of wood apple pulp as influenced by treatments and storage period (9 point hedonic scale)

Treatments	Mouth feel				Overall acceptability			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1- Incubation temperature 45^{0}C + pH 4.5	8.16	8.00	7.87	7.50	8.50	8.33	8.16	7.88
T_2- Incubation temperature 45^{0}C + pH 5.0	8.16	7.90	7.80	7.37	8.50	8.27	8.00	7.80
T_3- Incubation temperature 45^{0}C + pH 5.5	7.50	7.30	6.88	*	7.33	7.16	6.90	*
T_4- Incubation temperature 50^{0}C + pH 4.5	8.00	7.87	7.66	7.30	8.00	7.70	7.50	7.00
T_5- Incubation temperature 50^{0}C + pH 5.0	8.00	7.83	7.16	7.00	8.00	7.50	7.33	7.00
T_6- Incubation temperature 50^{0}C + pH 5.5	7.60	7.27	7.20	*	7.50	7.30	7.00	*
T_7- Incubation temperature 55^{0}C + pH 4.5	6.88	6.66	6.50	6.33	7.40	7.33	7.16	6.50
T_8- Incubation temperature 55^{0}C + pH 5.0	6.66	6.50	6.33	*	7.33	7.20	6.67	*
T_9- Incubation temperature 55^{0}C + pH 5.5	6.60	6.40	6.27	*	7.00	6.60	6.50	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	6.50	6.33	6.16	6.00	6.88	6.66	6.50	6.16
Mean	**7.40**	**7.20**	**6.98**	**6.91**	**7.61**	**7.34**	**7.16**	**7.09**
S.Em±	0.10	0.07	0.07	0.08	0.07	0.08	0.09	0.07
C.D. @ 1%	0.38	0.31	0.31	0.33	0.32	0.34	0.36	0.30

*Sample spoiled

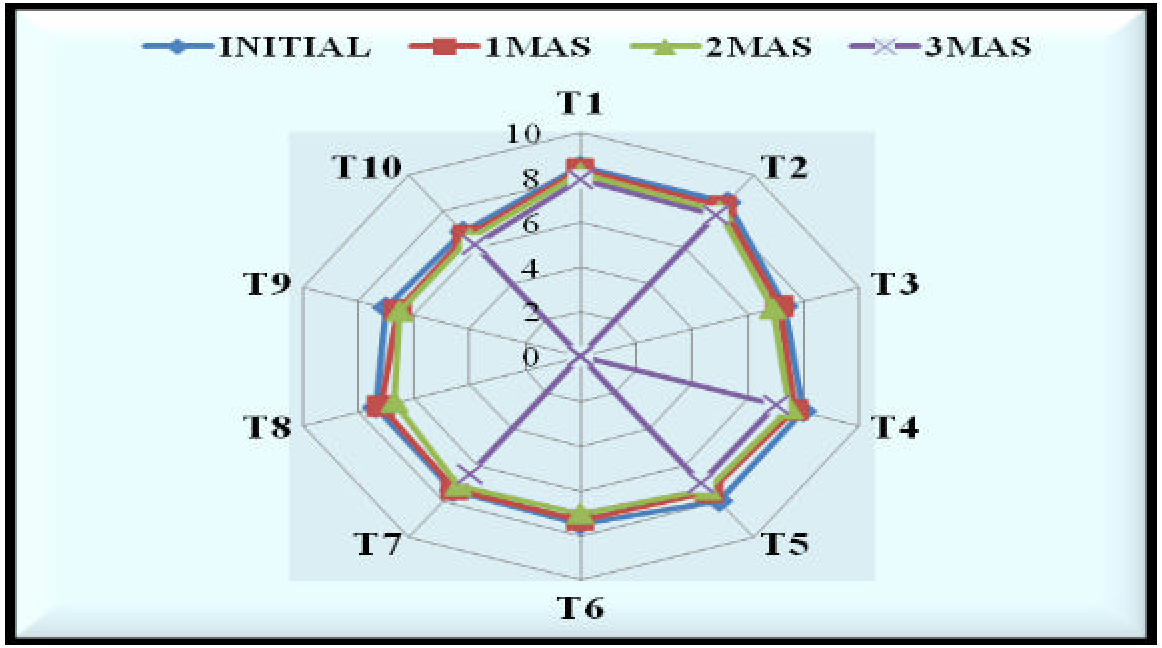

Fig. 4: Changes in overall acceptability of wood apple pulp as influenced by treatments and storage period (9 point hedonic scale)

T_1 - Incubation temperature 45^{0}C+ pH 4.5

T_2 - Incubation temperature 45^{0}C+ pH 5.0

T_3 - Incubation temperature 45^{0}C+ pH 5.5

T_4 - Incubation temperature 50^{0}C+ pH 4.5

T_5 - Incubation temperature 50^{0}C+ pH 5.0

T_6 - Incubation temperature 50^{0}C+ pH 5.5

T_7 - Incubation temperature 55^{0}C+ pH 4.5

T_8 - Incubation temperature 55^{0}C+ pH 5.0

T_9 - Incubation temperature 55^{0}C+ pH 5.5

T_{10} - Control (Incubation at ambient temperature with existing pH

4.1.1.11 Microbial load (CFU/ml)

The perusal of data presented in Table 7, indicates a gradual increase in microbial load of wood apple pulp throughout the storage period. As evident from the mean values, total bacterial count from 1 (2.56 CFU/ml) to 3 months after storage (6.88 CFU/ ml) and total fungal count from 1 (0.85 CFU/ml) to 3 months after storage (3.34 CFU/ml) showed an increasing trend of microbial load in wood apple pulp during storage.

Total bacterial count was found minimum in T_4 (1.66) while, maximum was observed in T_3 and T_{10} (3.33 CFU/ml each) after 1 month of storage. After 2 months of storage minimum was registered in T_2 (3.25 CFU/ml) whereas, maximum was recorded in T_6 (5.00 CFU/ ml each). After 3 months of storage, minimum bacterial count was registered in T_2 (5.00) while, maximum bacterial count was observed in T_5 (7.75 CFU/ml).

Total fungal count was recorded minimum in T_2 and T_7 (0.50 CFU/ml each) while, maximum was observed in T_3 and T_{10} (1.50 CFU/ml each). After 2 months of storage minimum was recorded in T_2 (1.00 CFU/ml) whereas, maximum was observed in T_3 (3.50 CFU/ml). At the end of storage, after 3 months, total fungal count was registered minimum in T_1 (2.75 CFU/ml) while, maximum fungal count was observed in T_5 (4.00 CFU/ml).

4.2 Experiment-II: Standardization of protocol for preparation of wood apple fruit bar

4.2.1 Preparation and preservation of wood apple fruit bar

In the present investigation, different treatments containing wood apple pulp, milk powder and varying levels of sugar, hydrogenated fat and citric acid were used to develop wood apple fruit bar and it was stored under refrigerated conditions for further studies. The results of the study are presented here under.

4.2.1.1 Moisture content (%)

The data on the moisture content of wood apple fruit bar as influenced by different treatments and storage period are presented in Table 8.

Table 7: Changes in total bacterial count and total fungal count of wood apple pulp as influenced by treatments and storage period

Treatments	Total bacterial count (10^{-5}CFU/ml)			Total fungal count (10^{-3}CFU/ml)		
	Months after storage					
	1	2	3	1	2	3
T_1- Incubation temperature 45^0C + pH 4.5	2.00	3.50	7.25	0.67	1.50	2.75
T_2- Incubation temperature 45^0C + pH 5.0	2.47	3.25	5.00	0.50	1.00	3.00
T_3- Incubation temperature 45^0C + pH 5.5	3.33	4.00	*	1.50	3.50	*
T_4- Incubation temperature 50^0C + pH 4.5	1.66	3.50	7.00	0.75	2.00	3.25
T_5- Incubation temperature 50^0C + pH 5.0	2.50	3.75	7.75	0.67	2.33	4.00
T_6- Incubation temperature 50^0C + pH 5.5	3.25	5.00	*	1.00	2.50	*
T_7- Incubation temperature 55^0C + pH 4.5	2.00	3.50	7.00	0.50	1.25	3.75
T_8- Incubation temperature 55^0C + pH 5.0	2.33	3.75	*	0.67	3.00	*
T_9- Incubation temperature 55^0C + pH 5.5	2.75	4.00	*	0.75	2.75	*
T_{10}- Control (Incubation at ambient temperature with existing pH)	3.33	3.75	7.33	1.50	2.50	3.33
Mean	**2.56**	**3.92**	**6.88**	**0.85**	**2.25**	**3.34**

*Sample spoiled

Mean values for moisture content of wood apple bar indicated decreasing trend throughout the storage period.

Significant differences were found between the treatments at 0, 1, 2 and 3 months after storage. T_5 recorded highest moisture content (17.38, 17.17, 16.91 and 16.68%) at 0, 1, 2 and 3 months after storage respectively. The minimum moisture content was recorded in T_4 (15.97, 15.88, 15.70 and 15.59%) which was on par with T_2 (16.03, 15.90, 15.71 and 15.60%) at 0, 1, 2 and 3 months after storage respectively.

4.2.1.2 Total soluble solids (^{0}B)

The data on the total soluble solids (TSS) content of wood apple fruit bar as influenced by different treatments and storage period are presented in Table 8 and Fig. 5. The perusal of the data indicates that, there were significant differences among the treatments and between the storage periods. It is evident from the table that the TSS content exhibited, increasing trend with the advancement of storage period.

Significantly, higher TSS was recorded in T_5 (73.00, 73.08, 73.20 and 73.33^{0}B) whereas, the lowest TSS was observed in T_4 (59.16, 59.28, 59.41 and 59.53^{0}B) at initial, 1, 2 and 3 months after storage respectively.

4.2.1.3 Titratable acidity (%)

The titratable acidity was expressed in terms of citric acid percentage of wood apple fruit bar. The changes in data of titratable acidity as influenced by different recipes are presented in Table 9 and depicted in Fig. 6. Significant difference among the treatments with respect to titratable acidity of wood apple bar was observed during initial and at different storage intervals.

At initial, 1, 2 and 3 months after storage, significantly maximum titratable acidity was recorded in T_4 (2.26, 2.25, 2.23 and 2.21%) followed by T_2 (2.25, 2.24, 2.21 and 2.19%) whereas, minimum was recorded in T_5 (1.86, 1.84, 1.81 and 1.78%) respectively.

4.2.1.4 pH

The pH of the wood apple fruit bar increased as the storage period progressed in all the treatments. The data reveals that there were significant differences among

Table 8: Changes in moisture content and total soluble solids of wood apple fruit bar as influenced by treatments and storage period

Treatments	Moisture content (%)				Total soluble solids (^{0}B)			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1	16.33	16.16	16.01	15.78	64.16	64.23	64.32	64.46
T_2	16.03	15.90	15.71	15.60	61.50	61.58	61.70	61.80
T_3	16.20	16.11	16.00	15.84	63.50	63.55	63.69	63.85
T_4	15.97	15.88	15.70	15.59	59.16	59.28	59.41	59.53
T_5	17.38	17.17	16.91	16.68	73.00	73.08	73.20	73.33
T_6	16.93	16.76	16.53	16.33	67.83	68.00	68.16	68.33
T_7	17.07	16.90	16.66	16.42	72.16	72.28	72.38	72.47
T_8	16.90	16.76	16.70	16.54	67.16	67.25	67.40	67.51
Mean	**16.60**	**16.45**	**16.28**	**16.09**	**66.05**	**66.17**	**66.31**	**66.47**
S.Em±	0.04	0.03	0.03	0.02	0.04	0.04	0.05	0.07
C.D. @ 1%	0.15	0.13	0.13	0.11	0.18	0.18	0.19	0.27

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

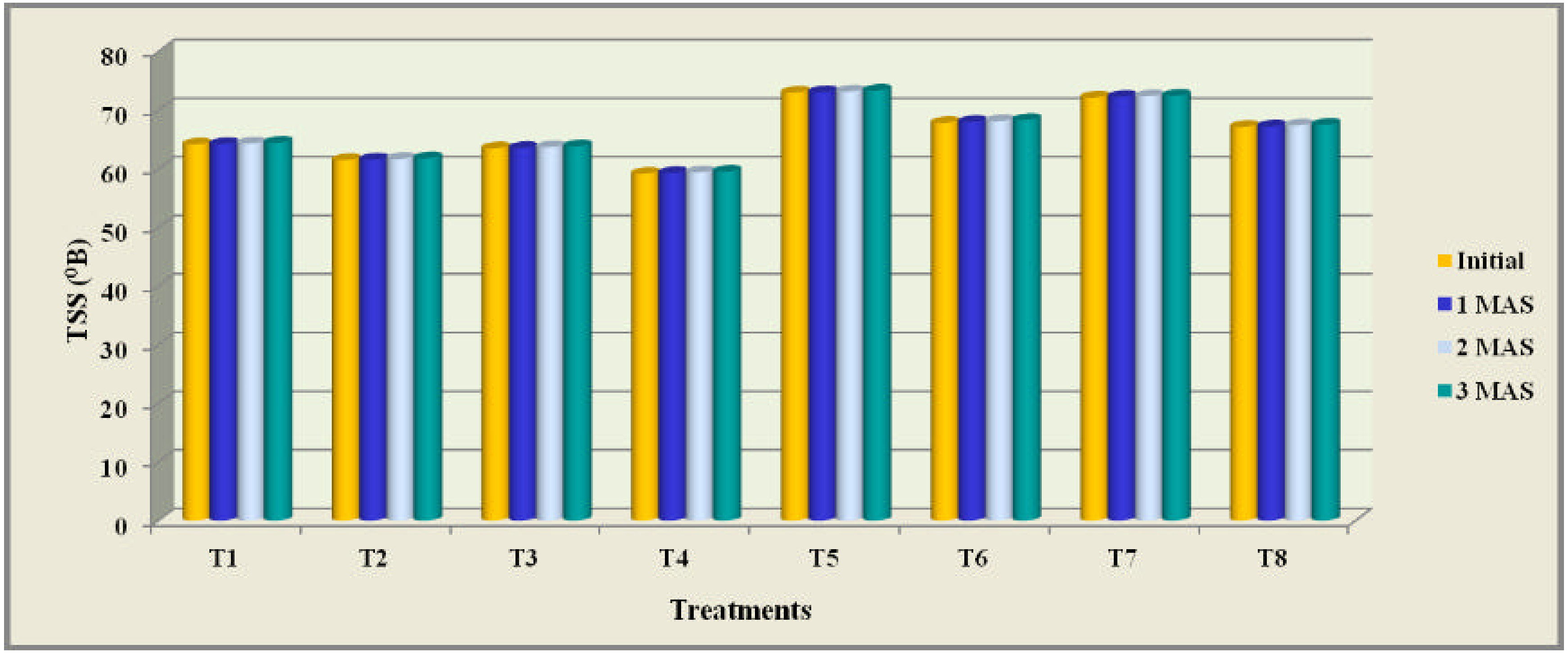

Fig. 5: Changes in total soluble solids (TSS) of wood apple fruit bar as influenced by treatments and storage period

T_1- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_2- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_3- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_4- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)
T_5- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_6- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_7- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_8- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)

Table 9: Changes in titratable acidity and pH of wood apple fruit bar as influenced by treatments and storage period

Treatments	Titratable acidity (%)				pH			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1	1.98	1.97	1.95	1.93	3.78	3.79	3.80	3.81
T_2	2.25	2.24	2.21	2.19	3.61	3.63	3.64	3.66
T_3	2.05	2.05	2.03	2.00	3.75	3.76	3.77	3.78
T_4	2.26	2.25	2.23	2.21	3.61	3.62	3.63	3.65
T_5	1.86	1.84	1.81	1.78	3.90	3.92	3.94	3.96
T_6	2.08	2.07	2.05	2.03	3.74	3.75	3.76	3.78
T_7	1.90	1.90	1.88	1.86	3.89	3.90	3.92	3.94
T_8	2.13	2.11	2.10	2.08	3.72	3.74	3.76	3.77
Mean	**2.06**	**2.05**	**2.03**	**2.01**	**3.75**	**3.76**	**3.77**	**3.79**
S.Em±	0.03	0.03	0.05	0.05	0.02	0.02	0.02	0.03
C.D. @ 1%	0.12	0.12	0.20	0.19	0.11	0.11	0.11	0.13

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

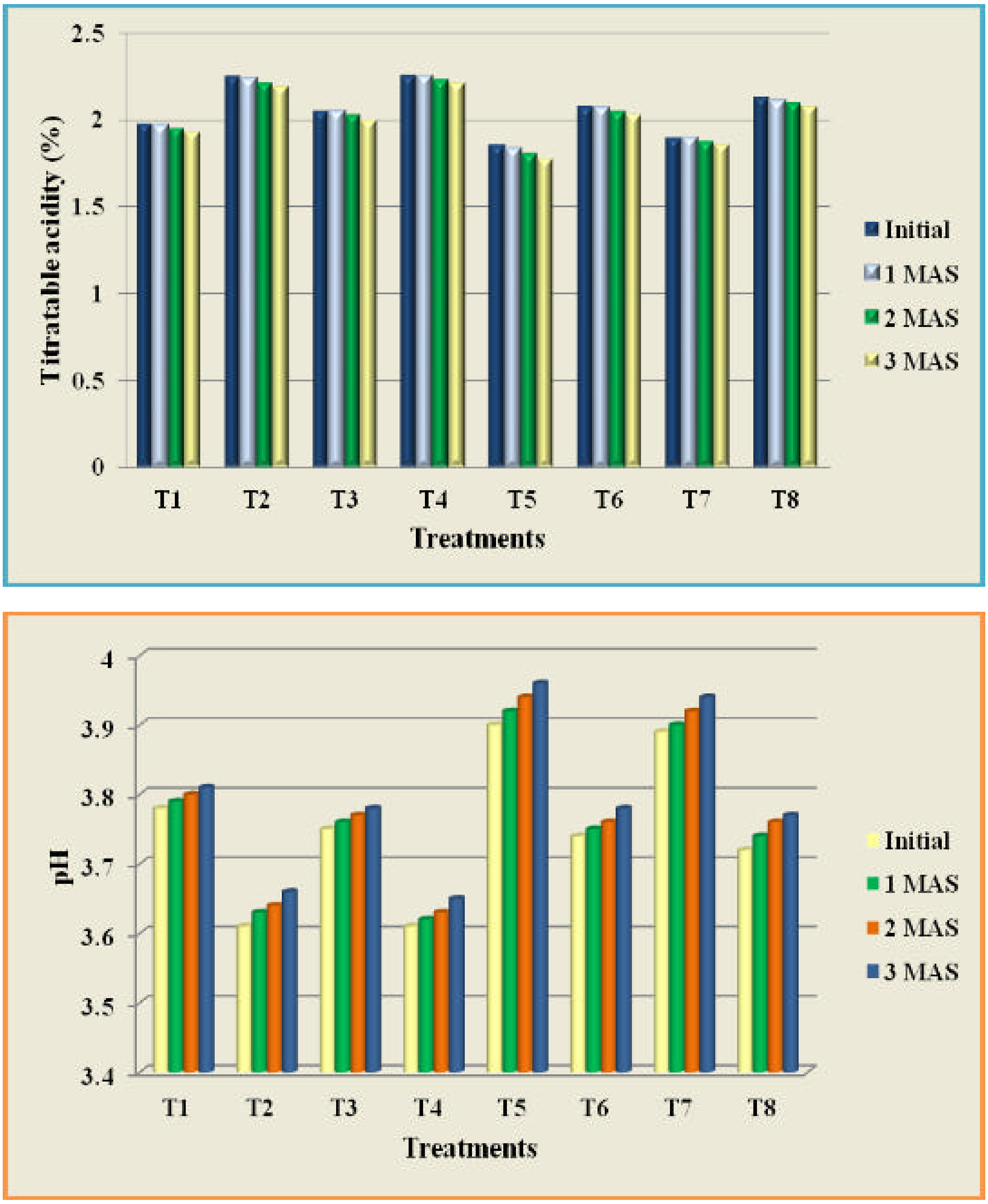

Fig. 6: Changes in titratable acidity and pH of wood apple fruit bar as influenced by treatments and storage period

T_1- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_2- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_3- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_4- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)
T_5- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_6- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_7- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_8- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)

the treatments (Table 9 and Fig. 6). Significantly minimum pH was recorded in T_4 (3.61, 3.62, 3.63 and 3.65) which was on par with T_2 (3.61, 3.63, 3.64 and 3.66) whereas, maximum pH was observed in T_5 (3.90, 3.92, 3.94 and 3.96) which was on par with T_7 (3.89, 3.90, 3.92 and 3.94) respectively, at 0, 1, 2 and 3 months after storage.

4.2.1.5 Ascorbic acid content (mg/100 g)

The retention of ascorbic acid content was found to have significant differences among the treatments initially as well as during the storage period. Ascorbic acid presented decreasing trend with the increase in the storage period up to three months (Table 10).

Initially and 1 month after storage, the maximum ascorbic acid content was noticed in T_2 (1.91 and 1.84 mg/100 g) which was on par with T_1 (1.88 and 1.79 mg/100 g), T_4 (1.88 and 1.75 mg/100 g) and T_3 (1.86 and 1.75 mg/100 g) while, minimum ascorbic acid content was recorded in T_7 (1.62 and 1.54 mg/100 g) respectively.

After 2 months of storage, maximum ascorbic acid content was recorded in T_2 (1.64) which was on par with T_1 (1.62 mg/100 g), T_3 (1.58 mg/100 g) and T_4 (1.56 mg/100 g) whereas, minimum ascorbic acid content was recorded in T_6 (1.36 mg/ 100 g). Similarly, after 3 months of storage significantly maximum ascorbic acid was recorded in T_4 (1.42 mg/100 g) which was on par with T_2 (1.40 mg/100 g), T_1 (1.38 mg/100 g) and T_3 (1.36 mg/100 g) whereas, minimum was noticed in T_6 (1.12 mg/ 100 g).

4.2.1.6 Pectin (%)

The data on pectin content of wood apple bar as influenced by different recipes are presented in Table 10. The results indicated that, there were no significant differences among the treatments at initial and during the storage period.

4.2.1.7 Reducing sugars (%)

Percentage of reducing sugars content of wood apple bar was increased with the advancement of the storage period. The data on reducing sugars content of wood apple bar as influenced by the treatments are presented in Table 11.

Table 10: Changes in ascorbic acid and pectin content of wood apple pulp as influenced by treatments and storage period

Treatments	Ascorbic acid (mg/100 g)				Pectin (%)			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1	1.88	1.79	1.62	1.38	1.34	1.34	1.34	1.34
T_2	1.91	1.84	1.64	1.40	1.32	1.32	1.32	1.30
T_3	1.86	1.75	1.58	1.36	1.33	1.33	1.32	1.32
T_4	1.88	1.75	1.56	1.42	1.33	1.33	1.33	1.32
T_5	1.68	1.60	1.37	1.23	1.32	1.32	1.31	1.31
T_6	1.65	1.58	1.36	1.12	1.35	1.35	1.35	1.33
T_7	1.62	1.54	1.37	1.16	1.32	1.32	1.32	1.31
T_8	1.70	1.64	1.40	1.23	1.34	1.34	1.34	1.34
Mean	**1.77**	**1.68**	**1.48**	**1.29**	**1.33**	**1.33**	**1.33**	**1.32**
S.Em±	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02
C.D. @ 1%	0.11	0.09	0.11	0.14	NS	NS	NS	NS

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

NS- Non Significant

Table 11: Changes in reducing sugars, non-reducing sugars and total sugars of wood apple fruit bar as influenced by treatments and storage period

Treatments	Reducing sugars (%)				Non-reducing sugars (%)				Total sugars (%)			
	Months after storage											
	Initial	1	2	3	Initial	1	2	3	Initial	1	2	3
T_1	12.85	12.89	12.93	13.13	30.21	30.21	30.19	30.09	44.66	44.70	44.73	44.82
T_2	11.33	11.36	11.45	11.65	28.83	28.82	28.73	28.60	41.68	41.70	41.73	41.76
T_3	12.37	12.41	12.48	12.62	29.35	29.34	29.30	29.20	43.27	43.30	43.32	43.36
T_4	10.81	10.85	10.92	11.08	28.27	28.25	28.21	28.12	40.57	40.59	40.62	40.69
T_5	16.78	16.86	16.96	17.18	32.90	32.85	32.77	32.63	51.42	51.44	51.46	51.52
T_6	15.47	15.50	15.54	15.75	31.47	31.44	31.40	31.32	48.60	48.60	48.63	48.70
T_7	16.55	16.60	16.64	16.80	32.81	32.80	32.79	32.69	51.09	51.13	51.16	51.22
T_8	14.93	14.97	15.00	15.18	31.60	31.58	31.57	31.44	48.20	48.22	48.24	48.28
Mean	**13.88**	**13.93**	**13.99**	**14.17**	**30.68**	**30.65**	**30.62**	**30.51**	**46.18**	**46.21**	**46.23**	**46.29**
S.Em±	0.06	0.07	0.08	0.08	0.12	0.12	0.12	0.11	0.09	0.08	0.07	0.06
C.D. @ 1%	0.26	0.30	0.32	0.33	0.50	0.50	0.50	0.47	0.35	0.33	0.31	0.29

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

Significantly maximum per cent of reducing sugars was noticed in T_5 (16.78, 16.86, 16.96 and 17.18%) whereas, minimum per cent of reducing sugars was noticed in T_4 (10.81, 10.85, 10.92 and 11.08%) respectively at initial, 1, 2 and 3 months after storage.

4.2.1.8 Non-reducing sugars (%)

The non-reducing sugars content of wood apple bar as influenced by different treatments are presented in Table 11. Initially and 1 month after storage, significantly maximum non-reducing sugars content was observed in T_5 (32.90 and 32.85%) followed by T_7 (32.81 and 32.80%) whereas, minimum non-reducing sugar content was observed in T_4 (28.27 and 28.25%) respectively.

After 2 and 3 months of storage, significantly highest non-reducing sugar content was noticed in T_7 (32.79 and 32.69%) which was statistically on par with T_5 (32.77 and 32.63%) whereas, minimum non-reducing sugars was noticed in T_4 (28.21 and 28.12%) respectively.

4.2.1.9 Total sugars (%)

The observations on the total sugars content of wood apple bar as influenced by different treatments and storage period are presented in Table 11. The total sugar content of wood apple fruit bar increased as storage period advances.

At 0, 1, 2 and 3 months after storage, significantly maximum total sugar content was recorded in T_5 (51.42, 51.44, 51.46 and 51.52%) whereas, minimum total sugar content was recorded in T_4 (40.57, 40.59, 40.62 and 40.69%) respectively.

4.2.1.10 Calcium (mg/100 g)

The data on calcium content of wood apple fruit bar as influenced by different treatments are presented in Table 12. Decreasing trend in calcium content was observed during storage of wood apple fruit bars for 3 months.

The maximum calcium content was observed for in T_1 (68.67, 68.64, 68.60 and 68.53 mg/100 g) whereas, minimum calcium content was observed in T_8 (64.97, 64.95, 64.90 and 64.87 mg/100 g) at initial stage, 1, 2 and 3 months after storage respectively.

Table 12: Changes in calcium and phosphorous content of wood apple fruit bar as influenced by treatments and storage period

Treatments	Calcium (mg/100 g)				Phosphorous (mg/100 g)			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1	68.67	68.64	68.60	68.53	18.55	18.50	18.49	18.45
T_2	68.42	68.40	68.41	68.38	18.53	18.50	18.46	18.40
T_3	67.86	67.82	67.80	67.75	18.32	18.30	18.30	18.24
T_4	67.53	67.50	67.46	67.43	18.27	18.26	18.21	18.19
T_5	65.31	65.30	65.25	65.23	17.50	17.49	17.48	17.45
T_6	65.27	65.25	65.24	65.16	17.43	17.42	17.39	17.31
T_7	65.13	65.10	65.06	65.01	17.19	17.17	17.13	17.09
T_8	64.97	64.95	64.90	64.87	17.19	17.14	17.10	17.04
Mean	**66.64**	**66.62**	**66.59**	**66.55**	**17.87**	**17.84**	**17.82**	**17.77**
S.Em±	0.03	0.05	0.05	0.05	0.04	0.05	0.03	0.03
C.D. @ 1%	0.13	0.18	0.18	0.17	0.16	0.18	0.14	0.13

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

4.2.1.11 Phosphorous (mg/100 g)

The observations on the phosphorous content of the wood apple fruit bar as influenced by the different treatments are presented in Table 12. The data reveals that there were significant differences among treatments and the phosphorous content decreased as the storage period advances.

Initially, 1, 2 and 3 months after storage, significantly maximum phosphorous content was noticed in T_1 (18.55, 18.50, 18.49 and 18.45 mg/100 g) which was statistically on par with T_2 (18.53, 18.50, 18.46 and 18.40 mg/100 g) while, minimum was recorded in T_8 (17.19, 17.14, 17.10 and 17.04 mg/100 g) respectively.

4.2.1.12 Organoleptic evaluation

The wood apple fruit bar prepared with different recipes were subjected to organoleptic evaluation to assess the quality attributes like colour and appearance, flavor, taste, texture and overall acceptability.

4.2.1.12.1 Colour and appearance

It was evident from the table that the colour and appearance exhibited decreasing trend with the increase in storage period irrespective of the treatments (Table 13). Initially, no significant differences were observed for the colour and appearance of wood apple fruit bar. After 1 month of storage, maximum score was recorded in T_6 and T_7 (8.50 each) which was on par with T_8 (8.33), T_5 and T_4 (8.20 each) while, minimum was score was recorded in T_2 (7.33).

After 2 and 3 months of storage, significantly maximum score for colour was registered in T_7 (8.50 and 8.33) followed by T_6 (8.33 and 8.20) whereas, minimum score was registered in T_2 (7.20 and 7.00) respectively.

4.2.1.12.2 Flavour

Table 13 reveals the data on flavour of wood apple bar as influenced by different recipes during different months of storage. The data reveals that there were significant differences among the treatments and during the storage. It revealed a decreasing trend with the advancement of storage period.

Table 13: Changes in colour and appearance, flavour and taste of wood apple fruit bar as influenced by treatments and storage period (9 point hedonic scale)

Treatments	Colour and appearance				Flavour				Taste			
	Months after storage											
	Initial	**1**	**2**	**3**	**Initial**	**1**	**2**	**3**	**Initial**	**1**	**2**	**3**
T_1	8.16	8.00	7.80	7.50	7.83	7.66	7.50	7.30	7.66	7.50	7.33	7.10
T_2	7.50	7.33	7.20	7.00	7.33	7.16	7.00	6.75	7.50	7.30	7.16	6.90
T_3	8.00	7.83	7.80	7.66	7.83	7.66	7.50	7.30	7.18	7.00	6.80	6.65
T_4	8.33	8.20	8.00	7.70	7.16	7.00	6.80	6.66	7.33	7.13	6.90	6.73
T_5	8.33	8.20	8.00	7.80	8.60	8.50	8.33	8.16	8.83	8.66	8.50	8.30
T_6	8.66	8.50	8.33	8.20	8.00	7.83	7.63	7.50	8.16	8.00	7.66	7.50
T_7	8.66	8.50	8.50	8.33	8.50	8.33	8.20	8.00	8.83	8.60	8.40	8.13
T_8	8.33	8.33	8.00	7.80	8.00	7.83	7.60	7.40	8.00	7.83	7.60	7.33
Mean	**8.24**	**8.12**	**7.90**	**7.65**	**7.90**	**7.74**	**7.57**	**7.38**	**7.93**	**7.75**	**7.54**	**7.33**
S.Em±	0.38	0.13	0.12	0.12	0.07	0.09	0.09	0.07	0.11	0.14	0.14	0.12
C.D. @ 1%	NS	0.56	0.51	0.51	0.27	0.37	0.37	0.27	0.45	0.58	0.58	0.48

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
NS- Non Significant

Significantly highest score for flavour of wood apple bar was observed in T_5 (8.60, 8.50, 8.33 and 8.16) which was on par with T_7 (8.50, 8.33, 8.20 and 8.00) whereas, minimum was observed in T_4 (7.16, 7.00, 6.80 and 6.66) respectively at initial, 1, 2 and 3 months after storage.

4.2.1.12.3 Taste

The data on taste of wood apple bar indicated that there were significant differences among the treatments and values were found to decrease with the progress in storage (Table 13). At initial, 1, 2 and 3 months after storage, maximum score for taste was noticed in T_5 (8.83, 8.66, 8.50 and 8.30) followed by T_7 (8.83, 8.60, 8.40 and 8.13) while, the minimum was in T_3 (7.18, 7.00, 6.80 and 6.65) respectively.

4.2.1.12.4 Texture

The data on texture of wood apple bar reveals that there were significant differences among treatments and mean values (7.16 to 6.61) from initial to 3 months after storage showed a decrease in score with the advancement of storage period (Table 14).

Highest score for texture of wood apple fruit bar was observed in T_2 (7.83, 7.66, 7.50 and 7.30) which was on par with T_3 (7.66, 7.50, 7.30 and 7.16), T_4 (7.50, 7.35, 7.13 and 7.00) and T_1 (7.50, 7.30, 7.10 and 6.90) while, minimum score was in T_8 (6.50, 6.27, 6.15 and 5.93) respectively.

4.2.1.12.5 Overall acceptability

The data on overall acceptability of wood apple bar as influenced by different recipes are presented in Table 14 and depicted in Fig. 7. The score for overall acceptability indicates their decrease linearly from initial stage of 7.74 to 7.16 after 3 months of storage. Maximum scores for overall acceptability was registered in T_5 (8.50, 8.33, 8.20 and 8.00) and T_7 (8.50, 8.33, 8.16 and 8.00) while, minimum scores was recorded in T_1 (7.00, 6.83, 6.66 and 6.50) at initial, 1, 2 and 3 months after storage respectively.

Table 14: Changes in texture and overall acceptability of wood apple fruit bar as influenced by treatments and storage period (9 point hedonic scale)

Treatments	Texture				Overall acceptability			
	Months after storage							
	Initial	1	2	3	Initial	1	2	3
T_1	7.50	7.30	7.10	6.90	7.00	6.83	6.66	6.50
T_2	7.83	7.66	7.50	7.30	7.16	7.00	6.83	6.66
T_3	7.66	7.50	7.30	7.16	7.50	7.30	7.10	6.80
T_4	7.50	7.35	7.13	7.00	7.33	7.16	7.00	6.70
T_5	6.83	6.60	6.43	6.20	8.50	8.33	8.20	8.00
T_6	6.66	6.47	6.27	6.10	8.00	7.83	7.50	7.33
T_7	6.83	6.60	6.50	6.33	8.50	8.33	8.16	8.00
T_8	6.50	6.27	6.15	5.93	8.00	7.80	7.50	7.33
Mean	**7.16**	**6.96**	**6.79**	**6.61**	**7.74**	**7.57**	**7.36**	**7.16**
S.Em±	0.14	0.18	0.14	0.11	0.07	0.06	0.10	0.09
C.D. @ 1%	0.55	0.73	0.55	0.43	0.27	0.23	0.41	0.37

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

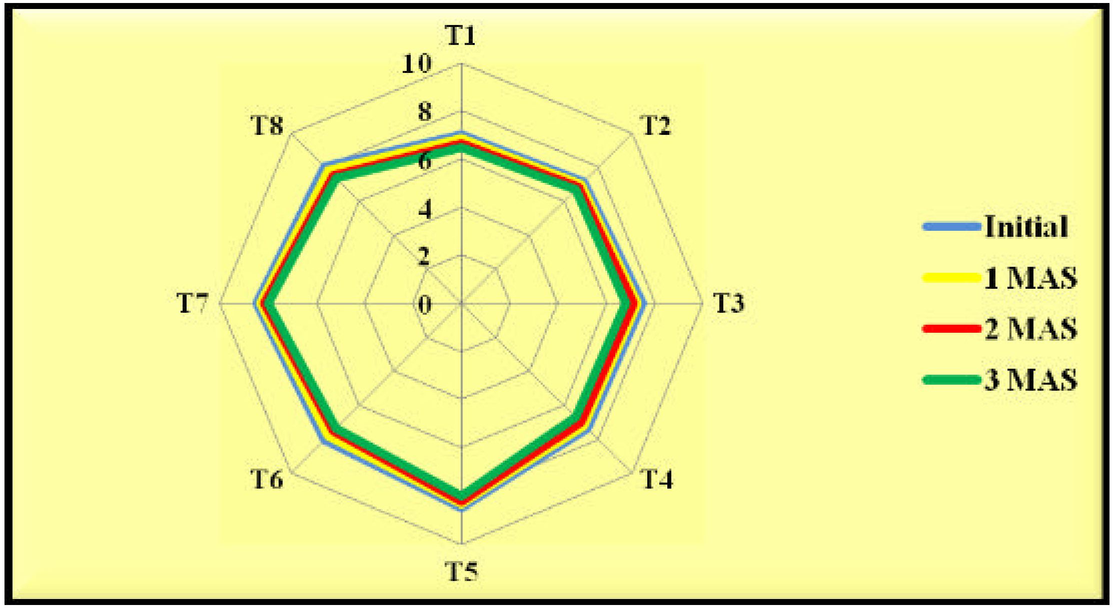

Fig. 7: Changes in overall acceptability of wood apple fruit bar as influenced by treatments and storage period (9 point hedonic scale)

T_1- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_2- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_3- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_4- Pulp (1000g) + Sugar (750g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)
T_5- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.25%)
T_6- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (100g) + Citric acid (0.50%)
T_7- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.25%)
T_8- Pulp (1000g) + Sugar (1000g) + Milk powder (200g) + Hydrogenated fat (200g) + Citric acid (0.50%)

4.2.1.13 Total microbial load (CFU/ g)

The data on the microbial (Bacterial and Fungal) load of wood apple fruit bar indicated that the microbial population showed an increasing trend in their number during the storage period of 3 months (Table 15).

At 1 month after storage, bacterial count was recorded minimum in T_5 and T_2 (0.16 CFU/ ml) whereas, maximum was observed in T_1, T_3 and T_6 (0.50 CFU/ ml each). After 2 months of storage bacterial count was observed minimum in T_2 (0.33 CFU/ ml) whereas, maximum was registered in T_1 and T_6 (0.75 CFU/ ml each). Total bacterial count was noticed minimum in T_4 and T_7 (0.66 CFU/ ml each) while, maximum in T_1, T_3 and T_6 (1.00 CFU/ ml each) after 3 months of storage.

Total fungal count was observed minimum in T_2, T_4, T_6 and T_7 (0.16 CFU/ ml each) while, maximum was registered in T_8 (0.50 CFU/ ml) after 1 month of storage. After 2 months of storage, it was recorded minimum in T_6 and T_7 (0.33 CFU/ ml) whereas, maximum, was observed in T_8 (0.75 CFU/ ml). At the end of storage period, fungal count was recorded minimum in T_7 (0.50 CFU/ ml) and maximum fungal count was registered in T_8 (0.87 CFU/ ml).

Table 15: Changes in total bacterial count and total fungal count of wood apple fruit bar as influenced by treatments and storage period

Treatments	Total bacterial count (10^{-5}CFU/ml)			Total fungal count (10^{-3}CFU/ml)		
	Months after storage					
	1	2	3	1	2	3
T_1	0.50	0.75	1.00	0.33	0.66	0.66
T_2	0.16	0.33	0.75	0.16	0.50	0.66
T_3	0.50	0.66	1.00	0.33	0.66	0.75
T_4	0.33	0.50	0.66	0.16	0.50	0.66
T_5	0.16	0.50	0.75	0.33	0.50	0.75
T_6	0.50	0.75	1.00	0.16	0.33	0.66
T_7	0.33	0.50	0.66	0.16	0.33	0.50
T_8	0.33	0.50	0.75	0.50	0.75	0.87
Mean	**0.35**	**0.56**	**0.82**	**0.26**	**0.52**	**0.68**

T_1- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_2- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_3- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_4- Pulp (1000 g) + Sugar (750 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)
T_5- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.25%)
T_6- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (100 g) + Citric acid (0.50%)
T_7- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.25%)
T_8- Pulp (1000 g) + Sugar (1000 g) + Milk powder (200 g) + Hydrogenated fat (200 g) + Citric acid (0.50%)

5. DISCUSSION

Wood apple is a highly nutritious and seasonally available fruit having rich source of protein, iron, calcium and phosphorous and is easily perishable. The flesh is pleasant having refreshing, aromatic and sour-sweet taste. Excellent flavour, nutritional value and medicinal characteristics of fruit indicate its potentiality for processing into valuable products. But difficulty in extraction of pulp has become a major bottle neck in converting of these fruits into valuable products, mainly due to its compact fibrous and mucilaginous flesh which also contains numerous seeds. Hence it is difficult to consume the pulp directly and is not popular as a desert fruit.

By reviewing the literature, it has become evident that very little attention has been given to develop the processing technologies for wood apple. Based on the available technologies for other fruits processed products such as jam, jelly, chutney, juices, RTS, nectar, blended juice and dehydrated products can be tried for the domestic as well as for international markets. Further, sincere efforts are needed to standardize the processing techniques and evaluate the consumer acceptance and economic viability of commercialization of these products. Out of several products dehydrated products such as fruit bars are manufactured as an important fruit by product in industries based upon the high solid- high acid principle. Not only such fruit concentrates an important method of preserving fruits, but it is an important utilization of fruits (Vidhya and Narain, 2011).

Therefore, in order to explore the possibilities of utilizing the wood apple fruits for processing, an attempt has been made to find out the effective methods for extraction of wood apple pulp, to standardize the protocol for preparation of wood apple fruit bar and to study their storage stability under ambient and refrigerated conditions respectively for 3 months.

5.1 Standardization of wood apple pulp extraction method using pectinase enzyme

Extraction of pulp from wood apple fruits is not easy process as compared to juicy fruits such as citrus, grapes *etc.*, due to its compact fibrous and mucilaginous pulp with numerous seeds. Generally, three methods of juice extraction are employed *viz.*, cold, hot and enzymatic methods. Mechanical crushing of pectin rich fruits yields a fruit juice with high viscosity, which remains bound to the pulp in the form of jellified mass. It is difficult to extract this juice by pressing or using other mechanical methods. Enzymatic treatment prior to mechanical extraction has shown significant increase in juice recovery as compared to cold and hot extraction methods (Joshi *et al.*, 1991). Enzymatic treatment of fruits results in collapsing of cell wall and release of nutritional components from the interior of the cells (Qin *et al.*, 2005).

Enzymatic degradation of the biomaterial depends upon the type of enzyme, incubation time, incubation temperature, enzyme concentration, agitation, pH and use of different enzyme combinations (Sharma *et al.*, 2014). These parameters need to be optimized for obtaining maximum recovery of juice. Therefore, the present study was taken to optimize hydrolysis pretreatment parameters like incubation temperature and pH for the maximal juice yield from the wood apple pulp and to study its storage stability by studying its biochemical, organoleptical and microbial changes during storage.

5.1.1 Extraction and preservation of wood apple pulp

5.1.1.1 Pulp recovery (%)

The recovery of pulp is most important from the point of cost effectiveness of a product. In the present investigation, highest recovery of pulp was obtained by treating the pulp with an incubation temperature of 45^0C + pH 5.0 followed by 50^0C + pH 4.5. The highest recovery at 45^0C incubation temperature may be attributed to maximum activity of pectinase enzyme at this temperature. This is in contrast with Devi *et al.* (2008) who had reported an optimum temperature of 45^0C for *Aspergillus sp*. for pectinase production. Beyond 50^0C a drastic decrease in pectinase activity was observed by Tapre and Jain (2014). The decrease in juice yield of enzymatically treated pulp at higher temperature is due to denaturation of proteins which leads to decrease in enzyme activity (Singh *et al.*, 2012). The results were in agreement with the findings of Sharma and Joshi (2016) in wood apple at 40^0C, Singh *et al.* (2012) in bael at 47^0C, Kaur *et al.* (2011) in guava at 43.3^0C and Ghosh *et al.* (2017) in jamun at 45^0C.

The maximum activity of pectinase enzyme was found to be at pH 5 followed by pH 4.5. Suresh and Viruthagiri (2010) reported an increase in pectinase activity with an increase in pH from 4 to 5. However, further increase in pH beyond 5 reduced its activity. It reflects the preference of fungi *Aspergillus niger* to lower pH for its growth and metabolism. The optimum pH for maximum activity of food grade pectinase enzyme was observed to be at 4.5 (Kumar and Muzaffar, 2015). Similar findings have also been reported by Srivatsava and Tyagi (2013) in apple at pH 5, Suresh and Viruthagiri (2010) at pH 5 and Meena *et al.* (2015) at pH 4.5.

In case of processed products, yield is not a soul criterion for evaluating the efficiency of a treatment. Quality of the product is of prime importance as it is directly related to consumer acceptability in the commerce. The physico-chemical characteristics of fruit plays an important role in the development of processing technology and quality of final product [Chopra and Singh (2001) in wood apple, Kotecha and Kadam (2002) in tamarind; Manikanta (2005) in guava].

5.1.1.2 Total soluble solids and sugars

Different methods of extraction had a pronounced effect on total soluble solids of extracted wood apple pulp. Maximum TSS was observed in T_2 (6.23^0B) followed by T_1 (6.15^0B). Higher degree of brix level in these treatments may be attributed to the greater degree of tissue breakdown so it releases more components that contribute to soluble solids [Pilnik and Varagan (1993) and Lellan *et al.* (1985)]. The trend in slight increase in TSS and total sugars due to enzymatic treatments are also been reported by Ahmed *et al.* (2014) in guava, jackfruit and pineapple juice.

Irrespective of the treatments, the stored wood apple pulp recorded a slight increase in total sugars with the advancement in storage period. The variations in the rate of breakdown of polysaccharides like starch, pectin, cellulose into simple soluble molecules in the presence of organic acid might be responsible for the changes observed in wood apple pulp (Chandana, 2016). After 3 months of storage period, maximum TSS was recorded in T_2 (6.88^0B). Similar observations were made by Chandana (2016) in wood apple squash and nectar, Chowdhury *et al.* (2008) in wood apple juice, Jana and Singh (2015) in bael pulp, Kundu *et al.* (2015) in plum pulp and Muhammad *et al.* (2011) in apple pulp.

The results of total sugars of the pulp indicated significant differences among treatments and during the storage period. The increase in reducing sugars (3.17. 3.26, 3.39 and 3.53%) was correlated with the decrease in non-reducing sugars (1.31, 1.25, 1.23 and 1.22%) at 0, 1, 2 and 3 months after storage. The mean values (4.56, 4.59, 4.69 and 4.91%) of total sugars shows an increasing trend with the advancement of storage period which might be due to the fast hydrolysis of polysaccharides like pectin, cellulose, starch, *etc.* and its conversion into simple sugars at room temperature. Increase in reducing sugars content in the pulp during storage might be due to conversion of non-reducing to reducing sugars. These results are in conformity with the results of Kumhar *et al.* (2014) who observed increase in total sugar content of custard apple pulp during storage at ambient temperature. Gothwal *et al.* (1998) observed an increase in reducing sugars in chemically preserved and heat processed plum pulp during nine months of storage. Hussain *et al.* (2003) also observed an increasing trend in content of reducing sugars during storage of mango pulp for 270 days. Increase in reducing and total sugars and decrease in non-reducing sugars is a general phenomena as witnessed by many workers Chandana (2016) in wood apple squash and nectar, Jana and Singh (2015) in bael pulp, Hussain *et al.* (2003) in mango pulp, Muhammad *et al.* (2011) in apple pulp and Kavya (2014) in custard apple pulp.

5.1.1.3 Titratable acidity and pH

In the present investigation, acidity was found to decrease with the increase in the storage period. Variation observed in titratable acidity and pH within the treatments may be related to the initially adjusted pH at the time of treatment. It is well-established fact that acidity and pH are inversely proportional. Increase in the values of pH of wood apple pulp with advancement in the storage time reflected the decrease in the titratable acidity. Reduction in acidity level in pulp and increase in pH during storage owes to chemical interaction between the organic constituents of the pulp induced by temperature and actions of the enzymes as reported by Palaniswamy and Muthukrishna (1974) and Nath *et al.* (2005). The decrease in acidity might also be due to hydrolysis of polysaccharides into simple sugars and non-reducing sugars into reducing sugars where acid is utilized for converting them into reducing sugars and influenced further by temperature.

Similar findings were also reported by Chowdhury *et al.* (2008) in wood apple juice, Chandana (2016) in wood apple squash and nectar, Tiwari and Deen (2015) in bael RTS, Bons and Dhawan (2013) in guava pulp, Ahmad *et al.* (2000) in guava pulp and Muhammad *et al.* (2011) in apple pulp,.

5.1.1.4 Ascorbic acid and Pectin content

Ascorbic acid is one of the major nutritional components of wood apple pulp. With respect to ascorbic acid content of fresh wood apple pulp maximum retention was observed in T_{10} (3.46 mg/100 g) which was incubated at ambient temperature and existing pH whereas, it was found lowest in T_9 (2.25 mg/100 g) incubated at 55^0C with 5.5 pH. This might be due to the thermal degradation of ascorbic acid during processing at higher temperature which results in its loss at maximum level.

Irrespective of the treatment ascorbic acid content of wood apple pulp reduced considerably during storage as the time moved on. This fact is evident from the mean ascorbic acid level 2.85, 2.77, 2.65 and 2.63 mg/100 g observed at 0, 1, 2 and 3 months respectively after storage. The decline in ascorbic acid content could be due the oxidation during storage as it is very sensitive to heat and light [Pandey and Singh (1998); Adsule and Roy (1975); Yeom *et al.* (2000)]. Declining trend in ascorbic acid content of stored products was noticed by Chandana (2016) in wood apple squash and nectar; Patil (1991) in wood apple; Kumhar *et al.* (2014) in custard apple pulp; Durrani *et al.* (2010) and Muhammad *et al.* (2011) in apple pulp.

Purpose of pectinolytic enzymes addition is degradation of protopectin and partly pectins from primary cell wall and middle lamella which is responsible for higher juice yield (Kashyap *et al.*, 2001; Will and Dietrich, 2006). In the present investigation, pectin content was found lower in T_2 (0.43). This is due to the higher degree of breakdown of pectin by pectinase enzyme (Torres *et al.*, 2006) whose activity was found maximum in this treatment. Lower amount of pectin content signifies maximum breakdown of pectic substances which is advantageous. Tapre and Jain (2014) also reported that enzymatic treatment of fruit pulp results in breakdown of pectin. Irrespective of treatments a gradual decrease in pectin content was observed with the advancement of storage. Similar results were also reported by Wang *et al.* (1995).

5.1.1.5 Organoleptic evaluation

Evaluation of sensory qualities of the product is an important tool for deciding the consumer acceptability. Quality aspects of the food such as colour, flavour and nutritional value generally reduces with the increase in storage period. Human plays an important role in the evaluation of organoleptic characters of a product. Hence, in the present investigation, semi- trained panelists comprising teachers and post graduate students of Kittur Rani Channamma College of Horticulture, Arabhavi were involved in the evaluation process.

The mean score for overall acceptability of wood apple pulp varied from 7.61 in fresh to 7.09 at the end of 3 month of storage period indicating decrease in performance over time. The maximum score was recorded in T_1 (8.50-7.88) and T_2 (8.20 to 7.80) incubated at 45^0C throughout the storage period and minimum score was recorded in T_{10} (6.16). The juice obtained through T_1 and T_2 were more clearer compared to other treatments due to maximum solubilization of pectic components and also had more total soluble solids and total sugar content. It was also reported that at higher temperature there will be loss of colour, flavour and taste due to heating which was also reported by Dengale *et al.* (1998) in sapota pulp and Swetha (2016) in custard apple pulp. The gradual decrease in organoleptic scores was also reported by Chandana (2016) in wood apple squash and nectar stored for 3 months under ambient conditions.

5.1.1.6 Microbial population

The microbial population showed an increase in their number during storage. However such a marginal increase did not affect the wholesomeness of product up to 2 months. Pasteurization of wood apple pulp might have helped in controlling and limiting the microbial load to a safer level up to 2 months whereas, after 2 months, spoilage of T_3, T_6, T_8 and T_9 was observed. This might be due to higher pH level of these treatments which might have favored the growth of micro organisms and resulted in there spoilage compared to other treatments. Similar increase in microbial load was observed in wood apple squash (2.42 to 6.63 CFU/ ml) and nectar (2.42 to 5.08 CFU/ml) stored for 3 months under ambient conditions by Chandana (2016), Hussain *et al.* 2003 in pasteurized mango pulp ($2x10^5$ to $4.6x10^9$ CFU/ml) and Swetha (2016) in custard apple pulp.

5.2 Standardization of protocol for the preparation of wood apple fruit bar

Direct consumption of wood apple pulp in its purest form is not relished because of sour and astringent taste. Hence, it is necessary to convert the wood apple pulp into diversified processed products such as fruit leather or bar. These fruit bars are concentrated form of dehydrated fruit products with high nutritious value and easy to handle. However, very little work has been done on working out the protocol for the preparation of wood apple fruit bar. Therefore, in the present investigation an attempt was made to standardize the protocol for the preparation wood apple fruit bar.

Basically for the preparation of fruit bar, the pulp is mixed with appropriate quantities of ingredients such as sugar, pectin, acid, soy protein, corn syrup, starch, hydrogenated fat, milk powder and colour which would enhance its nutritional and organoleptic acceptability by consumers (Diamante *et al.*, 2014). In the present investigation, wood apple fruit bars were prepared by blending wood apple pulp and milk powder with different proportions of sugar, hydrogenated fat and citric acid. Quality of these fruit bars were evaluated at initial and for three months during storage based on their acceptability through organoleptic evaluation, biochemical/ nutritional constitution and microbial changes.

5.2.1 Preparation and preservation of wood apple fruit bar

5.2.1.1 Moisture content

The preservation of fruit bar depends on moisture content *i.e.*, 15-25 per cent (Perera, 2005). The moisture content of the freshly prepared wood apple fruit bar increased with the increase in sugar content which ranged from 15.97 to 17.38 per cent. Similar observations were made by Jain and Nema (2007) in guava leather where increase in moisture content was observed with increased sugar content. Bhatt and Jha (2015) found that 17.40 per cent moisture level in wood apple bar had extended shelf life and retained the sensory and physical quality up to six months.

In the present investigation, irrespective of treatments a gradual decrease in moisture content of wood apple fruit bar was observed with the advancement of storage period. This fact is evident from the mean moisture content of 16.79, 16.57, 16.31 and 16.11 per cent observed at 0, 1, 2 and 3 months after storage respectively. The decrease in moisture content seemed to be due to natural dehydration of product during storage (Aggarwal and Kaur 2014). Similar findings were observed by Safdar *et al.* 2014 in guava leather and Aggarwal and Kaur (2014) in carrot bar stored under refrigerated conditions; Bhatt and Jha (2015) in wood apple bar and wood apple mango bar; Shakoor *et al.* (2015) in guava bar and Kumar *et al.* (2015) in papaya leather.

5.2.1.2 Total soluble solids and sugars

The TSS is an important criterion for dessert quality of a product. The TSS content of fresh fruit bar increased with increased concentration of sugar (Jain and Nema. 2007). The TSS (73^0B) of wood apple fruit bar was significantly maximum in T_5 (Pulp 1000 g + Milk powder 200 g + Sugar 1000 g + citric acid 0.25% + hydrogenated fat 100 g) whereas, minimum value (59.16^0B) was recorded in T_4 (Pulp 1000 g+ Milk powder 200 g + Sugar 750 g + citric acid 0.5% + hydrogenated fat 200 g). The maximum TSS of T_5 could be attributed to higher amount of sugar added to it. The TSS content of fruit bars also decreases with the increase in citric acid level but TSS of fruit bars prepared with different levels of citric acid increases with the increase in storage period (Singh *et al.* 2015).

The TSS of wood apple bar recorded a slight increase in total soluble solids irrespective of the treatments with the advancement in storage period. This fact is evident from the mean TSS of 66.05, 66.17, 66.31 and 66.47^0B observed at 0, 1, 2 and 3 months after storage respectively. This might be due to the conversion of polysaccharides like starch, gums and pectin into soluble sugars (Singh *et al.*, 2004). At the end of 3 months of storage period, maximum TSS was observed in T_5 (73.33^0B) whereas, minimum value was recorded in T_4 (59.53^0B). Similar findings were observed by Kuchi *et al.* (2014) in guava jelly bar stored under refrigerated conditions; Safdar *et al.* (2014) in guava leather and Anju *et al.* (2014) in peach soya fruit bar. However the rate of increase in TSS content was relatively slower than the earlier reported studies due to refrigerated storage of wood apple fruit bar samples since at low temperature storage, the rate of reactions are significantly slower as compared to high temperature storage.

The total sugars, reducing sugars and non- reducing sugars of wood apple fruit bar was found maximum in T_5 (Sugar 1000 g+ citric acid 0.25%+ hydrogenated fat 100 g) whereas, minimum value was exhibited by T_4 (Sugar 750 g + citric acid 0.5% + hydrogenated fat 200 g) for all these parameters at initial and during storage period.

A slight increase in total sugar content was observed in all the fruit bars during the entire storage period. This could be due to conversion of insoluble polysaccharides and other carbohydrate polymers to soluble sugars and inversion of non-reducing sugars. Roy and Singh (1979) observed increase in total sugar content of bael fruit products during storage. Similar increasing trend were reported by Vidhya and Narain (2011) in wood apple fruit bar; Bafna and Marimahalai (2014) in kokum fruit bar; Kuchi *et al.* (2014) and Safdar *et al.* (2014 in guava jelly bar and guava leather respectively under refrigerated condition.

Reducing sugar content of all wood apple fruit bars increased during storage period irrespective of the treatments. This could be due to the inversion of non-reducing sugars that are being converted to reducing sugars by hydrolysis (Roy and Singh 1979). Bhatt and Jha (2015) observed similar increase in reducing sugar content in wood apple bar and wood apple mango bar during storage for 6 months. Similar increasing trend was observed by Aruna *et al.* (1999) in papaya bars; Hemakar *et al.* (2000) in mango guava sheet; Manimegalai *et al.* (2001) in jack fruit leather; Kumar and Manimegalai (2002) in sapota fruit bar and Sandhu *et al.* (2001) in fruit bar from guava and sapota.

Non-reducing sugar content of all fruit bars decreased during storage. The reduction may be due to increase in reducing sugars by acid hydrolysis and subsequent inversion of non reducing sugars. Aruna *et al.* (1999) reported that non-reducing sugar of papaya fruit bar decreased significantly during storage. Similar reduction in non-reducing sugars was reported by Bhatt and Jha (2015) in wood apple fruit bar and wood apple mango bar, Rao and Roy (1980) in mango bar and Manimegalai *et al.* (2001) in jackfruit leather.

5.2.1.3 Titratable acidity and pH

The significantly highest titratable acidity in the fresh wood apple fruit bar was recorded in T_4 (2.26%) containing sugar of 750 g + hydrogenated fat of 200 g + citric acid of 0.50 per cent followed by T_2 (2.25%) containing sugar of 750 g + hydrogenated fat of 100 g + citric acid of 0.50 per cent whereas the lowest titratable acidity was recorded in T_5 (1.86%) containing sugar of 1000 g + hydrogenated fat of 100 g + citric acid of 0.25 per cent. Further, it was observed that acidity of the leather also decreased significantly with increase in sugar content. Similar results were also reported by Jain and Nema (2007) in guava leather.

In the present investigation, storage for 3 months under refrigerated conditions had a minimum decrease in the acidity of wood apple fruit bar. The continuous decrease in acidity values were apparently due to the reaction of acids with basic minerals in the products or due to the loss of ascorbic acid. Aggarwal and Kaur (2014) in carrot bar and Kuchi *et al.* (2014) in guava leather (0.752 to 0.600 %) stored under refrigerated conditions for two months observed similar decrease in acidity. Similar results were also obtained by Hemakar *et al.* (2000) in mango guava sheet; Sharma *et al.* (2013) in apricot fruit bar and Kumar *et al.* (2012) in papaya leather.

The pH of all the treatments increased with increase in the storage period. The increase in the pH of the wood apple bar varied from fresh (3.75) to 3 months after storage (3.79). It was observed that, titratable acidity decreased with the increase in storage period. The decrease in titratable acidity mirrored the increase in pH. The rise in pH and decrease in titratable acidity indicates that the acid concentrations in the fruit bar declined with the increase in storage period. However this increase in pH was found to be minimum as it was stored under refrigerated conditions. Similar findings were reported by Kuchi *et al.* (2014); Sharma *et al.* (2013) and Kumar *et al.* (2012).

5.2.1.4 Ascorbic acid and Pectin content

Ascorbic acid is one of the major nutritional components of wood apple bar. In the present investigation, significant decrease in ascorbic content was observed with the increase in sugar content in the recipes. Similar results were found by Jain and Nema (2007) in guava leather.

In the present investigation, ascorbic acid content of wood apple bar was found to decrease from an initial mean value of 1.77 to 1.29 mg/100 g after 3 months of storage. The loss in ascorbic acid content is propably attributed to oxidation of ascorbic acid to dehyro ascorbic acid followed by hydrolysis of the later to 2, 3- diketogluconic acid, which then undergoes polymerization to other nutritionally in active products. Safdar *et al.* (2014) noticed loss of ascorbic acid in guava leather (78.46- 55.51 mg/100 g) stored for 3 months under refrigerated conditions. Similar decrease in ascorbic acid content during storage has also been reported by Jain and Nema (2007) in guava leather (176.27- 104.87 mg/100 g) and Ashaye *et al.* (2005) in pawpaw leather (83.33- 74.70 mg/100 g) and guava leather (260.0- 237.0 mg/100 g) respectively; Sreemathi *et al.* (2008) in sapota -papaya bar during 3 months of storage; Krishnaveni *et al.* (1999) in jackfruit bar and Kotlawar (2008) in fig leather.

5.2.1.5 Calcium and Phosphorous

In the present investigation, significantly maximum calcium (68.67 mg/100 g) and phosphorous (18.55 mg/100 g) content in wood apple fruit bar was observed in T_1 (1000 g pulp + 750 g sugar + 200 g milk powder +100 g hydrogenated fat + 0.25% citric acid) and minimum was observed in T_8 (1000 g pulp +750 g sugar + 200 g milk powder +100 g hydrogenated fat + 0.50% citric acid). This might be because, as the calcium and phosphorous content are present only in the pulp and milk powder, the higher values of these were found in the treatments containing lesser total ingredients. Calcium content of 207 mg per 100 g and phosphorous content of 85 mg per 100 g has been reported by Anitha *et al.*, 2016 in wood apple leather.

The mean values of calcium (66.64, 66.62, 66.59 and 68.55 mg/100 g) and phosphorous (17.87, 17.84, 17.82 and 17.77 mg/100 g) respectively at 0, 1, 2 and 3 months after storage showed a decreasing trend with the advancement of storage period. Light, oxygen and water content will affect the mineral content during storage which will result in oxidation and reduction of these minerals. Vidhya and Narain (2011) observed similar decrease in calcium (18.1-16.80 mg/100 g) and phosphorous (31.60 to 29.90 mg/100 g) content in wood apple bar stored for 3 months under ambient conditions. Similar findings were also reported by Attri *et al.* (1998) in papaya leather and toffee; Bafna and Manimehalai (2014) observed a loss of 6 per cent calcium content in kokum bar during storage for 75 days; Sharma (2014) in

Jamun-mango blended jam and Sindhumathi and Amrutha (2014) in coconut based jam stored under refrigerated conditions.

5.2.1.6 Organoleptic evaluation

Quality is the ultimate criteria of the desirability of any food product to the consumer, whereas sensory quality is a combination of different senses of perception coming in to play in choosing a product. Evaluation of sensory quality of a product is an important tool for deciding the consumer acceptability. Human plays an important role in the evaluation of organoleptic characters of a product. This evaluation serves as a guide to consumer acceptability. Hence, in the present investigation, semi-trained panelists comprising teachers and post graduate students of Kittur Rani Channamma College of Horticulture, Arabhavi were involved in the evaluation process.

However, considering the performance of wood apple fruit bar with respect to colour, taste and flavour T_5 (1000 g pulp +1000 g sugar +200 g milk powder +100 g hydrogenated fat + 0.25 per cent citric acid) stands superior followed by T_7 (1000 g pulp +1000 g sugar +200 g milk powder +200 g hydrogenated fat + 0.25 per cent citric acid). This may be due to the presence of higher amount of sugar content with lower amount of acidity which results in greater flavor, taste and overall acceptability compared to other treatments.

The minimum score for overall acceptability throughout the storage period was recorded by T_4 followed by T_3, T_2 and T_1 which might be due to presence of lower amount of sugar and higher level of acidity which has resulted in decrease in taste in these treatments. The texture was found superior in wood apple fruit bar containing lesser amount of sugar, because with the increase in the sugar content the texture became soft and chewiness of fruit bar was reduced.

As increase in storage period, there was a gradual decrease in sensory values. The mean score for overall acceptability of wood apple fruit bar decreased from an initial value of 7.74 to 7.16 at the end of 3 months of storage. A decline in score for texture might be attributed to decrease in the moisture content throughout the storage period. The overall decline in sensory score for wood apple bar during storage is due the decline in score for color, flavour, taste, texture and overall acceptability. Similar decrease in sensory scores were also reported by Anitha *et al.* (2016) in wood apple leather (8.65-6.95) stored under refrigerated conditions and in wood apple bar stored under ambient conditions for 3 months (Vidhya and Narain, 2011).

5.2.1.7 Changes in microbial population

The quality of the product may deteriorate during storage due to the effect of various treatments employed in the preparation of the product. The microbial population showed a slight increase in their number during the storage period of three months (Table 15). However, such a marginal increase did not affect the wholesomeness of the product as it was stored under refrigerated conditions. Increase in microbial load in wood apple fruit bar during storage may be attributed to the slow rate of chemical and enzymatic reactions. Similar results are reported by Anitha *et al.* (2016) in wood apple leather and Vidhya and Narain (2011) in wood apple bar, Safdar *et al.* (2014) in guava leather and Bafna and Manimehalai (2014) in kokum fruit bar.

6. SUMMARY AND CONCLUSIONS

An investigation on the "Studies on processing of wood apple pulp for value addition" was conducted at the Department of Post Harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka during 2016-17. Two experiments were conducted to standardize the wood apple pulp extraction method using pectinase enzymes and standardization of protocol for the preparation of wood apple fruit bar and storage stability of these products. The salient features of the present investigation are presented here under.

6.1 Standardization of wood apple pulp extraction method using pectinase enzyme

Among different extraction methods using pectinase enzyme, maximum recovery of pulp (81.60 and 80.85%), TSS (6.23 and 6.15^{0}B), reducing sugars (3.55 and 3.35 %) and total sugars (5.12 and 5.05%) with lower pectin content (0.43 and 0.45%) was obtained by incubating the wood apple pulp at the temperature of 45^{0}C +5 pH and at 45^{0}C + 4.5 pH respectively at 0.2 per cent pectinase enzyme concentration for 2 hrs.

The results of storage stability of wood apple pulp for 3 months under ambient conditions (25-28^{0}C temperature and 33-35% RH) revealed that the chemical constituents *viz.*, total soluble solids, reducing sugars, total sugars and pH were found to increase marginally from 5.90 to 6.39^{0}B, 3.17 to 3.53 per cent, 4.56 to 4.91 per cent and 4.89 to 4.99 respectively, whereas decrease in titratable acidity, pectin content, non-reducing sugars and ascorbic acid values from 1.63 to 1.50 per cent, 0.66 to 0.57 per cent, 1.31 to 1.22 per cent and 2.85 to 2.62 mg/100 g respectively was observed for 3 months.

During storage period of 90 days the mean organoleptic score decreased from an initial value of 7.45 to 5.61 for colour, 7.83 to 7.14 for flavour, 7.85 to 6.29 for taste, 7.40 to 6.91 for mouth feel and 7.61 to 7.09 for overall acceptability. The results of organoleptic evaluation indicated that overall acceptability wise T_1 (Temperature of 45^{0}C + 5 pH) and T_2 (Temperature of 45^{0}C +5 pH) were found superior in their acceptability than other treatments throughout the course of investigation. There was marginal increase in microbial load, but it did not affect the wholesomeness of the product up to 2 months. However, spoilage of T_3, T_6, T_8 and T_9 was observed after 2 months of storage whereas, T_1, T_2, T_4, T_5, T_6 and T_{10} were still found to be acceptable at the end of storage period.

6.2 Standardization of protocol for preparation of wood apple fruit bar

The wood fruit bar was prepared using 8 recipes which consists of 2 levels of sugars (750 and 1000 g), hydrogenated fat (100 and 200 g) and citric acid (0.25 and 0.5 per cent) and constant amount of wood apple pulp (1000 g) and milk powder (200 g). Significant differences were observed with respect to phyisco-chemical parameters between the treatments. The chemical constituents *viz.*, TSS, reducing sugars, total sugars and pH were found to increase marginally from 66.05 to 66.47^{0}B, 13.88 to 14.17 per cent, 46.18 to 46.29 per cent and 3.75 to 3.79 respectively, whereas titratable acidity (2.06 to 2.01%), ascorbic acid (1.77 to 1.28 mg/100 g), non-reducing sugars (30.68 to 30.51%), calcium (66.64 to 66.55 mg/100 g) and phosphorous (17.87 to 17.77 mg/100 g) decreased after 3 months of storage.

The mean organoleptic score decreased significantly from an initial value of 8.24 to 7.90 for colour and appearance, 7.90 to 7.38 for flavour, 7.93 to 7.33 for taste, 7.16 to 6.61 for texture and 7.74 to 7.16 for overall acceptability with the advancement of storage period. The results of the organoleptic evaluation particularly indicated that T_5 (wood apple pulp 1000 g + sugar 1000 g + milk powder 200 g + hydrogenated fat 100 g + citric acid 0.25%) and T_7 (wood apple pulp 1000 g + milk powder 200 g + sugar 1000 g + hydrogenated fat 200 g + citric acid 0.50%) found superiority in their acceptability compared to other treatments throughout the organoleptic study. It appears that highly acceptable with respect to flavour and taste in the treatments (T_5 and T_7) have been achieved through the combination of higher quantity of sugars with lesser per cent of acidity. There was a marginal increase in microbial load (total bacterial count and fungal count) of wood apple bar during storage. However, it did not cause any spoilage even up to three months of storage.

Conclusion

- Among the different treatments imposed on wood apple pulp, T_1 (Incubation temperature 45^0C + pH 4.5) and T_2 ((Incubation temperature 45^0C + pH 5.0) was found to be good with better pulp recovery, phyisco-chemical and organoleptic characters.
- Wood apple bar prepared from T_5 (wood apple pulp of 1000 g + sugar of 1000 g + milk powder of 200 g + hydrogenated fat of 100 g + citric acid of 0.25%) and T_7 (wood apple pulp of 1000 g+ sugar of 1000 g + milk powder of 200 g + hydrogenated fat of 200 g + citric acid 0.50%) resulted in superior quality fruit bar with respect to phyisco-chemical characters and organoleptic traits.

Future line of work

- Protocols for long term storage of wood apple pulp in combination with chemical preservatives + pasteurization.
- Mixed fruit leather of wood apple with other fruits such as guava and mango may be tried.
- Studies can be done on the effect of different packaging material on storage stability of wood apple fruit bar.
- The large scale preparation of wood apple fruit bars (T_5 and T_7) may be tried.

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STUDIES ON PROCESSING OF WOOD APPLE (*Feronia limonia* L. Swingle) PULP FOR VALUE ADDITION

KOUSTUBHA M GOWDA **2017** **Dr. LAXMAN KUKANOOR**
Major Advisor

ABSTRACT

A research investigation entitled "Studies on processing of wood apple (*Feronia limonia* L. Swingle) pulp for value addition" was carried out in the Department of Post Harvest Technology, Kittur Rani Channamma College of Horticulture, Arabhavi during the academic year 2016-17. The experiments were conducted to standardize the wood apple pulp extraction method using pectinase enzyme and to standardize the protocol for the preparation of wood apple fruit bar and to study the storage stability of the products.

Among different extraction methods using pectinase enzyme, incubation of wood apple pulp at 45°C + 5 pH and 45°C + 4.5 pH at 0.2 per cent pectinase enzyme concentration for 2 hrs gave maximum recovery of pulp (81.60 and 80.85%), TSS (6.23 and 6.15°B), reducing sugars (3.55 and 3.35%), total sugars (5.12 and 5.05%) with lower pectin content (0.43 and 0.45%) respectively. The results of storage for 3 months under ambient conditions revealed that the chemical constituent's *viz.*, total soluble solids, reducing sugars, total sugars and pH were found to increase whereas titratable acidity, pectin content, non-reducing sugars, ascorbic acid and organoleptic scores decreased. The wood apple pulp was found to be microbiologically safe upto 3 months of storage.

Wood apple fruit bar prepared from T_5 (wood apple pulp of 1000 g + sugar of 1000 g + milk powder of 200 g + hydrogenated fat of 100 g + citric acid of 0.25%) and T_7 (wood apple pulp of 1000 g + sugar of 1000 g + milk powder of 200 g + hydrogenated fat of 200 g + citric acid 0.50%) resulted in superior quality fruit bar with respect to phyisco-chemical characters and organoleptic traits. During 3 months of storage under refrigerated conditions the TSS, reducing sugars, total sugars and pH were found to increase whereas titratable acidity, ascorbic acid, non-reducing sugars, calcium, phosphorous and organoleptic scores decreased. The wood apple fruit bar was found to be microbiologically safe upto 3 months of storage under refrigerated conditions.

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