DEVELOPMENT OF OSMODEHYDRATED BILIMBI (*Averrhoa bilimbi* L.) AND ASSESSMENT OF BIOACTIVE COMPOUNDS

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"DEVELOPMENT OF OSMODEHYDRATED BILIMBI (*Averroha bilimbi* L.) AND ASSESSMENT OF BIOACTIVE COMPOUNDS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"DEVELOPMENT OF OSMODEHYDRATED BILIMBI (*Averroha bilimbi* L.) AND ASSESSMENT OF BIOACTIVE COMPOUNDS"** is a record of research work done independently by Ms. Aparna G. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of Ms. Aparna G. S. a candidate for the degree of **Master of Science in Horticulture** with major in Post Harvest Technology agree that the thesis entitled **"DEVELOPMENT OF OSMODEHYDRATED BILIMBI (*Averroha bilimbi* L.) AND ASSESSMENT OF BIOACTIVE COMPOUNDS"** may be submitted by Ms. Aparna G. S., in partial fulfilment of the requirement for the degree.

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LIST OF ABBREVATIONS

^0C	Degree Celsius
%	Per cent
min	Minutes
mL	Milli litre
CD	Critical difference
CfFU	Colony forming unit
CRD	Completely Randomised Design
CV	Critical Value
et al.	And co-workers
g	Gram
Mm	Milli molar
H	Hour
$\mu g\ g^{-1}$	Micro gram per gram
Mg	Milligram
mL^{-1}	Per millilitre
NS	Non significant
viz.,	Namely
TSS	Total Soluble Solids
OD	Osmotic Dehydration
SG	Solid gain
WL	Weight loss
WR	Weight reduction

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Introduction

1. INTRODUCTION

Fruits and vegetables have the status of 'functional foods', capable of promoting good health and preventing or alleviating diseases. Fruit consumption choices are no longer based purely on taste and personal preference but also based on a desire for better health. Diverse agro climatic conditions of the country favour the cultivation of wide range of fruit crops. Kerala is blessed with an array of minor fruits grown in the homesteads and remain underexploited. Bilimbi is such an underexploited fruit, which is commonly seen in the homesteads of Kerala and major part of production is wasted even though they have medicinal properties for the effective management of several human ailments.

Averrhoa bilimbi L. commonly known as 'bilimbi' belongs Oxalidaceae family and native of Malaysia and Indonesia. Bilimbi fruits are widely cultivated in Southern India as a backyard fruit crop. It has been widely used in traditional medicine to treat cough, cold, itches, boils, rheumatism, syphilis, diabetes and whooping cough. Pharmacological studies have shown that the fruit alleviates hypertension (Goh, *et al.*, 1995). Bilimbi fruits can also be used as a dietary ingredient to prevent as well as treat hyperlipidemia (Ambili *et al.*, 2009). Bilimbi fruits after primary processing can be used for the development of various secondary products *viz.,* squash, pickle, jam etc. Realizing the importance of this under exploited fruit and its high perishability, bilimbi can be preserved through processing methods without the loss of bioactive compounds.

Osmotic dehydration is the phenomenon of removal of water from lower solute concentration to higher concentration through a semi permeable membrane results in the equilibrium condition in both sides of membrane (Tiwari, 2005). This has wide application in the preservation of food-materials since it lowers the water activity of fruits and vegetables. Osmotic dehydration is preferred to other methods due to their color, aroma, nutritional constituents and flavor compound retention value.

Partially dehydrated fruits through osmodehydration can be added to foods such as desserts, yogurt, ice-cream, confectionery and bakery products and after additional drying, this can also be used as components of cereals or snacks for direct consumption (Lenart, 1996; Torreggiani and Bertolo, 2001). The concentration of osmotic solution was an important tool to reduce the water content with little damage on the quality of fresh products (Lazarides, 2001).

The phytochemical screening of bilimbi investigated by Hasanuzzaman *et al.* (2013) revealed this fruit as the potent source of different phytochemical constituents on different extractives including, phenol, flavonoid, tannin which are responsible for antioxidant action. Muhamed (2013) studied extraction of bioactive compounds of bilimbi which could be used for functional food product development. Bakul *et al.* (2013) reported that freshly made concentrated bilimbi juice has very high oxalic acid content and consumption carries a high risk of developing acute renal failure by deposition of calcium oxalate crystals in renal tubules. Soumya and Nair (2014) studied biochemical profile of bilimbi and concluded that fruits are safe for consumption and could benefit as a supplementary food source.

The chemical characterization and quantification of their bioactive components in processed products are important for assessing their nutritional value and final quality of the product. Hence the present study is proposed to standardize the process variables for developing osmodehydrated bilimbi fruits and also to analyse the effect of primary processing methods in retention of bioactive compounds.

Review of Literature

2. REVIEW OF LITERATURE

Fruits and derived products have a beneficial effect on the human health. In recent years, the development of intermediate moisture food by osmotic dehydration has received much importance among consumers. Even though, air drying is the most widely used technique for dehydrated fruit and vegetable production, this may be detrimental, affecting both nutritional and sensory quality of heat-sensitive products (Ruiz-Lopez *et al.*, 2010). Osmodehydration allow development of new product and make them storable for long time without refrigeration with minimum energy (Wang and Xi, 2005; Pisalker *et al.,* 2014).

Averrhoa bilimbi, an underutilized fruit crop which has not received much attention as antioxidant sources as compared to commercial fruits which might be due to its less popularity with measure promotional campaigns and lack of information on nutritional compositions and physical qualities of bilimbi product (Ikram *et al.*, 2009).

The present study is focused on standardization of osmodehydration techniques for bilimbi fruit and assessment of bioactive compound in primary processed fruits. This chapter describes the review of related research findings done in past years.

2.1 DEVOLOPMENT OF OSMODEHYDRATED BILIMBI

Dehydration is considered as one of the oldest form of preservation known to man which results in production of food with long durability (Nastaj and Witkiewicz, 2004). Osmodehydration is considered as an effective method for preservation of fruits and vegetables. According to Sapata *et al.* (2009) osmotic dehydration (OD) can be named as dewatering and impregnation by immersion in concentrates or by immersion of fruits and vegetable in concentrated solutions or syrups of soluble solids, without phase change. Osmodehydration is a simple process, which facilitates processing of fruits and vegetables such as banana, sapota, fig, guava, pineapple, apple mango, grapes, carrots, pumpkins, etc. with retention of initial fruit characteristics like colour, aroma, texture and nutritional composition (Chavan, 2012).

By removing 50% of the water through osmosis from fresh ripe fruits like banana, mango, apple, sapota, papaya, strawberries and other tropical fruits, followed by vacuum drying provides products which could be used as ready to eat snacks or making confectionary items and ice creams (Bongirwar,1997). This technique can be used for producing high quality products, which provides minimum thermal degradation of nutrients due to low temperature water removal process (Kar and Gupta, 2001; Rastogi *et al.,* 2002; Sodhi *et al*., 2006).

Lerici *et al.* (1985), Rastogi and Raghavarao (1997), Erle and Schubert (2001) and Rastogi *et al.* (2004) stated that the process variables of osmotic dehydration *viz.,* pre-treatment, temperature, concentration of the solution, agitation, additives and immersion time had influenced mass transfer and product quality. Pisalkar *et al.* (2014) observed that osmotic dehydration provides high retention of colour, aroma, nutritional constituents, and flavour compounds.

2.1.1 Mass Transfer Characters

In osmotic dehydration the rate of water loss depends on several factors such as solution concentration, its temperature, contact time, level of agitation, sample size and geometry, solution to solid volume ratio and operating pressure etc (Rastogi *et al*., 1997). Water loss during osmotic dehydration increases with increase in temperature and sucrose concentration (Torreggiani, 1993; Fito and Chiralt, 1997; Tortoe, 2004; Garcia-Segovia *et al*., 2010; Pisalkar *et al*., 2011). The effect of solution concentration on mass transfer rates (water loss, solids gain and weight reduction) during osmodehydration, using sucrose as dehydrating agent, has been studied for a numbers of fruits such as pear (Park *et al*., 2002), carrot (Rastogi *et al*., 2002), pineapple (Rastogi and Raghavarao, 2002). Water loss and solid gain linearly increases during osmosis with increase in temperature and concentration of osmotic solution (Kumar and Devi, 2011; Sasikumar *et al*., 2013). Osmotic dehydration removes 30 to 70 per cent of water from fruits (Akbarian *et al.*, 2014).

Varany-Anond *et al.* (2000) conducted an osmotic experiment and studied the effect of temperature, concentration of sucrose solution (50-70^{o}B) and processing time (2-4 h) on water loss and solid gain in mango and the highest water loss to solid gain ratio was observed with 60°Brix sucrose syrup under 55°C for 6 h of immersion time. Low solid gain resulted in high WL/SG ratio was reported in apple immersed in salt solution (Sereno, 2001). Mauro *et al.* (2004) reported that when banana and apple slices dipped in 70^{0} and 50^{0}B respectively at an osmotic solution temperature of 50^{0}C for 3 h immersion time recorded optimum water loss and sugar gain. The reduction of weight (WR), loss of water (WL %) and Solute (sugar) Gain (SG %) were observed during osmotic dehydration of mango slices. The phenomena of mass transfer were affected by temperature and process time. Temperature and process time were different from the range of 40 to 120 minutes and 30 to 50^{0}C respectively (Gabriela *et al.*, 2004).

Pedapathi and Tiwari (2007) observed the effect of osmotic concentration (50, 60, 70 ^{0}B) and duration (4, 18, 24 hours) of osmosis on weight loss, solid gain and yield of osmodehydrated guava slices of two varieties. A range of values for weight loss (22.73-34.55%), moisture loss (36.16-53.24%), yield (32.37-39.67%), total sugars (39.02-63.32%) in guava slices were recorded for osmotic pretreatment in 70^{0}B syrup for 24 hours. Jain *et al.* (2011) observed the maximum water loss of 28% with optimum sugar gain of 4% for the 60^{o} B syrup concentration at 37°C for syrup to fruit ratio as 4:1 in 4.25 h of osmotic dehydration of papaya fruit slices. Chavan (2012) stated osmodehydration as a dynamic process where water removes at a faster rate during initial hours and then slows down, while sugar penetration is very slow at first but increases with the time. According to Khanom (2014) water loss, solid gain, weight reduction and TSS during osmotic dehydration of pineapple slices increased with increase in concentration. Pedapati and Tiwari (2014) observed an increase in duration of osmosis and syrup concentration resulted in increased weight loss in guava fruit.

Osmotic treatment of guava fruit slices at 60 ^{0}B at 50 °C followed by drying at 60^{o}B yielded a good quality product (Castro *et al.*, 2016).

Osmotic dehydration studies was done in bilimbi by Rittirut and Siripatana (2009) and observed that half ripe, mature bilimbi fruits were suitable for osmodehydration and blanching before dehydration process helped in better mass transfer at 30^{0}B sugar concentration for an immersion time of 3000 minutes. They also reported that the effect of operating temperature and concentration of osmotic solution on mass transfer characteristics of bilimbi fruit during process. The investigation revealed that 40 ^{0}C yielded lowest mass transfer and for 50 and 60 ^{0}C there were no significant difference. Increased solution concentration led to increase in WL, Acid loss up on the time but decreased soluble solid gain. They also studied the effect of blanching in hot water for one minute as a pre-processing method prior to osmodehydration in bilimbi fruit and found that blanching not only led to higher water loss, solid gain and acid loss but also higher shrinkage compared to non blanched bilimbi. In order to reduce acidity of bilimbi fruits, fruits were soaked in sugar solutions of 30, 50, 65 ^{0}B for 24 hours prior to fermentation (Berkley, 2010). Ruiz- Lopez *et al.* (2011) conducted a study on carambola fruits and found sucrose as better osmotic agent than fructose and glucose for osmodehydration by favoring greater water loss-to-solute gain ratios at comparable mass transfer rates. A study conducted by Campos *et al.* (2012) in star fruit samples observed that an increased osmotic solution concentration elevated the mass transfer characters like solid gain and water loss. They also observed that osmodehydration of carambola fruits were more effective in first two hours and then started to show small mass transfer.

Lakkond (2002) revealed that sapota slices steeped in 50 ^{0}B sugar syrup containing 0.1% KMS and 0.05 % citric acid for 12 hours gave maximum recovery of dehydrated slices. Rashmi *et al.* (2005) reported that during osmosis of pineapple slices for 24 h in 50^0, 60^0 and 70^{0}B sugar syrup concentration, maximum dry fruit yield was obtained at 60^{0}B syrup concentration.

2.1.2 Biochemical Parameters

Osmodehydrated aonla fruits showed better retention of ascorbic acid and sugars and with reduced acidity (Pragathi *et al.*, 2003). Geetha *et al.* (2006) conducted a study on osmotic concentration kinetics on aonla preserve and reported that total sugar and TSS increased with the increase in sugar syrup concentration and temperature, while the content of moisture and ascorbic acid decreased.

Surabhi *et al.* (2007) observed that there was increase in total soluble solids of osmodehydrated pineapple slices when treated with 70^0B sugar solution having final TSS of 79^0B at 50^0 C. Bernardi *et al.* (2009) reported that there was an increase in TSS of osmodehydrated ripe mango slices up to 35^0B when treated with 60^0B sugar syrup and dried at 45^0 C. Osmotic dehydration process increased TSS of pineapple slices by three times (Dionello *et al.* 2009)

Kumar *et al.* (2008) reported that the total sugar content of osmotic dehydrated guava slices varied from 33 to 60 per cent and reducing sugar content of osmotic dehydrated guava slices varied from 22 to 28 per cent. Sagar and Suresh (2009) reported that osmotic drying substantially increased the sugar content and reduced the acidity without changing colour, texture, and original flavor of mango fruit slices. A study conducted by Ram *et al.* (2010) on the effect of various pre-treatments on the quality of dehydrated papaya revealed that papaya slices prepared using glucose syrup 60^0B for 12 h immersion as the best treatment in terms of moisture percentage, TSS, reducing sugar, total sugar, titratable acidity, dehydration ratio, colour, flavour, texture and overall acceptability.

According to Sapata *et al.* (2009) osmotic dehydration did not influence the pH. With increase in pre treatment time in sucrose total titratable acidity was decreased in apricot cubes (Riva *et al.*, 2005). Fasogbon *et al.* (2013) reported that osmodehydration decreases pH of pineapple slices. Osmodehydrated cantaloupes showed slightly increased pH when compared with fresh sample and total acidity decreased (Phisut *et al.*, 2013a and Phisut *et al.*, 2013b).

Lohachoompol *et al.* (2004) studied the effects of osmotic treatment with sugar on the anthocyanin content and antioxidant activity of subsequent dried blueberries. Sanjinez-Argandoña (2005) investigated the degradation of ascorbic acid and carotenoid present in osmotic pretreated and convective dried guava fruit slices. According to Peiró-Mena *et al.* (2007); Warczok *et al.* (2007); Falade and Igbeka, (2007) during osmotic dehydration loss of acids, vitamins, polysaccharides and minerals occurs which flow from the fruit to the osmotic solution.

A study conducted Giovanelli *et al.* (2012) reported that the blanching step prior to osmodehydration increased the mass transfer phenomena and reduced the loss of phenolic compounds, improved the retention of antioxidant capacity in the final product blue berry. Antioxidant activity and total phenolic compounds of osmodehydrated blue berries were lost significantly during process (Giovanelli *et al.*, 2013). Osmotic dehydration caused significant loss in antioxidant activity and phenolic content of cantaloupes when compared with fresh sample (Phisut *et al.*, 2013a and Phisut *et al.*, 2013b).

2.1.3 Sensory Analysis of Osmodehydrated Fruits

Osmotic dehydration of fruits reduces heat damages to colour, flavour and prevents browning of the fruit (Jackson and Mohamed, 1971). Osmodehydration process also brings some undesirable changes like loss in nutritional quality and change in colour and flavour (Jain and Verma 2003). Water removal leads to a serious loss of the nutritive and sensory properties of the food (Stojanovic and Silva, 2007).

Banana slices dehydrated after treating with 0.25% KMS + 1.0 per cent $CaCl_2$ or 60°Brix syrup + 0.5 % $CaCl_2$ yielded acceptable products (Unde *et al.*, 2001). Lakkond (2002) reported that sapota slices steeped in 50°Brix sugar syrup containing 0.1% KMS and 0.5% citric acid for 12 hrs received higher organoleptic scores for colour and appearance (4.03), taste (3.64), texture (4.00), flavour (3.39) and overall acceptability (3.80) as compared to other treatments. The sensory evaluation of osmodehydrated jackfruit revealed that the highest overall acceptability (91%) was observed in the fruit osmosed in 70% sugar with 2% salt solution and oven dried at 50°C. Based on the quality analyses, osmotic solution of 70% sugar with 2% salt and drying temperature of 50°C were selected as the best combination for osmo-air drying of jackfruit (Prasannath and Mahendran, 2009).

Osmotic dehydration process of cantaloupe was carried out by Phisut *et al.* (2013) used different concentrations of $CaCl_2$ (2% and 3%) and calcium lactate (2% and 3%) with 3 hours of dipping time. The highest texture (6.78) value was recorded in $CaCl_2$ 3% with 3 hours and the highest (6.84) taste value was recorded in calcium lactate 2%. The sensory parameter *viz.* appearance, chewability, transparency, taste, flavor and colour of osmo-dried samples obtained were of better quality compared traditional (sun- dried) samples. Sugar provides sweet taste, flavor and freshness to the product; they also contribute to the product quality (Sahari *et al.*, 2012).Osmotic pretreatment with 70^0Brix sugar syrup for 18 hours resulted in highest sensory score (81.97) in karonda compared to control (Suhasini, 2013).

2.1.4 Storage Studies of Osmodehydrated Fruits

2.1.4.1 Biochemical Parameters of Stored Osmodehydrated Fruits

Bolini *et al.* (2006) reported that osmo-dehydrated papaya showed slight decrease in acidity after third day of storage and there was no significant change in acidity until the fifteenth day of storage. Kumar *et al.* (2008) observed that there was increasing acidity of osmodehydrated guava slices from 0.4 to 1.8 per cent during storage period of 3 months at ambient conditions.

The mean pH value of osmodehydrated strawberry fruit decreased and titratable acidity increased during a three month of storage. Storage results also revealed that decrease in ascorbic acid (54.82 to 30.08 mg/100 g), non-reducing sugar (20.41 to 13.36%), color score (9 to 4.96), texture score (9 to 5.14), flavor score (9 to 5.23) and overall acceptability score (9 to 5.40),while the increasing trend was found for TSS (17.17 to 21.01^{0}B), titratable acidity (0.38 to 0.53%) and reducing sugar (8.35 to11.16%) in strawberry fruits (Khan *et al.,* 2014).

The osmo-dehydrated product prepared out of carambola slices showed a shelf-life of six months at room temperature (37°C). Changes in some physicochemical (TPC, TFC, carotenoid, Vitamins, antioxidant potential) and sensory attributes (colour, texture, overall acceptability) were studied during storage of osmodehydrated carambola slices (Roopa *et al*., 2014). The bio-chemical properties (sugars, pH, acidity, ascorbic acid content), microbial load and organoleptic quality were evaluated during the storage period of 4 months in the osmodehydrated karonda slices. Osmodehydrated karonda slices (70 ^{0}B for 24 h) and during stotrage acidity of slices reduced from 2% to 1.85% and total sugar increased from 51.91% to 59.17 %. There was also loss in ascorbic acid during storage of karonda slices (Suhasini, 2014).

2.1.4.2 Microbial Analysis

The application of this combination of parameters like slight reduction in water activity, lowered pH, addition of single/combined safe antimicrobial agents, moderate heat treatment may act as synergistically to inhibit microbial growth resulting in stable products at room temperature as reported by Jorge and Favetto (1992). Osmotically dehydrated guavas stored in modified atmospheric packaging showed good microbial safe conditions during storage (Pereira *et al*., 2004)

Jack fruit was preserved by osmotic dehydration with sugar concentration *viz.*35^0, 40^0, 45^0 and 50^{0}Brix. The products were packed in high density polyethylene bags and stored in ambient temperature for a period of 8 months. Minimum microbial count (8 CFU) was recorded for osmosis in 50^{0}Brix sugar solution followed by 45^0Brix sugar solution (Rahman *et al.,* 2012). Osmodehydrated pineapples undergo further drying and cool storage at 4 ºC were found to be effective to extend the shelf life of pineapple up to 14 days, 35 days and 49 days for 100 : 0, 25 : 75 and 0 : 100 (% sucrose: % sorbitol), which were treated with sorbitol as osmotic solutions. All three formulations showed a good microbial stability throughout the extended storage during which the total plate count for bacteria, yeast and mould were within under the limits of bacteria at less than 106 CFU/g and yeast and mould at less than 104 CFU/g (Hui *et al.*, 2017).

2.1.4.3 Sensory Analysis

Osmodehydrated pineapple slices steeped in 60^0B sugar syrup concentration were most acceptable with respect to colour, texture and flavour after 6 months of storage as compared to other steeping concentrations (Rashmi *et al.,* 2005). Sabrina *et al.* (2009) observed that there will be decline in overall accepatability of osmodehydrated mango slices during storage. Osmodehydrated products are characterized by low water activity and this ensures high stability during storage (Abraao *et al.*, 2013).

2.2 BIOCHEMICAL PROPERTIES OF BILIMBI FRUIT

Pharmacological studies have shown that bilimbi fruit alleviates hypertension (Goh *et al.*, 1995). *A. bilimbi* has been widely used in traditional medicine for cough, cold, itches, boils, rheumatism, syphilis, diabetes, whooping cough and (Abas *et al.*, 2006). Bilimbi fruits can also be used as a dietary ingredient to prevent as well as treat hyperlipidemia (Ambili *et al.*, 2009 and fruit is taken as a cure for fever and inflammation and to stop rectal bleeding and alleviate internal heamorrhoids (Roy *et al.*, 2011) .

Tan *et al.*, 2005 identified amino acids, citric acid, cyanidin–3–O–β–D–glucoside, phenolics, potassium ion, sugars and vitamin A as the chemical constituents of *A.bilimbi* and it is used as antibacterial, antiscorbutic,treatment of fever, mumps, pimples, inflammation of the rectum and diabetes (decoction of the leaves), treatment of itches, boils, rheumatism, cough and syphilis (paste of leaves) treatment of scurvy, bilious colic, whooping cough, hypertension and treatment of children's cough (syrup of flowers) and treatment of stomach ache (fruits). Mature *Averrhoa* fruits are acidic, with high fiber content and are high in minerals such as calcium, phosphorous, iron and potassium. These fruits are rich source of vitamin C, antioxidants and are low in fat (Bhaskar and Shantaram, 2013).

TSS (Total Soluble Solids) of ripe bilimbi fruit was found to be ranging from 4.64 – 5.06 as reported by Lima *et al.* (2001). Studies conducted by Soumya and Nair (2014), reported reducing sugar content of ripe bilimbi fruits as 2.1± 0.13 mg g^{-1} tissue.

Oxalic acid has been identified as the main acid in carambola and in bilimbi (Joseph and Mendonca, 1989). Lima *et al.* (2001) reported that bilimbi fruits are acidic with very low pH values ranging from 0.9-1.27 they also reported that oxalic acid content of ripe fruits were 8.57 and 9.82 g/100g during dry and rainy season respectively. Bilimbi contain very low pH due to the presence of many organic acids such as oxalic acid, citric acid, malic, ascorbic and tartaric acid (shui *et al.*, 2002). According to Bhaskar and Shantaram (2013) pH of bilimbi fruit ranged from 2.16 ± 0.11. Soumya and Nair (2014) observed pH of ripe bilimbi as 1.86 g^{-1} oxalic acid and titratable acidity of 0.434±0.12 (g $-^{1}$oxalic acid equivalent)

Antioxidant compounds play an important role in reducing the risk of many chronic diseases such as cancer, coronary heart disease, and immune system decline has been well documented. Several studies have demonstrated a relationship between consumption of fruits and a lower incidence of degenerative diseases such as heart disease, arthritis and ageing (Blumberg, 2003; Kaur and Kapoor, 2001; Abas *et al.*,2006; Patras, *et al.*, 2009). Muhammad (2013) stated that an increase in the consumption of fruits and vegetables is related with a decrease in the rate of cardiovascular disease and reduce risks of certain cancers.

The phytochemical screening of bilimbi was investigated by Hasanuzzaman *et al.* (2013) and revealed this fruit as the potent source of different phytochemical constituents on different extractives including, phenol, flavonoid, tannin which are responsible for antioxidant action. Muhamed (2013) studied the extraction of bioactive compounds of bilimbi and stated that it could be used for functional food product development. Soumya and Nair (2014) studied biochemical profile of bilimbi and concluded that these fruits are safe for consumption and could benefit as a supplementary food source.

Bilimbi fruit extracts showed a strong DPPH radical scavenging activity with IC_{50} value of 20.35µg/ml and remarkable total antioxidant capacity (417.093 ± 6.577 mg g^{-1} in ascorbic acid equivalent (AAE) (Abas *et al.*, 2006). Ikram *et al.* (2009) evaluated the antioxidant activity and total phenol content (TPC) of bilimbi, and recorded a content of 1261.63 mg/100 g and 91.8% antioxidant capacity based on β-carotene bleaching assay method and 38.09 ± 1.87% was the DPPH activity for water extracted raw bilimbi.

Plant phenolics are a major group of compounds that act as primary antioxidants or free radical scavengers. Flavonoids and tannins are phenolic compounds (Polterait, 1997). A correlation study conducted between total phenolic content and antioxidant activity revealed that the samples with high total phenolic content exhibited a high antioxidant activity (Amin and Lee, 2005). Total phenolic content bilimbi ranged from 50.23-68.67mg of GAE/g (Hasanuzzaman *et al.* 2013). According to Aklima *et al.* (2014) bilimbi fruit contain 6.08+0.9 mg g^{-1} of total phenol. Asna and Noriham (2014) recorded total phenol content of bilimbi fruit as 41.00±2.75 mg GAE g^{-1} and also reported that antioxidant activity of bilimbi fruit is mainly due to phenolic content.

Various flavonoids (myricetin, luteolin, quercetin and apigenin) have been quantified (Hui and Suhaila, 2001) in various fruits. Bilimbi fruits showed a total flavanoid content of 23.32±3.50 mg QE/g in a study conducted by Asna and Noriham (2014). Solvent extraction of bilimbi with methanol (50%) yielded a total flavonoids content of 568.75 μg ml^{-1} QE (Muhamad, 2013). Carotenoid content in bilimi fruit was estimated as 0.035 mg (Roy *et al.*, 2011).

Consumption of a large amount of oxalate could be fatal to humans because of oxaloses or the formation of calcium oxalate deposits in vital tissues or organs of the body (Sanz and Reig, 1992). Oxalate is the conjugate base of oxalic acid which can bind to metal ions such as Ca^{2+} and Mg^{2+} to form precipitates in the body. Consumption of high oxalate-containing foods may result in hyperoxaluria and subsequent formation of insoluble calcium oxalate crystals, a primary component of kidney stones (Wahsh *et al.,* 2012). Bakul *et al.* (2013) reported that freshly made concentrated bilimbi juice has very high oxalic acid content and consumption carries a high risk of developing acute renal failure by deposition of calcium oxalate crystals in renal tubules.

Joseph and Mendonca (1989) studied the variation of oxalic acid level in different season in bilimbi fruits and reported that it varied from 9.86-10.8 mg g^{-1} to 8.45-9.00 mg g^{-1} in ripe fruits. Bilimbi harvested during rainy season had higher oxalic acid content than dry season fruit (Lima *et al.,* 2001). Soumya and Nair (2014) evaluated the oxalate content in ripe and unripe bilimbi and reported as 6.13±0.38 and 3.12 ±0.49 mg g^{-1} respectively.

2.2.1 Effect of Primary Processing on Biochemical Properties of Bilimbi

Nilugin and Mahendran (2011) conducted studies on drying of bilimbi and found that nutritional parameters of bilimbi powder differed significantly among the drying treatments. Rawson *et al.* (2011) found that most of the bioactive compound in plants for example flavonoid, phenolic, antioxidant, carotenoid and vitamin C will change their chemical and physical structure also loss the bioavailability due to the thermal degradation process when exposed to high temperature. Pre-treatments and drying temperature were reported as important variables to improve mass and heat transfer as well as the biochemical and antioxidant properties of bilimbi (Shahari *et al.,* 2015).

Freeze dried bilimbi contain a total phenol content of 629.17 mg GAE /100g which is significantly lower than that of carambola and total phenol as 153.38 mg Rutin/100g (Yan *et al.,* 2016). Bilimbi contain 182 .98 mg/100g of vitamin C on dry weight basis. The fruit segments osmotically dehydrated with salt (2%) retained a higher content of vitamin C compared to those subjected to a supplementary pretreatment by blanching process (Shahari *et al.,* 2015).

Longer osmotic concentration time resulted in increased loss of phytonutrients (phenols and anthocyanins) in blueberries, mainly due to the leaching into sucrose solution and negative influence of oxygen (Stojanovic and Silva, 2007). Antioxidant activity and total phenolic compounds of osmodehydrated blue berries were lost significantly during process (Giovanelli *et al.*, 2013). Osmotic dehydration caused a significant loss in antioxidant activity and phenolic content of cantaloupes when compared with fresh sample (Phisut *et al.*, 2013a and Phisut *et al.*, 2013b). Osmodehydration results in products with high TSS, total sugar and reducing sugar. Several research workers reported that uptake of solutes and a resultant increase in sugar content in fruit slices is characteristic phenomenon of the osmosis process (Torreggiani, 1993; Chavan *et al.*, 2010, Amin and Hossain., 2012 and Patil *et al.,* 2013). Suresh (2009b) reported that osmotic drying substantially increased the sugar content and reduced acidity.

Blanching treatments are classified according to the heat medium used, blanching in boiling water and steam blanching and hot water blanching has the advantage of a homogenous heat treatment (Ioannou and Ghoul, 2013).

Ascorbic acid, the antioxidant vitamin is heat liable and sensitive to oxygen and oxidizing agent. Though blanching treatment inactivates browning enzymes, it causes vitamin loss by thermal degradation, diffusion and leaching (Negi and Roy, 2000). Water blanching of aonla fruit at 100^0C for 7 min lead to decrease in vitamin C content (Gudapaty *et al*., 2010).Water blanching of fruits and vegetables have certain drawbacks like leaching of nutrients to water

(Mazzeo *et al.*, 2011). An experiment conducted in non conventional vegetables revealed that, blanching before diet preparation considerably reduced vitamins and carbohydrate composition of leaves (Nkafamiya *et al.*, 2010. Shubhra *et al.* (2014) found that blanching had a negligible effect on reducing sugar and non reducing sugar in aloe gel.

Thermal treatment, including blanching, boiling and baking, reduces the ascorbic acid and total phenolic contents and antioxidant activities (Crozier *et al.,* 1997; Amin *et al.,*2006). Stewart *et al.* (2000) observed that the total phenol content of peppers, green beans, and spinach were increased by blanching; indicating that heat treatment increases the level of free flavonols. Wen *et al.* (2010) stated that phenol content either decreases or increases according to the type of vegetable after blanching. In contrast, other studies revealed that thermal treatment actually increases the total phenolic content or radical scavenging abilities of vegetables (Turkmen *et al.*, 2005; Oboh., 2015). The above results demonstrate that the blanching process has different effects on different product. Blanching reduced the phenol content from 23 mg/100 to 21mg/100g. Blanching increased TSS of aloe gel from 2 to 2.2 and reduced ascorbic acid content (Shubhra *et al.*, 2014). Oboh (2015) reported that blanching increases the total phenol content in green leafy vegetables by up to 200%.

Dewanto *et al.* (2002) found that, heating treatment significantly increases the biological activities of the fruits and vegetables compared to fresh one due to the various chemical changes during thermal processing. This fact supported by Stahl and Sies (1992) in the tomatoes and carrots which have higher content of lycopene and -carotene after cooked rather than fresh one. Recently, numerous studies revealed that, most of polyphenol and antioxidant activity derived from citrus peel affected by heating treatment (Jeong *et al.*, 2004). For instance, Jeong *et al.* (2004) illustrated that, the antioxidant activity derived from citrus peel relatively increases when exposed to heat treatment. Garau *et al.* (2007) also mentioned that, heat treatment at 50 and 60°C may be interrupt the plant cell wall and enhance the antioxidant capacity of citrus (*Citrus aurantium* v.

Canoneta). Moreover it has been found that, the heat treatment significantly increases the antioxidant activity of blood orange juice, and grape seed (Scalzo *et al*., 2004; Kim *et al*., 2006). Blanching for 3 minutes in hot water and steam increased the antioxidant activity, phenol and flavanoid content of aloe gel (Cherian, 2016)

Technological measures in vegetable processing, *viz.*washing, blanching, shredding, freezing and canning can contribute to changes in the nutritional value, including the level of unwanted compounds (Bednar *et al.*1991; Ezeagu and Fafunso, 1995). Mosha (1995) recommended blanching as an effective method for reducing the antinutritional factors in green vegetables. Processing with the use of water (washing, blanching) usually reduces the content of nitrates, nitrites and oxalates (Gebczynski , 2002). Jaworska (2005) conducted a study to determine the effect of blanching or cooking of the raw material, and its freezing or sterilization and storage period, on the content of nitrates, nitrites and oxalates in preserved spinach and New Zealand spinach. Blanching and cooking significantly reduced the nitrate and oxalates in the spinach.

Considerable work had also been carried out on the reduction of oxalic acid content by precipitation techniques involving ultra filtration and vacuum concentration in carambola (Wang *et al*., 1998). Pretreatment to the juice was found essential to minimize the formation of kidney stones a common problem associated with the product with high concentration of oxalic acid. Osmo air drying treatment reduced the anti nutritional factors like tannin in aonla fruit compared to other drying because of leaching (Pragathi *et al.,* 2003).

Materials and Methods

3. MATERIALS AND METHODS

The materials used and the methodologies adopted during the present investigation "Development of osmodehydrated bilimbi (*Averroha bilimbi* L.) and assessment of bioactive compounds" conducted with the objective to standardize process variables for osmodehydrated bilimbi and to assess the retention of bioactive compounds are described in this chapter. The experiment was conducted as two separate part.

3.1 Development of osmodehydrated bilimbi

3.2 Assessment of bioactive compounds

3.1 DEVELOPMENT OF OSMODEHYDRATED BILIMBI

The experiment was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2015-2017. Bilimbi fruits of uniform size, maturity, free from pests, diseases and mechanical damages were harvested from the Instructional Farm, Vellayani. Uniform sized bilimbi fruits were washed in water and surface dried. Fruits were pricked and then blanched in hot water for one minute as a pretreatment.

3.1.1 Mass Transfer Characters of Osmosed bilimbi

Osmotic solutions (sucrose) of three different concentrations *viz*., 40, 60, 80^0B were prepared and 0.1% of potassium meta bisulphite was added to the osmotic solutions.

Blanched bilimbi fruits were immersed in 40^0B (C_2), 60^0B (C_2) and 80^0B (C_3) osmotic solution (sucrose) for an immersion time of 60 minutes (T_1) 120 minutes (T_2) and 180 minutes (T_3) with three replication. The ratio of fruits to osmotic solution was maintained at 1:2 and the temperature of osmotic solution was maintained at 40 ^{0}C. Drained bilimbi fruits were analysed for various mass transfer characters.

Mass transfer characters *viz.*, solid gain, water loss, percentage weight reduction and ratio of water loss to solid gain (WL/SG) were determined and optimized values were calculated.

3.1.1.1 Solid Gain (%)

Solid gain (%) was determined using the procedure followed by (Kowalski and Mierzwa, 2011).

$$SG(\%) = \frac{St - Si}{mi} X\,100$$

Where, S_t = dry mass at time t, S_i = Initial dry mass (of fresh) and m_i= initial mass of wet sample.

3.1.1.2 Water Loss (%)

Weight of fresh fruit and weight after osmosis was recorded in electronic balance (Cyber Lab-0.01mg to 1000mg). Dry mass of fresh fruit and dry mass after osmosis were recorded and water loss in terms of percentage was calculated by the method described by Sridevi and Genitha (2012) using following formula

$$WL(\%) = \frac{(Wo - Wt) + (St - So)}{Wo} x100$$

W_o = Initial weight of fruit slices

W_t = Weight of fruit slices after osmotic dehydration

S_0 = Initial dry mass of fruit slices

S_t = Dry mass of fruit slices after osmotic dehydration

3.1.1.3 Weight Reduction (%)

Weight reduction in terms of percentage was calculated using the method described by Yadav and singh (2014).

$$WR(\%) = \frac{Mo - M}{Mo} x100$$

Mo = Initial mass of fruit slices prior to osmosis (g)

M = Mass of fruit slices after osmosis (g)

3.1.1.4 Ratio of Water Loss to Solid Gain **(WL/SG)**

It is expressed as ratio of calculated value of water loss and solid gain.

$$\frac{WL}{SG} = \frac{\%waterloss}{\%solidgain}$$

3.1.2 Dehydration of Osmosed Bilimbi Fruit

Osmosed bilimbi fruits were dried in a cabinet tray drier (Gallen Kamp hot box) at a temperature of 50 ^{0}C till the fruits attained a moisture content of 19±1%. Yield, biochemical parameters and sensory attributes of osmodehydrated bilimbi were analysed (Plate 1.).

3.1.2.1 Yield (%)

Weight of osmodehydrated product obtained from a known quantity of fresh bilimbi fruits were recorded and the yield was calculated using the formula.

$$\text{Yield} = \frac{\text{weight of dehydrated fruit}}{\text{wight of fresh fruit}} \text{ x } 100$$

3.1.2.2 Biochemical Parameters

Biochemical parameters *viz.* free acids, total sugar, reducing sugar, vitamin C and antioxidant activity were analysed.

3.1.2.2.a Free Acids (%)

The titrimetric method of Cox and Person as described by Ranganna (1986) was adopted for the estimation of free acids.

3.1.2.2.b Reducing Sugar (%)

The titrimetric method of Lane and Eynon as described by Ranganna (1986) was adopted for the estimation of reducing sugar. Percentage of reducing sugar was calculated according to the following formula

$$\text{Reducing sugar} = \frac{\text{Glucose Eq. (0.05) x Total volume made up (ml)}}{\text{Titre value x Weight of the pulp (g)}} \text{ x } 100$$

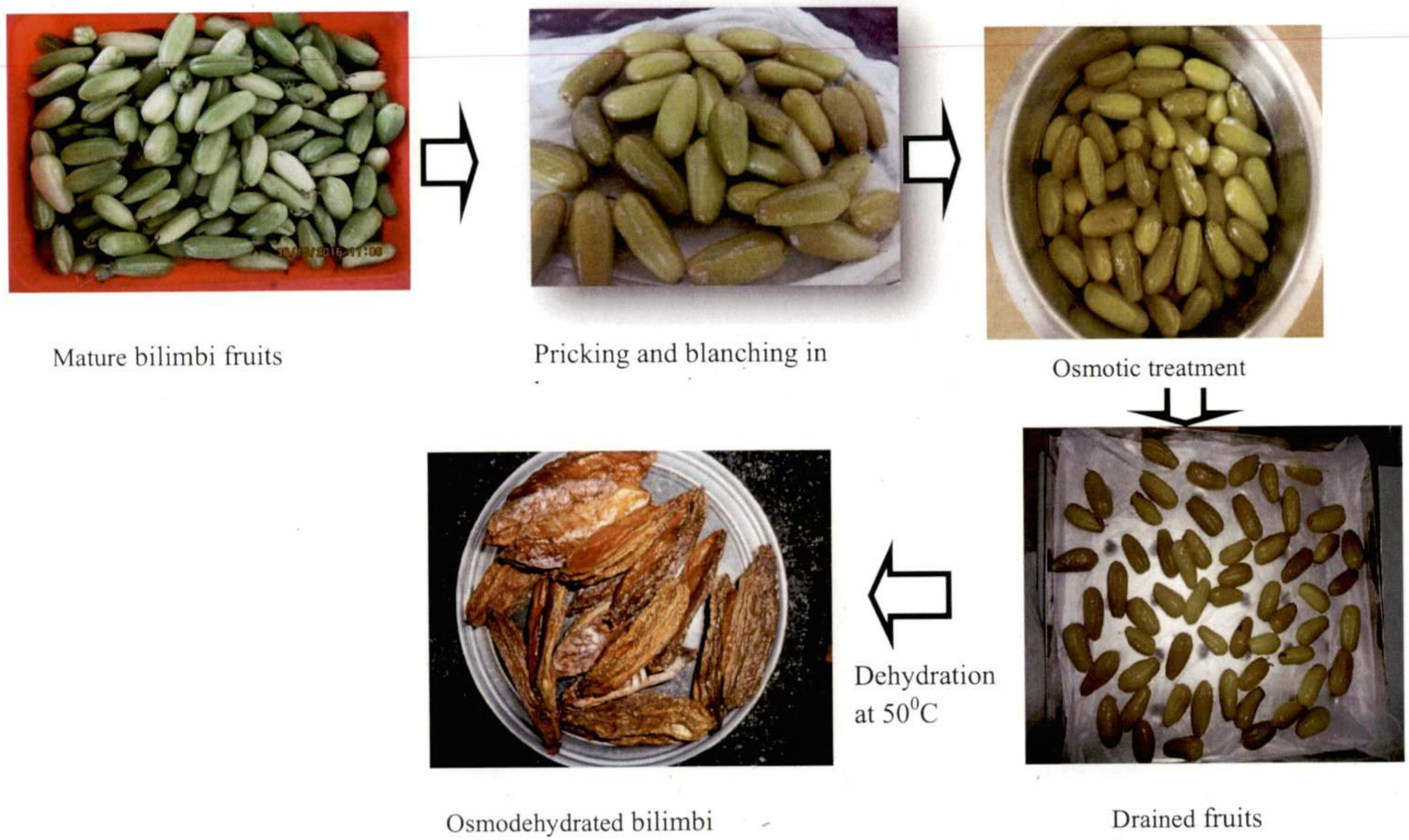

Plate 1. Development of osmodehydrated bilimbi

3.1.2.2. c Total Sugar (%)

The total sugar content was expressed as per cent (Ranganna, 1986) according to the following formula

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total vol. made up (ml) x Vol. made up after inversion (ml)}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (ml)}} \times 100$$

3.1.2.2. d Vitamin C (mg/100g)

The titrimetric method described by Ranganna (1986) was adopted using 2. 6 dichlophenol Indophenol method.

$$\text{Vitamin C} = \frac{\text{Titre value X Dye factor X Volume made up (ml)}}{\text{Aliquat. of extract taken (ml) X Wt. of sample (g)}} \times 100$$

3.1.2.2. e Antioxidant Activity (%)

Total antioxidant activity of osmodehydrated bilimbi was determined using 2, 2- diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured according to the procedure described by Sharma and Bhat (2009). Scavenging effect was expressed as per cent DPPH as shown in the following equation:

$$\text{\% inhibition of DPPH} = \frac{\{A_{blank} - A_{sample}\} \times 100}{A_{blank}}$$

Where,

A_{blank} – Absorbance of DPPH solution without sample

A_{sample} – Absorbance of the test sample after 30 min

3.1.2.3 Sensory Analysis

Osmodehydrated bilimbi fruits prepared by different treatments were evaluated for sensory characteristics *viz.*, appearance, colour, flavour, taste, texture and overall acceptability by 30 semi trained members. Each character was given a score from 1 to 9 according to Hedonic rating (Ranganna, 1986). Sensory analysis was carried out to obtain the best 3 treatments from total 9 treatments.

Like extremely -9

Like very much - 8

Like moderately - 7

Like slightly - 6

Neither like nor dislike -5

Dislike slightly -4

Dislike moderately -3

Dislike very much -2

Dislike extremely -1

The score was statistically analysed using Kruskall-Wallis test (chi-square value) and ranked (Shamrez *et al.*, 2013).The best three treatments were selected for further storage studies.

3.1.3 Storage Studies of Osmodehydrated Bilimbi

Storage potential of three best osmodehydrated bilimbi treatments was studied. Osmodehydrated bilimbi fruits (50 g) were prepackaged and sealed in polypropylene covers (200 gauge) labeled as per the treatments and were stored at room temperature (30±2 ^{0}C) and RH 80 to 85%) in five replications. The stored products were analyzed for biochemical, sensory and microbial parameters at monthly interval for a period of four months.

3.1.3.1 Biochemical Parameters

3.1.3.1.a Free Acids (%)

Free acidity during storage was calculated as described in 3.1.2.2.a

3.1.3.1.b Reducing Sugar (%)

Reducing sugar during storage was calculated as described in 3.1.2.2.b

3.1.3.1.c Total Sugar (%)

Total sugar during storage was calculated as described in 3.1.2.2.c

3.1.3.1.d Vitamin C (mg/100g)

Vitamin C during storage was calculated as described in 3.1.2.2.d

3.1.3.1.e Antioxidant Activity (%)

Antioxidant activity during storage was calculated as described in 3.1.2.2.e

3.1.3.2 Sensory analysis

Sensory analysis was conducted as described in3.1.2.3

3.1.3.3 Evaluation of Microbial Counts during Storage

The quantitative assay of the micro flora in stored samples was carried out by serial dilution spread plate techniques. Nutrient agar and Rose Bengal agar medium were used for the enumeration of bacterial and fungal population of dehydrated fruits respectively.

$$\text{No. of colony forming units Per gram of samples} = \frac{\text{Total no. of colony formed x dilution factor}}{\text{Aliquot taken}}$$

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3.2 ASSESSMENT OF BIOACTIVE COMPOUNDS

Bilimbi fruits were subjected to different primary processing methods and effect of primary processing on retention of bioactive compounds was analysed.

3.2.1. Treatments

M_1: Osmodehydration

M_2: Drying

M_3: Hot water blanching

M_4: Steam blanching

M_5: Fresh bilimbi (control)

Bioactive compounds present in osmodehydrated bilimbi (the best treatment from 3.1) were compared with that of dried bilimbi, bioactive compounds in fresh bilimbi (control) were analysed and compared with other primary processed bilimbi *viz*. hot water blanched and steam blanched.

3.2.1.1 Osmodehydration

Best treatment from the Experiment 3.1.3 was repeated for quantifying bioactive compounds.

3.2.1.2 Drying

Fresh fruits were made in to longitudinal equal slices and salted (15%). Blimbi slices were kept in a cabinet tray drier (Gallen Kamp hot box) and dried at 55-60 ^{0}C temperature till the fruit slices reached 19$\pm$ 1% moisture content

3.2.1.3 Hot water Blanching

Bilimbi fruits were blanched by dipping in hot water for 3 min.

3.2.1.4 Steam Blanching

Bilimbi fruits were steam blanched for 3 min.

3.2.1.5 Fresh Bilimbi

Fresh and uniformly matured fruits were taken as control.

3.2.2 Biochemical Analysis

3.2.2.1 Total Soluble Solids (^oB)

Total Soluble Solids (TSS) was recorded by using digital refractometer (Atago - 0 to 53 ^oB) and expressed in ^{0} Brix. For dried and dehydrated products homogenized mixture of water and product is used as sample (FSSAI, 2015).

3.4.2.2 Free Acids (%)

Free acid content of bilimbi was calculated as described in 3.1.2.2.a

3.2.2.3 Reducing Sugar (%)

Reducing sugar of bilimbi sample was calculated as described as 3.1.2.2.b

3.2.2.4 Total Sugar (%)

Total sugar of bilimbi sample was calculated as described in 3.1.2.2.c

3.2.2.5 pH

pH of the bilimbi was measured by using pocket pH tester (Hanna instruments, pHep Tester).

3.2.2.6 Ascorbic Acid (mg/100g)

Ascorbic acid content of bilimbi was calculated as described in 3.1.2.2.d

3.2.2.7 Carotenoids (mg/100g)

Carotenoids were estimated as per the procedures of Saini *et al.* (2001) and expressed as mg/100g of treated fruit

3.2.2.8 Total Phenols

Total phenol content was estimated by using the method described by

Sadasivam and Manickam (1992). One gram of the sample was extracted with 10 times volume of 80 per cent ethanol. The homogenate was centrifuged at 10,000 rpm for 20 minutes. The supernatant was evaporated to dryness. The residue was dissolved in a known volume of distilled water (5 ml). 0.5 ml was pipette out of the aliquot in test tube and made up the volume to 3 ml with distilled water and add 0.5 ml Folin- Ciocalteau reagent was added and Na_2CO_3 20 per cent (2 ml) was added to the test tubes after 3 minutes and mixed it thoroughly. The test tubes were placed in boiling water for one minute, cooled and the absorbance was measured at 765 nm against the reagent blank. Standard curve using different concentrations of gallic acid was prepared and phenol content of the test sample was expressed as mg phenols $100g^{-1}$ sample bilimbi.

3.2.2.9 *Antioxidant Activity*

Antioxidant activity of bilimbi as DPPH assay was calculated as described in *3.2.2.5.e*

3.2.2.10 Total Flavonids

Total flavanoid content of the fruit extracts was determined according to the colorimetric assay described by Quettier-Deleu *et al.*(2000) 1 ml fruit extract was mixed with 4 ml of distilled water. Then, at zero time, 0.3 ml of (5% w/v) $NaNO_2$ was added. After 5 min, 0.3 ml of (10% w/v) $AlCl_3$ was added. After 6 min, 2 ml of 1 M NaOH was added and the volume was made up to 10 ml immediately by the addition of 2.4 ml distilled water. The solution was mixed vigorously, and the absorbance of the solution was measured a calibrated ultraviolet-visible spectroscopy at a wavelength of 510 nm. The result was expressed in μg quercetin equivalent/g sample by comparison with the quercetin standard curve, which was made under the same condition.

3.2.2.*11 Oxalate (mg/g)*

The titration method as described by Day and Underwood (1986) was followed. 1g of sample was weighed into 100 ml conical flask and 75ml 3M

H_2SO_4 was added and stirred for 1hr with a magnetic stirrer. This was filtered using a Whatman No 1 filter paper. 25ml of the filtrate was then taken and titrated while hot against 0.05M $KMnO_4$ solution until pale pink colour persisted for at least 30 sec. The oxalate content was calculated by taking 1ml of 0.05m $KMnO_4$ as equivalent to 2.2mg oxalate (Chinma and Igyor, 2007).

3.2.3 Statistical Design

The data generated from experiments were statistically analyzed using Completely Randomized Design (CRD).Sensory parameters were statistically analysed using Kruskall – Wallis Chi-square test.

Results

4. RESULTS

Results of the present investigation entitled "Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compounds" are presented in this chapter under following heads.

4.1 Development of osmodehydrated bilimbi

4.2 Assessment of bioactive compounds

4.1 DEVELOPMENT OF OSMODEHYDRATED BILIMBI

The effect of different osmotic concentration (40^0B, 60^0B and 80^0B) and immersion time (60 min, 120 min and 180 min) on mass transfer characters, yield and quality parameters of osmodehydrated bilimbi fruits were analyzed statistically and results are tabulated and described as below.

4.1.1 Mass Transfer Characters

Mass transfer characters *viz.,* solid gain, water loss, percentage weight reduction and ratio of water loss to solid gain were analysed.

4.1.1.1 Solid Gain (%)

Solid gain of osmodehydrated bilimbi fruits in different osmotic concentration and immersion time is shown in Table 1. Osmodehydrated bilimbi fruits at 40^0B (C_1) showed the lowest solid gain of 2.34 per cent, which is followed by 60^0B (C_2) with 3.83 percentage and the highest solid gain (4.69%) was observed for 80 ^{0}B (C_3). Among immersion time, T_3 (180 min) recorded the highest solid gain of 4.02 per cent followed by T_2 (120 min) with 3.62 per cent and the lowest solid gain (3.22 %) was recorded for T_1 (60 min).

Among the interaction effects, C_3T_3 (80^0B, 180 min) recorded the highest solid gain of 5.10 per cent followed by 4.67 per cent for C_3T_2 (60^0B, 120 min) and the lowest solid gain of 2.03 per cent was observed in C_1T_1 (40^0B, 60 min).

4.1.1.2 Water Loss (%)

Water loss of osmodehydrated bilimbi fruit was influenced significantly by osmotic concentrations and immersion time (Table 2). The highest water loss of 13.52 per cent was observed for the osmotic concentration C_3 (80^0B) and the lowest water loss of 5.78 per cent was recorded for C_1 (40^0B). The immersion time, 180 minutes (T_3) recorded the highest water loss of 11.44 per cent; whereas 120 min (T_2) recorded the water loss of 9.63 per cent and lowest water loss (7.21 %) was observed for 60 minutes immersion time (T_1).

Among the interactions, maximum water loss (16.72 %) was observed in C_3T_3 (80^0B, 180 min), while minimum water loss (4.58 %) was in treatment with osmotic concentration of 40^0B for immersion time of 60 minutes (C_1T_1).

4.1.1.3 Percentage Weight Reduction

Percentage weight reduction of osmodehydrated bilimbi fruits at different osmotic concentration and immersion time is given in Table 3. Osmosed bilimbi at 80^0B (C_3) recorded the highest weight loss of 18.88 per cent followed by C_2 (60^0B). The lowest weight reduction of 8.35 per cent was observed in C_1 (40^0B). When the effect of immersion time was considered T_1 (60 min) showed the lowest weight loss of 10.79 per cent where as T_3 (180 min) recorded the highest weight reduction (15.76%) and T_2 (120 min) showed a weight reduction of 13.64 per cent.

When interaction effects were studied C_3T_3 (80^0B, 180 min) recorded maximum weight reduction of 22.57 per cent followed by C_3T_2 (80^0B, 120 min).The minimum weight reduction of 6.73 per cent was observed for C_1T_1 ($40\,^0$ B, 60 min)

Table 1. Effect of osmotic concentration and immersion time on solid gain (%) of osmodehydrated bilimbi

Osmotic concentrations	Solid gain (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	2.03	2.37	2.63	2.34
C_2 (60^0B)	3.33	3.83	4.33	3.83
C_3 (80^0 B)	4.30	4.67	5.10	4.69
Mean (T)	3.22	3.62	4.02	
	CD (0.05)	C/T-0.0-.085	CxT-0.143	

Table 2. Effect of osmotic concentration and immersion time on water loss (%) of osmodehydrated bilimbi

Osmotic concentrations	Water loss (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	4.58	5.60	7.16	5.78
C_2 (60^0B)	7.25	9.26	10.45	8.98
C_3 (80^0 B)	9.81	14.04	16.72	13.52
Mean (T)	7.21	9.63	11.44	
	CD (0.05)	C/T-0.257	C xT-0.445	

Table 3. Effect of osmotic concentrations and immersion time on percentage weight reduction (%) of osmodehydrated bilimbi

Osmotic Concentrations	Weight reduction (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	6.73	8.30	10.02	8.35
C_2 (60^0B)	10.91	13.23	15.17	13.10
C_3 (80^0 B)	14.70	19.39	22.57	18.88
Mean (T)	10.79	13.64	15.76	
	CD (0.05)	C/T-0.267	CxT-0.463	

4.1.1.4 Ratio of Water Loss to Solid Gain

Ratio of water loss to solid gain of osmodehydrated bilimbi fruits in different osmotic concentration and immersion time are shown in Table 4. Osmodehydrated bilimbi fruits at 80^0B (C_3) showed the highest value (2.90%) for ratio of water loss to solid gain, which is followed by C_3 (40^0B) with the ratio of 2.47 per cent. Among immersion time, T_3 (180 min) recorded the maximum ratio of 2.75 per cent followed by T_2 (120 min) of 2.62 and the lowest ratio was recorded for T_1 (60 min) of 2.29 percent.

Among the interaction effects, C_3T_3 (80^0B, 180 min) recorded maximum ratio of water loss to solid gain of 3.25 per cent and the lowest ratio (2.17 %) was observed for C_2T_1 (60^0B, 60 min).

4.1.2 Yield

Yield of osmodehydrated bilimbi is depicted in Table 5. Osmotic concentration and immersion time significantly influenced yield of bilimbi. Yield of osmodehydrated bilimbi in C_3 (80^0 B) showed the highest (20.6 %) followed by C_2 (60^0 B) (19.81 %) and C_1 (40^0 B) recorded the minimum yield of 18.32 per cent. The immersion time of 180 minutes (T_3) recorded the highest yield of 20.01 per cent; whereas T_1 (120 min) recorded the lowest yield of 19.12 per cent.

Among the treatment combinations, the highest yield of 21.13 per cent was observed in 80^0 B, 180 min (C_3T_3) and the lowest yield of 18.03 was noticed in 40^0 B, 60 minutes (C_1T_1).

4.1.3 Biochemical Parameters

Biochemical parameters of osmodehydrated bilimbi fruits as influenced by osmotic concentrations and immersion time are described below.

Table 4. Effect of osmotic concentrations and immersion time on ratio of water loss to solid gain of osmodehydrated bilimbi

Osmotic concentrations	WL/SG			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	2.26	2.44	2.72	2.47
C_2 (60^0B)	2.17	2.41	2.27	2.29
C_3 (80^0 B)	2.43	3.01	3.25	2.90
Mean (T)	2.29	2.62	2.75	
	CD (0.05)	C/T-0.114	CxT-0.198	

Table 5. Effect of osmotic concentrations and immersion time on yield (%) of osmodehydrated bilimbi.

Osmotic concentrations	Yield (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	18.03	18.3	18.63	18.32
C_2 (60^0B)	19.33	19.83	20.27	19.81
C_3 (80^0 B)	20.00	20.67	21.13	20.60
Mean (T)	19.12	19.60	20.01	
	CD (0.05)	C/T-0.134	CxT-0.233	

Table 6. Effect of osmotic concentrations and immersion time on free acids (%) of osmodehydrated bilimbi

Osmotic concentrations	Free acids (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	4.16	3.72	3.41	3.76
C_2 (60^0B)	3.60	3.41	2.74	3.25
C_3 (80^0 B)	2.77	2.57	2.32	2.55
Mean (T)	3.51	3.23	2.82	
	CD (0.05)	C/T-0.064	CxT-0.11	

50.

4.1.2.1 Free acids (%)

Bilimbi fruits osmodehydrated in 80^0B (C_3) recorded the lowest value (2.55%) value for free acids followed by C_2 (3.25 %) and the highest free acids of 3.76 % was observed in C_1 (Table 6). With respect to immersion time, T_3 (180 min) recorded the lowest free acid content of 2.82 per cent and highest free acidity (3.51%) was with T_1 (60 min).

Among the interaction effects, highest free acid of 4.16 per cent was shown by C_1T_1 (40^0 B, 60 min) and the lowest (2.32%) was noticed in C_3T_3 (80^0 B, 180 min).

4.1.2.2 Ascorbic Acid (mg/100g)

Ascorbic acid content of osmodehydrated bilimbi showed significant difference among the treatments (Table 7). The highest ascorbic acid of 32.46 mg/100g was observed in osmotic concentration of 40^0B (C_1) followed by 60 ^{0} B (C_2) with 29.08 mg/100g. The lowest ascorbic acid of 23.34 mg /100g was shown by 80 ^{0} B (C_3). With respect to immersion time, T_1 (60 min) recorded the maximum ascorbic acid of 30.9 mg/100g while the minimum ascorbic acid of 25.62 mg/100g was noticed in 180 minutes (T_3) and T_2 (120 min) recorded 28.37 mg /100g of ascorbic acid.

Among the interaction effects, the lowest ascorbic acid (21.66 mg/100g) was observed in 80^0B, 180 min (C_3T_3). The highest percent of ascorbic acid (34.26 mg /100g) was noticed in 40^0B, 60 min (C_1T_1).

4.2.2.3 Total Sugar (%)

Total sugar of osmodehydrated bilimbi in different osmotic concentrations and immersion time are depicted in Table 8. The highest total sugar of 17.43 per cent was recorded by 80^0 B (C_3) whereas 40^0B (C_1) showed the lowest total sugar of 12.12 per cent. Among different immersion time, T_3 (180 min) recorded the highest total sugar of 15.98 per cent and T_1 (60 min) recorded the lowest total sugar of 13.40 per cent. When the interaction effects were studied, bilimbi dehydrated in 80^0B for 180 minutes (C_3T_3) had the highest total sugar of 18.53 per cent followed by C_3T_2 (80^0B, 120 min) with 17.61 per cent and the lowest total sugar of 11.44 per cent was noticed in C_1T_1 (40^0B, 60 min).

4.1.2.4 Reducing Sugar (%)

Reducing sugar content of osmodehydrated bilimbi showed significant difference for the treatments (Table 9). The highest reducing sugar (7.17 %) was noticed in osmotic concentration of 80^0B (C_3) followed by C_2 (60^0B) (5.25) and the lowest reducing sugar of 4.3% was recorded by C_1 (40^0B). Among immersing time, T_3 (180 min) recorded highest reducing sugar of 6.49% whereas bilimbi immersed for 120 minutes (T_2) and 60 minutes (T_1) recorded a reducing sugar of 5.65% and 4.76% respectively.

When interaction effects were studied, C_3T_3 (80^0B, 180 min) showed the highest reducing sugar (8.24 %) and the lowest (3.72%) reducing sugar was for C_1T_1 (40^0B, 60 min).

4.1.2.5 Antioxidant Activity (%)

Antioxidant activity of osmodehydrated bilimbi influenced by osmotic concentrations and immersion time are depicted in Table 10. Osmodehydrated bilimbi in osmotic concentration of 40^0B (C_1) showed the highest antioxidant activity of 54.44 per cent followed by C_2 (60^0B) with 51.64 per cent and the lowest (49.63%) was observed in C_3 (80^0B). Under different immersion time, T_1 (60 min) recorded the highest antioxidant activity of 54.11 per cent where as T_3 (180 min) recorded the lowest antioxidant activity of 49.79 per cent.

Table 7. Effect of osmotic concentrations and immersion time on ascorbic acid (mg/100g) of osmodehydrated bilimbi

Osmotic concentrations	Ascorbic acid (mg/100g)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	34.26	33.07	30.05	32.46
C_2 (60^0B)	33.15	28.98	25.14	29.08
C_3 (80^0 B)	25.29	23.05	21.66	23.34
Mean (T)	30.90	28.37	25.62	
CD (0.05) C/T-0.381 CxT-0.66				

Table 8. Effect of osmotic concentrations and immersion time on total sugar (%) of osmodehydrated bilimbi

Osmotic concentrations	Total sugar (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	11.44	12.06	12.82	12.12
C_2 (60^0B)	12.58	14.86	16.59	14.68
C_3 (80^0 B)	16.17	17.61	18.53	17.43
Mean (T)	13.40	14.84	15.98	
CD (0.05) C/T-0.268 CxT-0.219				

Table 9. Effect of osmotic concentrations and immersion time on reducing sugar (%) of osmodehydrated bilimbi

Osmotic concentrations	Reducing sugar (%)			
	Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T_3 (180)	Mean (C)
C_1 (40^0 B)	3.72	4.21	4.98	4.30
C_2 (60^0B)	4.36	5.15	6.24	5.25
C_3 (80^0 B)	6.19	7.06	8.24	7.17
Mean (T)	4.76	5.65	6.49	
CD (0.05) C/T-0.175 CxT-0.303				

When interaction effects were studied C_1T_1 (40^0B, 60 min) showed the highest antioxidant activity of 56.45 per cent and the lowest antioxidant activity of 47.81 per cent was observed in C_3T_3 (80^0B, 180 min)

4.1.3 Sensory Analysis

Osmodehydrated bilimbi obtained from different osmotic concentration of 40, 60 and 80^0B at an immersion time of 60, 120 and 180 minutes were analysed for various sensory attributes for their acceptance by using 9 point hedonic scale. The mean sensory scores of osmodehydrated bilimbi obtained with respect to taste, colour, flavour, texture and overall acceptability are presented in Table 11. It was observed that immersion in 80^0 B, 180 minutes (C_3T_3) resulted with highest mean score of 8.43 for taste followed by C_3T_2 (8.33) and C_2T_3 (60^0B, 180 min) with a mean score of 8.30. The mean scores for the sensory attribute colour recorded that the highest score (8.23) for C_2T_3 (60^0B, 180 min) followed by the treatment 80^0B, 180 minutes (8.17) and the lowest mean score (6.57) for colour was recorded for C_1T_1 (40^0B, 60 min). The lowest mean score of (6.90) for flavour was recorded in C_1T_1 (40^0B, 60 min bilimbi) while bilimbi osmodehydrated in 80^0B, 180 minutes recorded the highest mean score of 8.27. Fruits immersed in 80^0B for 120 minutes (C_3T_2) and 60^0B for 180 minutes (C_2T_3) recorded mean score for flavour as 8 and 7.97 respectively. Osmodehydrated bilimbi in 80^0B, 180 minutes recorded the highest mean score (8.47) for texture followed by C_2T_3 and C_3T_3 with a score of 8.4. Bilimbi in 40^0B, 60 minutes (C_1T_1) recorded the lowest mean score of 6.73.

The highest mean score of 8.43 for overall acceptability was viewed for bilimbi treated in 80^0B osmotic concentration for 180 minutes followed by 120 minutes immersion time (8.4) while poor acceptability with a mean score of 6.77 was recorded for the osmotic treatment of 40^0B for 60 minutes.

Mass transfer characters, biochemical parameters and sensory analysis of osmodehydrated bilimbi revealed that osmotic treatment C_3T_3 (80^0B, 180 min)

Table10. Effect of osmotic concentrations and immersion time on antioxidant activity (%) of osmodehydrated bilimbi

Osmotic concentrations	Antioxidant activity (%) Immersion time (minutes)			
	T_1 (60)	T_2 (120)	T3 (180)	Mean (C)
C_1 (40^0 B)	56.45	54.91	51.96	54.44
C_2 (60^0B)	53.85	51.49	49.59	51.64
C_3 (80^0 B)	52.01	49.06	47.81	49.63
Mean (T)	54.11	51.82	49.79	
CD (0.05)	C/T-0.374		CxT-0.647	

Table 11.Sensory analysis of osmodehydrated bilimbi

Treatments	Taste		Colour		Flavour		Texture		Overall Acceptabiliy	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
C_1T_1	6.87	9	6.57	8	6.90	9	6.73	9	6.77	9
C_1T_2	7.17	8	6.63	7	6.93	8	6.93	8	6.97	8
C_1T_3	7.40	7	6.70	6	7.30	7	7.17	6	7.20	6
C_1T_1	7.53	6	7.17	5	7.57	6	7.07	7	7.13	7
C_2T_2	7.83	5	7.30	4	7.70	5	8.00	5	7.97	5
C_2T_3	8.30	3	8.23	1	7.97	3	8.40	3	8.33	3
C_3T_1	8.17	4	8.13	3	7.90	4	8.10	4	8.10	4
C_3T_2	8.33	2	8.17	2	8.00	2	8.40	2	8.40	2
C_3T_3	8.43	1	8.13	3	8.27	1	8.47	1	8.43	1
KW value	99.84		150.64		155.57		200.93		184.54	
χ^2 (0.05)	15.50									

yielded the best osmodehydrated bilimbi followed by C_3T_2 (80^0B, 120 min) and C_2T_3 (60^0B, 180 min) with good retention of nutritional parameters and acceptability and were selected for storage studies.

4.1.4 Storage Studies

Osmodehydrated bilimbi fruits selected from the above experiment *viz*, 80^0B for 180 minutes (A_1), 80^0B for 120 minutes (A_2) and 60^0B for 180 minutes (A_2) were packaged in poly propylene and kept under room temperature for storage stability studies for four months. The stored osmodehydrated bilimbi fruits were analysed for biochemical, sensory and microbial parameters at monthly intervals.

4.1.4.1 Biochemical Parameters

4.1.4.1 .a. Free Acids (%)

Free acid content of selected osmodehydrated bilimbi (Table12.) was recorded as 2.74 per cent for treatment A_1 (60^0B, 180 min), 2.60 per cent for A_2 (80^0B, 120 min) and 2.32 per cent for A_3 (80^0B, 180 min) at the time of storage and it significantly reduced during storage. Free acids of osmodehydrated bilimbi in 60^0B for 180 minutes was observed as 2.67, 2.63, 2.59 and 2.54 (%) at 1^{st}, 2^{nd}, 3^{rd} and 4^{th} month of storage respectively. Osmodehydrated bilimbi sample A_2 (80^0B, 120 min) recorded free acids of 2.53 per cent after 1 month, 2.45 per cent after 2 months, 2.4 per cent after 3 months and 2.37 per cent after 4 months of storage. Free acids of treatment A_3 (80^0B, 180 min) during storage of first, second, third and fourth months was noticed as 2.26, 2.22, 2.16 and 2.06 per cent respectively.

Storage period significantly influenced free acid content of osmodehydrated bilimbi. The highest free acid content of 2.55 per cent was noticed at the time of storage whereas the lowest free acid of 2.32 per cent was observed after 4 months of storage.

4.1.4.1.b Reducing Sugar (%)

Reducing sugar of osmodehydrated bilimbi during storage is depicted in Table13. Bilimbi osmodehydrated in 60^0B for 180 minutes recorded a reducing sugar of 6.24 per cent, A_2 (80^0B, 120 min) recorded 7.62 per cent and 8.25% for bilimbi in A_3 (80^0B, 180 min) at the time of storage. During storage, there was no significant difference among the interaction effects between treatments and storage. Among the treatments osmodehydrated bilimbi in 80^0B for180 minutes (A_3) recorded the highest reducing sugar content of 8.48 per cent whereas lowest value (6.43%) was for A_1 (80^0B for 120 min). With respect to storage days, the highest reducing sugar content of 7.85 per cent was observed after four month of storage and lowest value (7.37%) at the time of storage.

4.1.4.1.c Total Sugar (%)

Bilimbi osmodehydrated in 60^0B for 180 minutes (A_1), 80^0B for 120 minutes (A_2) and 80^0B for 180 minutes (A_3) recorded a total sugar of 16.58, 17.54 and 18.56 per cent respectively at the time of storage (Table 14).

Among the osmodehydrated bilimbi treatments, the highest total sugar of 19.00 per cent was recorded for A_3 (80^0B for 180 min) followed by A_2 (80^0B for 120 min) with 18.09 per cent and the lowest total sugar of 17.03 per cent was observed for A_1 (60^0B for 180 min) on storage. During storage total sugar content increased, and the lowest total sugar of 17.56 per cent was noticed at the time of storage whereas the highest total sugar of 18.64 per cent was observed after fourth month of storage.

4.1.4.1 .d Ascorbic Acid (mg/100g)

Ascorbic acid of osmodehydrated bilimbi treatments is presented in Table 15. Bilimbi osmodehydrated in 60^0B for 180 minutes recorded an ascorbic acid content

Table12. Effect of storage on free acids (%) of osmodehydrated bilimbi

Osmodehydrated bilimbi	Free acids (%) Months after storage (M)					Mean(A)
	0	1	2	3	4	
A_1(60 ^{0}B ,180minutes)	2.74	2.67	2.63	2.59	2.54	2.63
A_2(80^{0}B, 120 minutes)	2.60	2.53	2.45	2.40	2.37	2.47
A_3(80^{0}B, 180 minutes)	2.32	2.26	2.22	2.16	2.06	2.20
Mean(M)	2.55	2.48	2.43	2.38	2.32	
CD A-0.009 M-0.011 A x M-0.019						

Table13. Effect of storage on reducing sugar (%) of osmodehydrated bilimbi

Osmodehydrated bilimbi	Reducing sugar (%) Months after storage (M)					Mean(A)
	0	1	2	3	4	
A_1(60 ^{0}B ,180minutes)	6.24	6.35	6.43	6.51	6.61	6.43
A_2(80^{0}B, 120 minutes)	7.62	7.73	7.89	8.09	8.18	7.9
A_3(80^{0}B, 180 minutes)	8.25	8.36	8.48	8.55	8.75	8.48
Mean(M)	7.37	7.48	7.60	7.72	7.85	
CD A-0.068 M-0.087 A x M-NS						

Table14.Effect of storage on as total sugar (%) of osmodehydrated bilimbi

Osmodehydrated bilimbi	Total sugar (%) Months after storage (M)					Mean(A)
	0	1	2	3	4	
A_1(60 ^{0}B ,180minutes)	16.58	16.74	16.95	17.32	17.56	17.03
A_2(80^{0}B, 120 minutes)	17.54	17.76	17.92	18.40	18.82	18.09
A_3(80^{0}B, 180 minutes)	18.56	18.68	18.95	19.26	19.55	19
Mean(M)	17.56	17.73	17.94	18.33	18.64	
CD A-0.107 M-0.138 A x M-NS						

of 25.30 mg/100g, A_2 (80^0B, 120 min) recorded 23.02 mg/100g and A_3 (80^0B, 180 min) showed 21.95 mg/100g at the time of storage. During storage, ascorbic acid for osmodehydrated bilimbi treatment 60^0B for 180 minutes (A_1) was observed as 24.65, 24.05, 23.57 and 23.00 mg/100g after 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} month of storage respectively whereas A_2 recorded ascorbic acid content of 22.49, 22.09, 21.45 and 20.97mg/100g for after 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} month of storage. Ascorbic acid of osmodehydrated bilimbi treatment A_3 (80^0B for 180 minutes) was noticed as 21.15 mg/100g after first month, 20.60 mg/100g after second month, 19.93 mg/100g after third month and 19.29 mg/100g after four month of storage.

Among the treatments of osmodehydrated bilimbi A_1 (60^0B for 180 min) recorded the highest ascorbic acid content of 24.12 mg/100g and lowest value (20.58) was for A_3 (80^0B for 180 min). With respect to storage months, the highest ascorbic acid content of 23.42 mg/100g was observed at the time of storage and lowest value of 21.09 mg/100g was recorded at the end of storage of four months.

4.1.4.1. e Antioxidant Activity (%)

Antioxidant activity of osmodehydrated fruits during storage is depicted in Table 16. Initial antioxidant activity was recorded as 49.58, 49.11 and 47.81 per cent respectively for treatments A_1 (60^0B for 180 min), A_2 (80^0B for 120 min) and A_3 (80^0B for 180 min). Osmodehydrated bilimbi sample in 60^0B for 180 minutes recorded an antioxidant activity of 48.89 per cent after one month of storage, 48.29 % after second month, 47.57 % after third month and 46.79 % after fourth month of storage. Antioxidant activity of bilimbi osmodehydrated in 80^0B for 120 minutes was noticed as 48.46% after first month, 47.98% after second month, and 47.09 % after third and 46.21% after four month of storage. Bilimbi osmosed in 80^0B for 180 minutes recorded lowest antioxidant activity of 47.10, 46.18, 45.46 and 44.59 per cent respectively for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} month of storage.

Table15. Effect of storage on ascorbic acid (mg/100g) of osmodehydrated bilimbi

Osmodehydrated bilimbi	Ascorbic acid (mg/100g) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1(60 ^{0}B ,180minutes)	25.30	24.65	24.05	23.57	23	24.12
A_2(80^{0}B, 120 minutes)	23.02	22.49	22.09	21.45	20.97	22.00
A_3(80^{0}B, 180 minutes)	21.95	21.15	20.6	19.93	19.29	20.58
Mean(M)	23.42	22.77	22.25	21.65	21.09	
CD(0.05) A-0.101 M-0.131 A x M-0.226						

Table16. Effect of storage on antioxidant activity (%) of osmodehydrated bilimbi

Osmodehydrated bilimbi	Antioxidant activity (%) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1(60 ^{0}B ,180minutes)	49.58	48.89	48.29	47.57	46.79	48.22
A_2(80^{0}B, 120 minutes)	49.11	48.46	47.98	47.09	46.21	47.77
A_3(80^{0}B, 180 minutes)	47.81	47.10	46.18	45.46	44.59	46.23
Mean(M)	48.84	48.15	47.49	46.71	45.86	
CD A-0.097 M-0.125 A x M-0.216						

With respect to storage, the highest antioxidant activity of 48.84 per cent was recorded at the time of storage and it reduced to 45.86 per cent at the end of 4^{th} month.

4.1.4.2 Sensory Analysis of Osmodehydrated Bilimbi during Storage

Sensory parameters *viz.,* taste, colour, flavor, texture and overall acceptability for stored osmodehydrated bilimbi were analysed using 9 point hedonic scale at monthly interval.

Effect of storage on taste of osmodehydrated bilimbi is depicted in Table17a. The highest mean score (8.43) was recorded for osmodehydrated bilimbi A_3 (80^0B, 180min) followed by A_2 (80^0 B, 120 min) with 8.33 and A_1 (60^0 B, 180 min) recorded a mean score of 8.30 at the time of storage. After one month of storage the osmodehydrated bilimbi at 80^0 B, 180 minute (A_1) recorded the highest mean score of 8.36 for taste and highest mean score of 8.33, 8.27 and 8.17 after 2^{nd}, 3^{rd} and 4^{th} months of storage at room temperature.

On analyzing the colour of the osmodehydrated bilimbi (Table17b), the highest mean score (8.23) was for A_1 (60^0B, 180min) followed A_2 (80^0B, 120min) with 8.17 and A_3 (80^0B, 180min) recorded a mean score of 8.13 at the time of storage. Bilimbi fruit osmodehydrated in 60^0B for 180 min recorded the highest mean score of 8.10 after first month, 8.00 after second, 7.83 after third and 7.66 after fourth months of storage. All osmodehydrated combination recorded acceptable scores after 4 month of storage.

Sensory analysis of flavor of osmodehydrated bilimbi fruits at the time of storage (Table17d) revealed that the highest mean score (8.27) was recorded by A_3 (80^0B for 180 min) followed by A_2 (80^0B for 120 min) with 8.0 mean score value and 7.97 for bilimbi osmodehydrated in 60^0B for 180 min (A_2). After four months of storage, the highest mean score for flavour was recorded by A_3 (80^0B for 180 min)

Table17a. Effect of storage on taste of osmodehydrated bilimbi

Osmotic treatments	Effect of storage on taste									
	Initial		1		2		3		4	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
A_1(60^{0}B ,180minutes)	8.30	3	8.23	3	8.17	3	8.07	3	8.00	3
A_2(80^{0}B,120 minutes)	8.33	2	8.30	2	8.27	2	8.23	2	8.15	2
A_3(80^{0}B,180minutes)	8.43	1	8.36	1	8.33	1	8.27	1	8.17	1
KW value	14.96		14.68		14.41		14.05		13.93	
χ^2 (0.05)	5.99									

Table17b. Effect of storage on colour of osmodehydrated bilimbi

Osmotic treatments	Effect of storage on colour									
	Initial		1		2		3		4	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
A_1(60 ^{0}B ,180minutes)	8.23	1	8.10	1	8.00	1	7.83	1	7.66	1
A_2(80^{0}B, 120 minutes)	8.17	2	8.00	2	7.96	2	7.73	2	7.59	2
A_3(80^{0}B, 180 minutes)	8.13	3	7.93	3	7.83	3	7.62	3	7.57	3
KW value	14.93		14.46		13.77		12.81		11.90	
χ^2 (0.05)	5.99									

Table17c. Effect of storage on texture of osmodehydrated bilimbi

Osmotic treatments	Effect of storage on texture									
	Initial		1		2		3		4	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
A_1 (60 ^{0}B ,180minutes)	8.40	2	8.30	2	8.23	2	8.17	2	8.13	2
A_2 (80^{0}B, 120 minutes)	8.40	2	8.27	3	8.23	2	8.13	3	8.07	3
A_3 (80^{0}B, 180 minutes)	8.47	1	8.37	1	8.30	1	8.23	1	8.17	1
KW value	15.23		15.12		14.98		14.81		14.78	
χ^2 (0.05)	5.99									

Table17d. Effect of storage on flavour of osmodehydrated bilimbi

Osmotic treatments	Effect of storage on flavour									
	Initial		1		2		3		4	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
A_1 (60 ^{0}B ,180minutes)	7.97	3	7.90	3	7.87	3	7.80	2	7.67	3
A_2 (80^{0}B, 120 minutes)	8.00	2	7.97	2	7.87	2	7.80	2	7.70	2
A_3 (80^{0}B, 180 minutes)	8.27	1	8.20	1	8.17	1	8.10	1	7.97	1
KW value	14.72		14.56		14.24		13.86		13.56	
χ^2 (0.05)	5.99									

(7.97) followed by A_2 (80^0B for 120 min) with 7.70 mean score and A_1 (80^0B for 180 min) recorded 7.67 and all treatments were acceptable for flavour.

Among the treatments, the highest mean score (8.47) for texture was recorded by A_3 (80^0B, 180 min) followed by A_1 (8.4) and A_2 (8.4) at the time of storage (Table 17c). Osmodehydrated bilimbi at 80^0B for 180 minutes recorded highest mean score of 8.37, 8.30 and 8.23 after first, second and third month of storage. At the end of storage period A_3 recorded the highest mean score of 8.17 for texture followed by A_1 (8.13) and A_2 (8.07).

Effect of storage on overall acceptability of osmodehydrated bilimbi is depicted in Table17e. The highest mean score (8.43) was recorded for osmodehydrated bilimbi A_3 (80^0B, 180min) followed by A_2 (80^0 B, 120 min) with 8.40 and A_1 (60^0 B, 180 min) recorded 8.33 at the time of storage. After one month of storage the osmodehydrated bilimbi at 80^0 B, 180 minutes (A_1) recorded the highest mean score of 8.37 for overall acceptability and highest mean score of 8.30, 8.23 and 8.17 after 2^{nd}, 3^{rd} and 4^{th} months of storage at room temperature.

4.2.3 Microbial Analysis

The osmodehydrated bilimbi fruits on storage for 4 months were microbiologically found safe (Table 18). For microbial stability, total plate count method was conducted on the samples at monthly intervals and the result showed that the microbial load for all the three samples increased with storage time and was within the permitted limit.

The lowest fungal load from 1.27 to 2.42 log CFU g^{-1} was observed for the osmodehydrated bilimbi in 80^0B for 180 minutes from the first month of storage to the end of storage of four months. The bacterial load for 60^0B for 180 minutes recorded as the highest which ranged from 2.30 to 4.35 log CFU g^{-1}. Osmodehydrated

Table 17e. Effect of storage on overall acceptability of osmodehydrated bilimbi

Osmotic treatments	Effect of storage on overall acceptability									
	Initial		1		2		3		4	
	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank	Mean score	Rank
A_1 (60 ^{0}B ,180minutes)	8.33	3	8.30	3	8.23	3	8.17	2	8.07	3
A_2 (80^{0}B, 120 minutes)	8.40	2	8.33	2	8.27	2	8.17	2	8.13	2
A_3 (80^{0}B, 180 minutes)	8.43	1	8.37	1	8.30	1	8.23	1	8.17	1
KW value	14.93		14.86		14.77		14.81		13.90	
χ^2 (0.05)	5.99									

Table 18.Microbial analysis during storage of osmodehydrated bilimbi.

Microbial count (log cfu/g)												
OD bilimbi	Fungi					Mean (A)	Bacteria					Mean (A)
	Months after storage (M)						Months after storage (M)					
	0	1	2	3	4		0	1	2	3	4	
A_1 (60^0B,180minutes)	0	1.89	2.28	2.57	2.84	2.34	0	2.30	2.76	3.55	4.35	3.24
A_2 (80^0B,120 minutes)	0	1.52	1.99	2.44	2.58	2.13	0	1.99	2.55	2.77	3.34	2.66
A_3 (80^0B, 180 minutes)	0	1.27	1.74	2.21	2.42	1.91	0	1.25	1.76	2.24	2.53	1.95
Mean(M)	0	1.56	2.01	2.41	2.61		0	1.85	2.36	2.85	3.41	
CD (0.05%) A- 0.070 M-0.081 A x M-NS							CD (0.05%) A- 0.015 M-0.018 A x M -0.031					

bilimbi A_3 (80^0B for 180 min) recorded lowest bacterial load ranging from 1.85 to 3.41 log CFU g^{-1}during storage.

The storage study of osmodehydrated bilimbi revealed that all the three treatments were microbiologically safe and acceptable up to four months of storage and the treatment 80^0B for 180 minutes was selected as the best treatment which exhibited highest acceptability during storage.

4.2 ASSESSMENT OF BIOACTIVE COMPOUNDS

Biochemical parameters *viz.*, TSS, free acids, pH, total sugar, reducing sugar vitamin C, carotenoids, phenols, total flavanoid, antioxidant activity and oxalate content in fresh (M_5) as well as primary processed bilimbi through osmodehydration (M_1), drying (M_2), hot water blanching (M_3) and steam blanching (M_4) were assessed and results are presented in this section (Table 19a and Table 19b).

On comparing biochemical parameters of dehydrated samples osmodehydrated bilimbi (M_1) recorded the highest TSS of 19.32 ^{0}B and dried bilimbi (M_2) recorded a TSS of 15.33 ^{0}B. Steam blanched bilimbi recorded a TSS of 3.92 ^{0}B which was higher than hot water blanched (M_3) (3.82) while the fresh bilimbi recorded a TSS of 4.10 ^{0}B.

Different primary processing treatments influenced free acid percentage of bilimbi fruit. Dried bilimbi (M_2) fruit recorded the highest free acid content of 4.94% and osmodehydrated bilimbi (M_1) recorded 2.33 per cent. Among blanching treatments, the highest (1.49%) was observed for steam blanching and lowest free acid content (1.40 %) was noticed in hot water blanching (M_3) while fresh bilimbi recorded a free acid content of 1.61 per cent.

Dried bilimbi fruits (M_2) noticed the highest pH of 0.68 and lowest pH of 0.37 was recorded in osmodehydrated bilimbi (M_1). Hot water blanched bilimbi (M_3) recorded the highest pH (1.58) and the lowest (1.02) was recorded for fresh bilimbi (M_5) whereas steam blanched fruits (M_4) observed a pH of 1.22.

Bilimbi fruits subjected to osmotic dehydration (M_1) perceived highest total sugar of 18.73% but dried fruit (M_2) recorded a lower value of 10.57%. Hot water blanching, steam blanching and fresh fruit did not show any significance difference in total sugar content and it ranged from 2.04 to 2.16 per cent.

Osmodehydrated bilimbi (M_1) recorded higher reducing sugar content of 8.22% followed by dried bilimbi (M_2) with 3.45 per cent. There was no significant difference for reducing sugar content between hot water blanched, steam blanched and fresh bilimbi and the amount ranged between 1.17 and 1.26 per cent.

Carotenoid content of bilimbi fruits showed difference with drying treatments where osmodehydrated bilimbi (M_1) recorded the highest of 0.46 mg/100 g whereas it was 0.42 mg/100g for dried fruit. No significant difference in carotenoid content was observed for hot water blanched, steam blanched and fresh bilimbi fruits and content ranged between 0.34 and 0.35mg/100g among the treatments.

Bilimbi fruits subjected to drying (M_2) noticed highest ascorbic acid content of 43.18 mg/100g and osmodehydrated bilimbi (M_1) recorded a content of 21.76 mg/100g. Steam blanched bilimbi fruit had the highest ascorbic acid content of 27.78 mg/100g, hot water blanched fruit recorded a value of 25.82 mg/100g whereas fresh fruit exhibited an ascorbic acid content of 30.19 mg/100g.

Phenolic content in dried bilimbi (M_2) was the highest (694.60 mg/100g) and osmodehydrated bilimbi (M_1) recorded a phenol content of 657.48 mg/100g. Steam blanched fruits (M_4) recorded the highest phenolic content of 1067.31 mg/100g and hot water blanched fruits recorded 1004.85 mg/100g where as fresh bilimbi fruits recorded the lowest value of 975.67 mg/100g as compared to blanched fruits.

Dried bilimbi fruits showed an antioxidant activity of 56.23 per cent whereas osmodehydrated fruits showed 48.23 per cent activity. Steam blanched fruits exhibited higher antioxidant activity of 74.83 % and hot water blanched bilimbi had an activity of 72.45 per cent where as fresh bilimbi recorded an antioxidant activity of 68.35 per cent.

Total flavanoid content of dried bilimbi was recorded as 338.02 $\mu g\ g^{-1}$ which was higher than osmodehydrated bilimbi fruits (241.20 $\mu g\ g^{-1}$). Total flavanoid of fresh fruit was recorded as 134.38 $\mu g\ g^{-1}$ whereas blanching increased the content and steam blanched fruit recorded the highest total flavanoid content of 198.92 $\mu g\ g^{-1}$ and it was 164.91 $\mu g\ g^{-1}$ for hot water blanched fruits.

An oxalate content of 31.78 mg g^{-1} was observed for the dried bilimbi fruits and osmodehydrated sample recorded a lower value of 24.34 mg g^{-1}. Water blanched bilimbi fruit recorded an oxalate content of 8.08 mg/ g^{-1} whereas it was 9.02 for steam blanched and oxalate content of fresh bilimbi was recorded as 9.44 mg g^{-1} . The analysis of biochemical parameters revealed that primary processing methods significantly influenced the bioactive compounds in bilimbi.

Table 19a. Biochemical parameters of primary processed bilimbi

Treatments	TSS (^{0}B)	Free acids (%)	Total sugar (%)	Reducing sugar (%)	pH	Ascorbic acid (mg/100g)	Carotenoid (mg/100g)	Phenol (mg/100g)	Antioxidant activity (%)	Total flavonoids(µg g^{-1})	Oxalates (mg g^{-1})
M_1- Osmodehydration	19.32	2.33	18.73	8.22	0.68	21.76	0.46	657.48	48.23	241.20	24.34
M_2-Drying	15.33	4.94	10.57	3.45	0.37	43.18	0.42	694.60	56.23	338.02	31.78
CD (0.05)	0.77	0.43	0.39	0.13	0.11	1.73	0.005	22.65	3.96	19.08	1.61

Table 19b. Biochemical parameters of primary processed bilimbi

Treatments	TSS (^{0}B)	Free acids (%)	Total sugar (%)	Reducing sugar (%)	pH	Ascorbic acid (mg/100g)	Carotenoid (mg/100g)	Phenol (mg/100g)	Antioxidant activity (%)	Total flavonoids (µg g^{-1})	Oxalates (mg g^{-1})
M_3-Hot water blanching	3.82	1.40	2.04	1.17	1.58	25.82	0.35	1004.85	72.45	164.91	8.08
M_4-Steam blanching	3.92	1.49	2.13	1.19	1.22	27.78	0.34	1067.31	74.83	198.92	9.02
M_5- Fresh bilimbi (Control)	4.10	1.61	2.16	1.26	1.02	30.19	0.35	975.67	68.35	134.38	9.44
CD (0.05)	0.11	0.09	NS	NS	0.16	2.06	NS	43.58	1.45	16.53	0.55

Discussion

5. DISCUSSION

The results obtained from the investigation on 'Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compounds' are discussed in this chapter under following headings.

5.1 Development of osmodehydrated bilimbi

5.2 Assessment of bioactive compounds

5.1. DEVELOPMENT OF OSMODEHYDRATED BILIMBI

5.1.1. Mass Transfer Characters

Mass transfer characters *viz.,* solid gain, weight reduction, water loss and ratio of water loss to solid gain play an important role in the development of osmodehydrated products were used to indicate the overall exchange of solute and water between bilimbi fruit and osmotic solution.

Solid gain of osmosed bilimbi increased with the increase in osmotic concentration and immersion time (Fig. 1). Osmodehydrated bilimbi in 80^0 B for an immersion time of 180 minutes recorded the highest solid gain of 5.10 per cent. These results are in conformation with the findings of Kumar and Devi (2011) for osmodehydration of pineapple which showed that increase in concentration led to increased solid gain and maximum solid gain of 14.9% was recorded after 6 h of immersion in 70°B. Extended osmotic treatment will increase the solute concentrations and increase of water loss and solid gain rate was also reported by Phisut (2012) in cantaloupes.

Water loss from bilimbi fruits against the time of osmosis at different osmotic concentration is presented in Fig. 2. Both immersion time and osmotic concentration significantly influenced water loss of osmodehydrated bilimbi. The highest water loss (16.72 %) was observed for osmosed bilimbi in 80 ^{0}B for 180 minutes of immersion time while lowest water loss (4.58 %) was in treatment

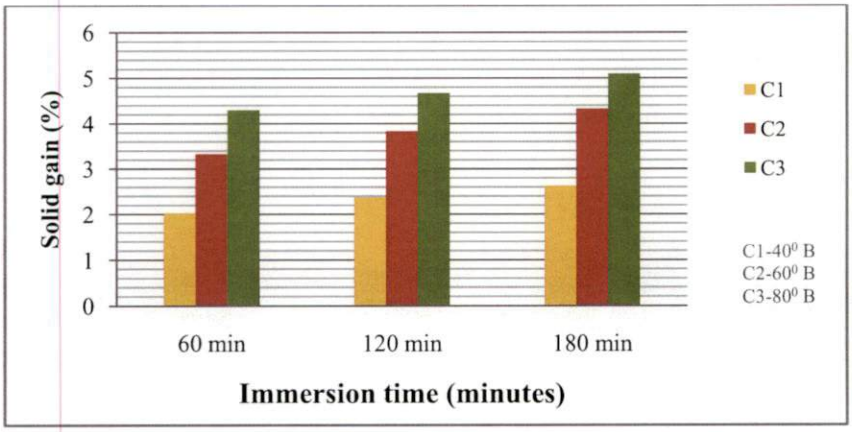


Fig. 1.Effect of osmotic concentration and immersion time on solid gain (%) of osmodehydratedbilimbi

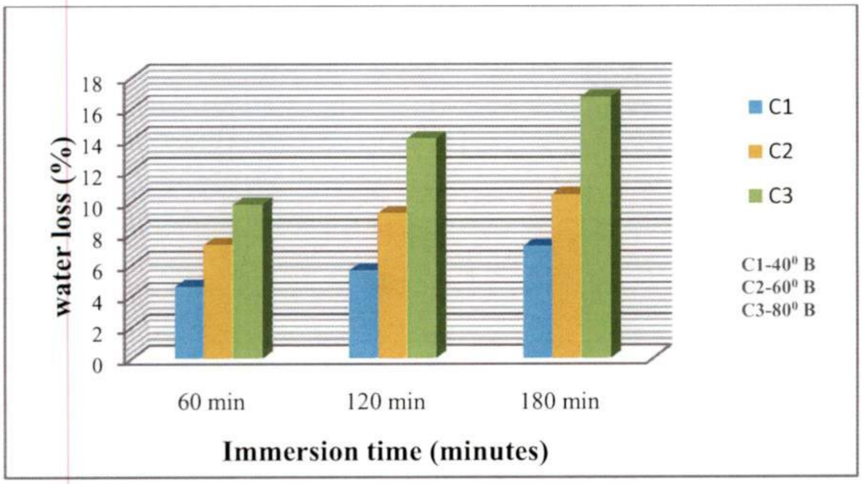


Fig. 2.Effect of osmotic concentration and immersion time on water loss (%) ofosmodehydratedbilimbi

40^0B for 60 minutes. The results are in line with the findings Rittirut and Siriptana (2007) in osmodehydrated bilimbi where highest water loss and acid loss was observed for highest concentration (70 ^{0}B) and immersion time (9,000 min). Similar results were reported by Alam and Singh (2008) in aonla were the water loss as well as solid gain increased non-linearly with time at all concentrations of osmotic solution.

Percentage weight reduction of osmodehydrated bilimbi increased with increase in concentration and immersion time. Osmodehydrated bilimbi at 80^0B for 180 minutes recorded maximum weight reduction of 22.57 per cent followed by osmotic treatment 80^0B for 120 minutes. Highest water loss with increase in osmotic concentration lead to highest weight reduction of osmodehydrated product. This was supported by the findings of Conway *et al.* (1983); Marcotte. (1991); Lenart, (1992) and Tortoe (2010).

Ratio of water loss to solid gain (WL/SG) is considered as a good indicator for maximisation of water loss and minimisation of solid gain. In the current study, WL/SG recorded a maximum ratio of 3.25 for the treatment 80^0B for 180 minutes and the lowest ratio (2.17) was observed in 60^0B for 60 minutes. Low solid gain resulted in high WL/SG ratio was reported in apple immersed in salt solution (Sereno, 2001). Sharma *et al.* (2006) reported that during osmodehydration water loss is always favored over solid gain.

Osmotic concentration and immersion time significantly influenced yield of bilimbi and increased with increase in osmotic concentration and immersion time. The highest yield of 21.13 per cent was observed when fruits are immersed in 80^0 B for 180 minutes and the lowest yield of 18.03 was noticed in 40^0 B for 60 minutes. This is in line with the reports of Pedpathi and Tiwari (2007) stated that osmodehydrated guava in 70 ^{0}B for 24 h exhibited highest yield of 39.67 per cent. Suhasini (2013) reported that increased osmotic concentration and immersion time also increased final yield of karonda.

5.1.3 Biochemical Parameters

Osmodehydration results in sweeter products as compared to conventionally dried products. Osmotically dehydrated fruits and vegetables become very attractive for direct use due to their physio chemical and sensory qualities (Tortoe, 2010). During osmosis water that flows from the fruit to the osmotic solution is accompanied by natural soluble substances such as sugar, minerals, salts, organic acids, *etc* (Peiro *et al.*, 2006). Biochemical properties of osmodehydrated bilimbi fruits were significantly influenced by osmotic concentrations and immersion time.

Bilimbi fruit immersed in 80^0 B sucrose solution for 180 minutes recorded the lowest free acid content of 2.31 per cent whereas the highest free acid of 4.16 per cent was shown by the treatment 40^0 B for 60 minutes. Acidity of fruits was decreased with increase in osmotic concentration and immersion time (Fig. 3). Rittirut and Siriptatana (2009b) also reported that during osmodehydration of bilimbi fruits acid loss increased with increase in syrup concentration. Various researchers reported that acidity of fruits decreased with increase in osmotic concentration and immersion time (Peiro-Mena *et al.*, 2007; Devic *et al.*, 2010; Vijayakumari *et al.*, 2007; Phisut *et al.*, 2013a; Phisut *et al.*, 2013b). Reduction in acidity can be attributed to the leaching of acid from fruits to the osmotic solution through a semi permeable membrane (Sagar and Kumar, 2009).

Ascorbic acid content of osmodehydrated bilimbi decreased with increase in concentration and immersion time. The highest percent of ascorbic acid (34.26 mg /100g) was noticed in treatment 40^0B for 60 minutes and the lowest ascorbic acid (21.66 mg/100g) was for bilimbi osmosed in 80^0B for 180 minutes. Loss of ascorbic acid, a water soluble vitamin in processed products was mainly due to leaching in syrup, oxidation as well as thermal degradation (Sanjinez-Argandoña, 2005). Several scientists reported that ascorbic acid losses during osmotic dehydration might be attributed to the leaching of the vitamin from the product to the osmotic solution during the osmotic process. (Chiralt and Talens., 2005); Mandala *et al.* 2005; Singh and Gupta. 2007; Shi and Xue 2009; Devic *et al.*, 2010; Nadia *et al.*, 2013; Phisut *et al.*, 2013a; Phisut *et al.*, 2013b).

Bilimbi osmodehydrated in 80^0B for 180 minute recorded highest total sugar (18.53%) (Fig. 4) and reducing sugar (8.24 %). The lowest total sugar of 11.44 per cent and 3.72% reducing sugar was noticed in 40^0B in 60 minutes. With increase in immersion time and sucrose concentration both total and reducing sugar increased. Geetha *et al.* (2006) observed that sugar percentage of osmodehydrated sample increases with increase in immersion time and concentration. Sagar and Suresh (2009b) reported that osmotic drying substantially increased sugar content and reduced acidity without changing colour, texture, and original flavor of mango fruit slices. Several research workers reported that uptake of solutes and a resultant increase in sugar content in fruit slices is characteristic phenomenon of the osmosis process (Torreggiani, 1993; Chavan *et al.*, 2010, Amin and Hossain, 2012 and Patil *et al.,* 2013).

Antioxidant activity of osmodehydrated bilimbi reduced significantly during osmodehydration. Bilimbi fruits immersed in 40^0B for 60 minutes showed the highest antioxidant activity of 56.45 per cent and the lowest antioxidant activity of 47.81 per cent was observed for the treatment 80^0B for 180 minutes. Padmanabhan and Jangle (2012) reported that antioxidant activity will be more if percentage of inhibition is higher. Similar results were also reported by Phisut *et al.* (2013a) and Phisut *et al.* (2013b) in cantaloups and low antioxidant activity can be attributed to high leaching of soluble antioxidant components during osmotic dehydration process. Giovanelli *et al.*, (2013) reported the significant loss in the antioxidant activity of osmo dehydrated blue berries during osmotic treatment.

5.1.4 Sensory Analysis

Osmotic concentration and immersion time significantly influenced the sensory quality *viz.*, taste, colour, flavour, texture and overall acceptability. It was

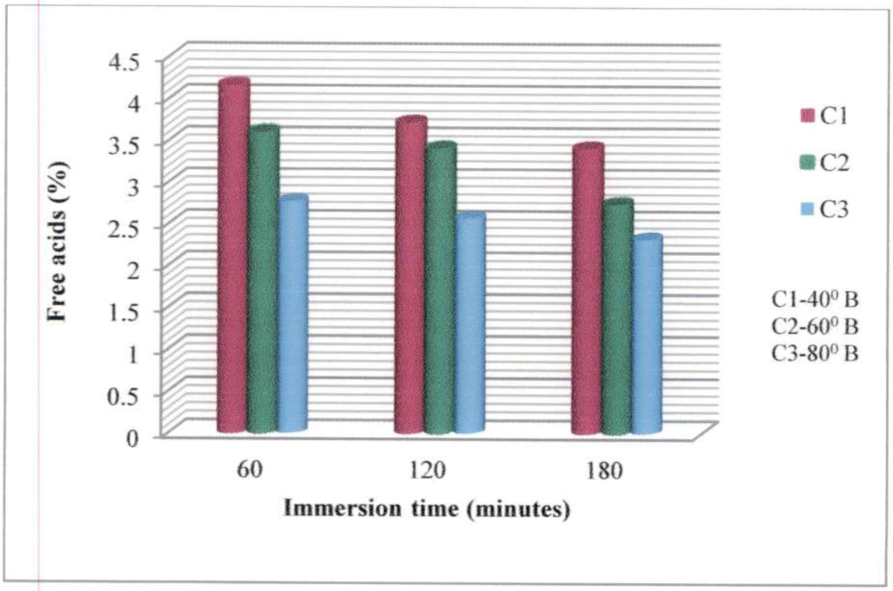


Fig. 3. Effect of osmotic concentration and immersion time on free acids (%) of osmodehydrated bilimbi

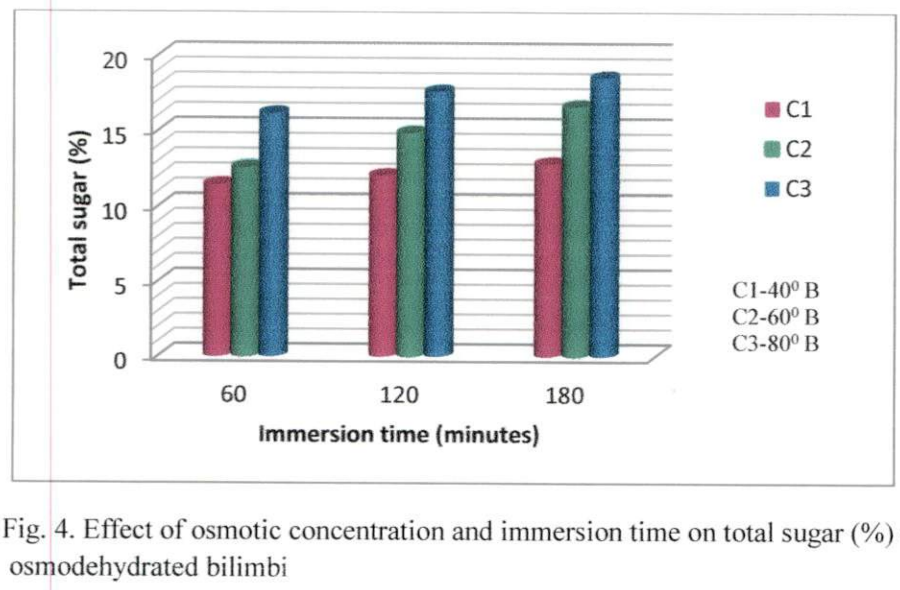


Fig. 4. Effect of osmotic concentration and immersion time on total sugar (%) of osmodehydrated bilimbi

observed that 80^0 B with180 minutes immersion time recorded highest mean score for taste (8.43), flavour (8.27), texture (8.47) and overall acceptability (8.43). Fruits immersed in 60^0B for 180 minutes the highest (8.23) sensory score for colour which was followed by the treatment 80^0B for 180 min (8.17). This was supported by the findings of Chiralt *et al.* (2001) who reported that water loss and sugar gain during osmotic dehydration may give some cryoprotectant effects on colour and texture in several fruits. Kumar *et al.*(2008) reported that osmotic drying substantially increased sugar content and reduced acidity without changing colour, texture, and original flavour of mango fruit slices. Osmotic pretreatment with 70^0B sugar syrup for 18 hours resulted in highest sensory score in karonda compared to control (Suhasini, 2013).

Studies conducted by Kumar and Sagar (2009) in pineapple, Prasannath and Mahendran (2009) in osmo dehydrated jackfruit, Chavan *et al.* (2010) in banana, Shafiq *et al.* (2010) in aonla, Kumar and Devi (2011) in pineapple slices, Nadia *et al.* (2013) in pear Suhasini (2013) in karonda and Kedarnath *et al.* (2014a) in sapota slices revealed the positive effect of osmotic dehydration on sensory qualities.

5.1.5 Storage Studies

Osmodehydrated bilimbi treatments with highest consumer acceptability selected for storage studies were 80^0B for 180 minutes (A_3), 80^0B for 120 minutes (A_2) and 60^0B for 180 minutes (A_1). They were kept under room temperature and were analysed for biochemical, sensory and microbial parameters at monthly intervals.

5.1.5.1 Biochemical Parameters

Free acid content of osmodehydrated bilimbi fruits was reduced during storage. Osmodehydrated bilimbi in 60^0B for 180 minutes recorded decrease in free acid content from 2.74 per cent to 2.54 % and for bilimbi in 80^0B for 120 minutes decrease from 2.60% to 2.37% and 2.32 per cent to 2.06 per cent for 80^0B in 180 minutes after four months of storage. Sagar *et al.* (1998) studied different quality parameters of dehydrated ripe mango slices and recorded that the acidity percentage decreased from 0.32 to 0.28 per cent after six months of storage. Similar results were observed by Bolini *et al.* (2006) in papaya, Auti (2012) in pineapple and Suhasini (2013) in karonda. The decrease in acidity during storage might be due to bio-conversion of acids into sugars (Lal *et al.,* 2015).

Reducing sugar and total sugar content of osmodehydrated biimbi increased slightly during storage but there was no significant difference among the osmotic treatment. Reducing sugar of osmodehydrated bilimbi in 80^0B for 180 minutes increased from 8.25% to 8.75% during storage. Similar results were reported by Sharma and Kaushal (1998) in plum and Sagar and Kumar (2009) in mango. Total sugar of treatment increased from 18.56% to 19.55% after a period of 4 months. The increase in total sugar content during storage is in consonance with Prasannath and Mahendran (2009), Sharma *et al.* (2006) and Rashmi *et al.* (2005). The possible reason for gradual increase in total sugars during storage period could be explained by the fact that the polysaccharides might have converted into monosaccharide (Lal *et al.,* 2015). The increase might also be attributed to hydrolysis of starch into sugars (Roy and Singh, 1979)

Ascorbic acid showed a decreasing trend in all the treatments over a storage period of four months at ambient conditions (Fig. 5.). During storage, ascorbic acid of osmodehydrated bilimbi in 60 ^{0}B for 180 minutes immersion time was decreased from 24.65 to 23.00 mg/100g and treatment 80 ^{0}B for 120 minutes ascorbic acid reduced from 22.49 to 20.97mg/100g. Ascorbic acid of osmodehydrated bilimbi in 80^0B for 180 minutes recorded lowest value (19.29 mg/100g) after four month of storage. The reduction in ascorbic acid content might be due to oxidation during storage at high ambient temperature (Pragati *et al.*, 2003). A similar trend in reduction of ascorbic acid was also observed in osmodehydrated pineapple by Rashmi *et al.* (2005) and Lal *et al.* (2015).

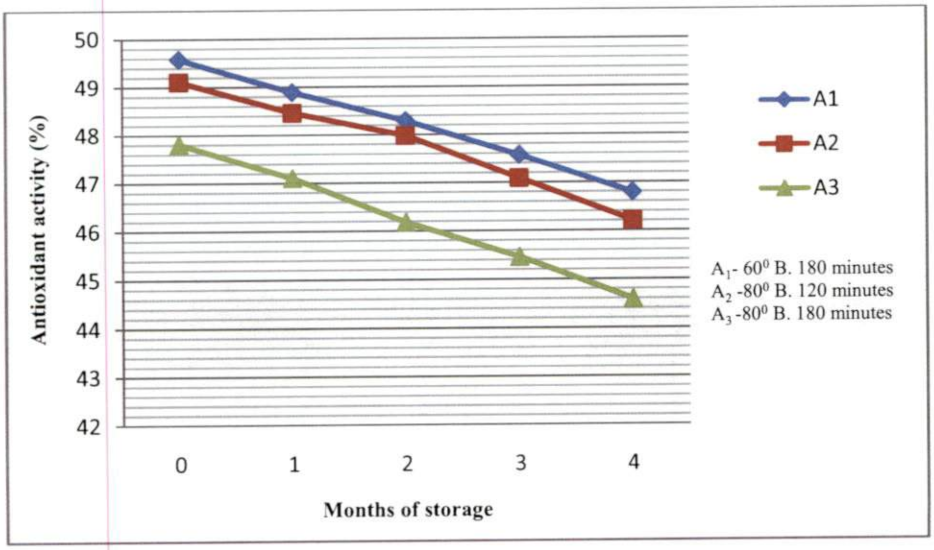


Fig. 5.Effect of storage on antioxidant activity (%) of osmodehydrated bilimbi

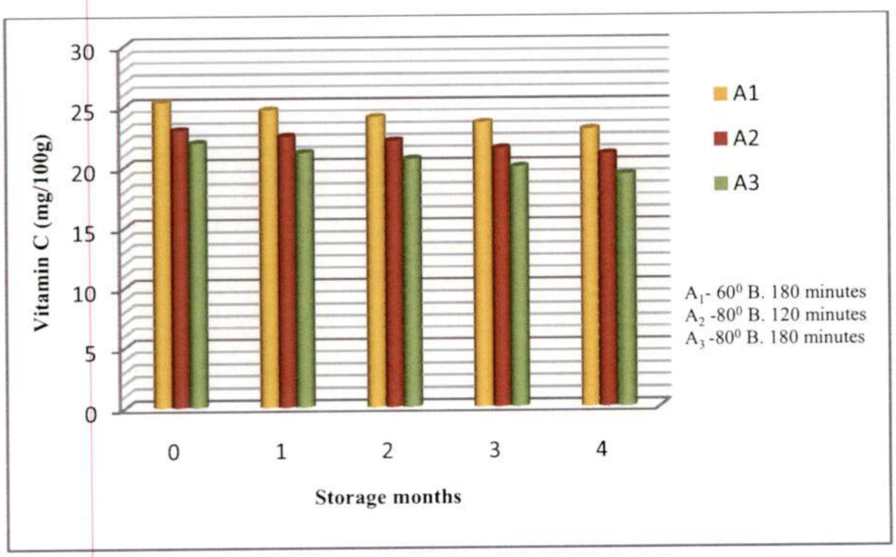


Fig. 6.Effect of storage on vitamin C (mg/100g) of osmodehydrated bilimbi

Osmodehydrated bilimbi in 60^0B for 180 minutes immersion recorded highest antioxidant activity of 49.58 per cent at the time of storage and which reduced to 46.79 per cent after fourth month of storage (Fig. 6.). The loss of total flavonoid content during storage of osmodehydrated pineapple was reported by Hui *et al.* (2017). Hasanuzzaman *et al.* (2013) stated that phenols, flavanoid and ascorbic acid contribute antioxidant activity of bilimbi.

5.1.5.1.2 Sensory Analysis

Sensory parameters *viz.,* taste, colour, flavor, texture and overall acceptability of osmodehydrated bilimbi were analysed monthly interval for a period of 4 months and analysis revealed a slight reduction in mean score for all the parameters towards the end of storage.

The mean score for taste decreased for all the stored bilimbi fruits and it decreased from 8.43 to 8.17 for the fruits with 80^0B in180minutes. Bilimbi osmodehydrated in 80^0B for 180minutes recorded highest values for flavour (7.97), textute (8.23) and overall acceptability (8.17) (Fig. 7.) after the fourth month of storage which was followed by the treatments 80^0B for 120minutes and 60^0B for 180minutes. Treatment 60 ^{0}B for 180 minutes recorded highest score for colour (7.66) at the end of storage.

Colour of the product is the key to success of a processed product in market. Colour is associated with the quality of product and may be taken as the indicator of level of natural deterioration of fresh foods (Krokida *et al.*, 2000). Colour score of fruit slices decreased during storage which may be due to absorption of atmospheric moisture and oxygen which influenced compositional status and also caramelization of sugar present in the product caused browning. Reduced mean score for flavour, taste and over all acceptability (Fig. 8.) during storage was supported by Awasthi *et al.* (1984) in banana, Aruna *et al.* (1999) in apple ,Narayana *et al.* (2003) in banana fig and Ahmed *et al.* (2004). Sabrina *et al.*(2009) observed that there will be decline in overall acceptability of osmodehydrated mango slices during storage.

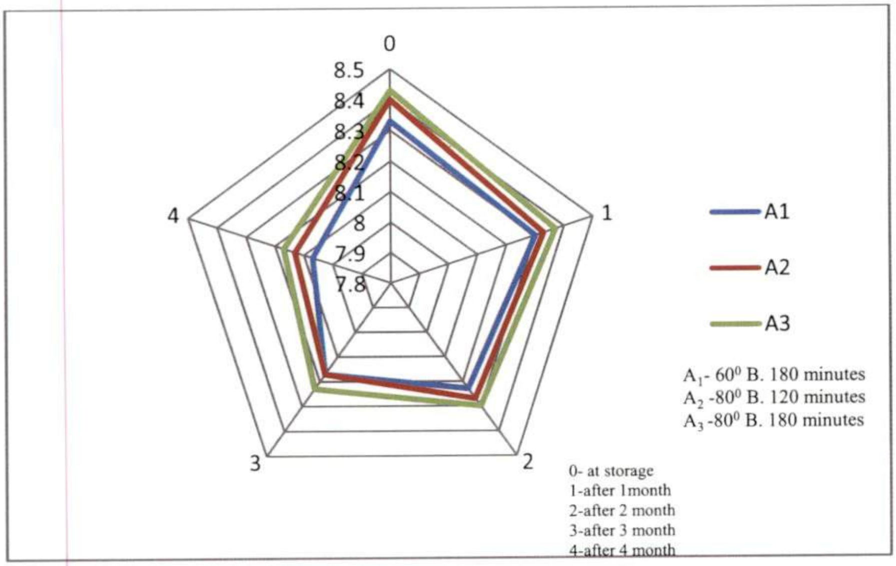


Fig. 7.Overall acceptability of osmodehydrated bilimbi during storage

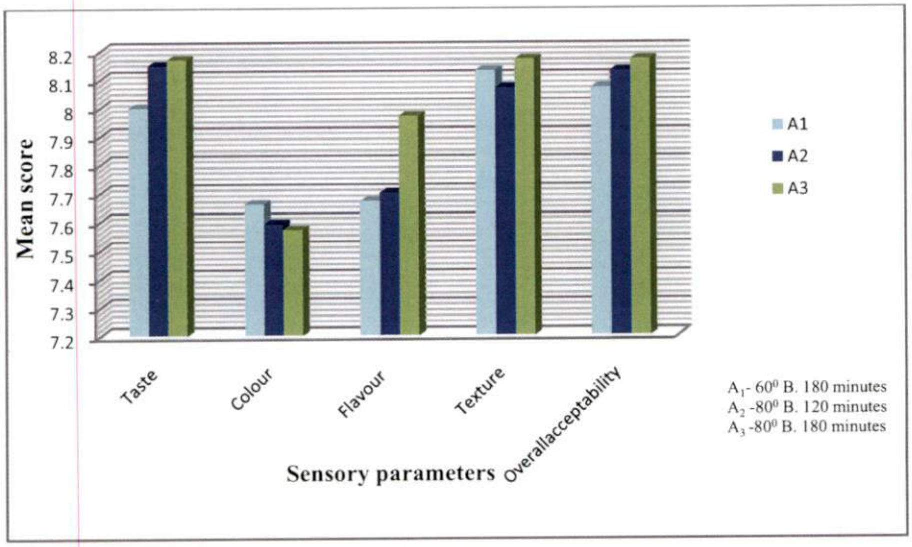


Fig. 8.Sensory parameters of osmodehydrated bilimbi at 4^{th} month of storage

5.1.5.3 Microbial Analysis

The osmodehydrated bilimbi fruits were microbiologically safe for a period of 4 months of storage. Microbial analysis was conducted for the samples at monthly intervals and the result showed that even though the microbial load for all the three samples slightly increased with storage, it was within the permitted limit as per FSSAI (2011) regulations.

Low microbial count may be probably due to addition of KMS, high acidity, increased sugar and low moisture of the osmodehydrated product. Same results were reported in osmodehydrated banana slices which were microbiologically safe for a period of 180 days (Chavan *et al.*, 2010). Rahman *et al.* (2012) reported that the higher concentration of sugar in the syrup and added preservative (KMS) coupled with low moisture content in storage prevented microbial growth. Osmodehydrated carambola fruit slices showed a shelf life of 8 month at ambient temperature (30 ± 2^0c) (Roopa *et al.,* 2014)

5.2 ASSESSMENT OF BIOACTIVE COMPOUNDS

The chemical characterisation and quantification of bioactive components in processed products are important for assessing the nutritional value and quality. Primary processed products are employed for the devolopment of secondary products and retention of bioactive compounds is greatly influenced by primary processing methods. Effect of primary processing methods *viz.,* osmodehydration, drying, hot water blanching and steam blanching in retention of bioactive compounds were studied.

Bilimbi osmodehydrated in 80^0B for 180 minutes recorded the highest TSS of 19.32 ^{0}B and dried bilimbi recorded a TSS of 15.33 ^{0}B where as TSS of fresh bilimbi was 4.10 ^{0}B. Drying of fruits will results in concentration of solids due to moisture loss which might be the reason for increased TSS in bilimbi. Impregnation of bilimbi fruits in sucrose solution facilitated solid gain, absorption of sugar by fruits from the osmotic solution yielded higher TSS of osmodehydrated bilimbi. Bernardi *et al.* (2009) described that TSS of osmodehydrated ripe mango slices increased up to 35^0B when treated with 60^0B sugar syrup and dried at 45^0C. Osmodehydration increased TSS of pineapple slices by three times (Dionello *et al.*, 2009). Blanching treatment significantly reduced the TSS of bilimbi fruits. Water blanching of bilimbi recorded lowest TSS of 3.82 ^{0}B whereas steam blanching recorded 3.92 ^{0}B as compared to 4.10 ^{0}B for fresh bilimbi. TSS of fruit includes sugar, organic acids, amino acids, soluble pectins and mineral salts (Rahman and Lamb 1991; Karathanos *et al.*, 1995) and water blanching of bilimbi might have resulted in leaching of acid and other solutes which contributed to lowest TSS. In contrary to this Workneh *et al.* (2014) reported that blanching treatment resulted in increase of TSS in pumpkin slices.

Different primary processing treatments influenced free acid percentage of bilimbi fruit. Dried bilimbi fruits recorded the highest free acid content of 4.94 per cent and osmodehydrated bilimbi recorded 2.33 per cent. Blanching treatment significantly reduced free acid content of bilimbi fruits. Steam blanched bilimbi recorded a free acid content of 1.49% and water blanched fruits reduced the free acid to 1.40% in comparison with fresh bilimbi (1.61%). The result agrees with the previous reports that dipping product in osmotic solutions and blanching reduced fruit acidity by leaching the titratable acid from the product (Ponting 1973; Brennand 1994). pH of dried and blanched bilimbi fruits differed significantly. Dried bilimbi fruits noticed the highest pH of 0.68 followed by osmodehydrated bilimbi (0.37). Paulson and Stevens (1974) showed that pH value was highly correlated with acidity which is in harmony with the present result of this study *ie,* pH value increases with decrease in acidity. Water blanched bilimbi recorded the highest pH (1.58) when compared with steam blanching (1.22) and fresh bilimbi (1.02). Bhaskar and Shantaram (2013) recorded a higher pH (2.16) for fresh fruit. Adubofuor *et al.* (2016) reported that blanching had no significant effect on pH of carrots.

Bilimbi fruits subjected to osmotic dehydration perceived highest total sugar (18.73%) and reducing sugar (8.22%) whereas dried fruit recorded total sugar of 10.57 per cent and 3.45 per cent reducing sugar. Suresh (2009b) reported that osmotic drying substantially increased sugar content which is due to solute uptake during osmodehydration and concentration of sugars. Hot water blanching, steam blanching and fresh fruit did not show any significance difference for total and reducing sugar. This was supported by the findings of Shubhra *et al.* (2014) who found that blanching had negligible effect on reducing sugar and non reducing sugar in aloe gel.

Osmodehydrated bilimbi recorded the highest carotenoid content (0.46 mg/100g) whereas it was 0.42 mg/100g for dried fruit. No significant difference in carotenoid content was observed for hot water blanched, steam blanched and fresh bilimbi fruits and value ranged from 0.34 - 0.35mg/100g among the treatments and results are in conformation with the value recorded by Roy *et al.* (2011). These results are supported by the finding of Rawson *et al.* (2011) who reported that the total carotenoid content in tamarillo nectar is not affected by thermal degradation.

Dried bilimbi noticed highest vitamin C (43.18 mg/100) compared to osmodehydrated bilimbi. This was supported by the findings of Shahari *et al.* (2015) who reported that fruits dehydrated with salt (2%) retained a higher content of vitamin C compared to those subjected to other supplementary pretreatments. Blanching treatments reduced vitamin C content of bilimbi fruits. Water blanched bilimbi recorded a vitamin C content of 25.82 mg/100g, it was 27.78 mg/100g for steam blanching whereas fresh fruit recorded a Vitamin C content of 30.19 mg/100g. Roy *et al.* (2011) estimated vitamin C content as 15.6 mg/100g in fresh fruit whereas Lima *et al.* (2011) reported that vitamin C of fresh fruit varies from 20.82 to 60.95 mg/100g. The loss in vitamin C content during blanching could be attributed to the fact that vitamin C is water soluble and not stable at high temperature. This was supported by the finding of Negi and Roy

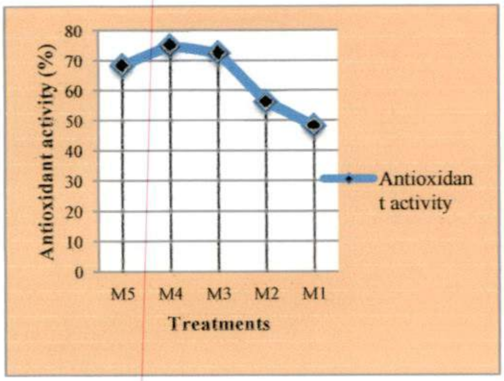
(2008) who reported that blanching treatments cause vitamin loss by thermal degradation, diffusion and leaching.

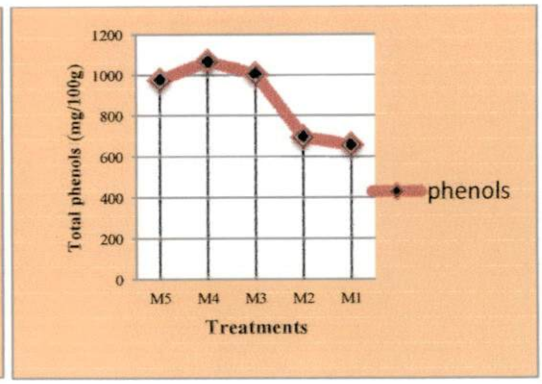
Total phenol in dried bilimbi was the highest (694.60 mg/100g) and osmodehydrated bilimbi recorded a phenol content of 657.48 mg/100g (Fig. 9a). Stojanovic and Silva (2007) reported that increased osmotic concentration and immersion time resulted in higher loss of phenol in blueberries due to the leaching into sucrose solution and negative influence of oxygen. Blanching treatment increased phenol content of bilimbi and steam blanched fruits recorded the highest phenolic content (1067.31 mg/100g) followed by water blanched (1004.85) whereas fresh bilimbi fruits recorded the lowest value (975.67 mg/100g). This agrees with the findings of Morales – de la Pena *et al.* (2011) who reported increase in phenol content with heat treatments and stated that the increase could be due to the formation of new phenolic compounds as a result of biochemical reactions during heat treatment or due to release of some free phenol acids or flavanoids as a result of some effect on cell membranes or in phenolic complexes with other compounds or due to inactivation of polyphenol oxidase enzyme (PPO) which prevents further loss of phenolic compounds or might be due to enhancement of phenolic concentration since heat treatment have induced favorable conditions to increase phenylanine ammonialyase (PAL) activity. Cherian (2015) reported that banching treatments increased total phenols in aloe gel.

Dried bilimbi fruits showed an antioxidant activity of 56.23 per cent (Fig. 9b) whereas osmodehydrated fruits showed 48.23 per cent activity. Phisut *et al.* (2013a) and Phisut *et al.* (2013b) reported the significant loss in antioxidant activity and phenolic content of osmodehydrated cantaloupes when compared with fresh sample. Anthocyanins, flavanols and ascorbic acid are damaged during the drying process as well as drop in antioxidant content may be due to oxidation and sensitivity while drying (Wojdylo *et al.*, 2009). Blanched fruits exhibited higher antioxidant activity (steam blanched- 74.83% and water blanched-72.45%) compared to fresh bilimbi (68.35%). Stem blanched bilimbi fruits exhibited higher antioxidant activity due to high phenols and total flavonoids. Same results were reported by Kaushal *et al.* (2013) in blueberry. Ikram *et al.* (2009) evaluated antioxidant activity and total phenol content of bilimbi, and recorded a content of 1261.63 mg/100 g and 91.8% antioxidant capacity. Asna and Noriham (2014) reported strong positive correlation between antioxidant activity and total phenols and total flavanoid.

Total flavanoid content of dried fruit was recorded as 338.02 µg g^{-1} which was higher than osmodehydrated fruits (241.20µg g^{-1}) (Fig. 9c). Yan *et al.* (2016) recorded flavanoid content of bilimbi as 153.38 mg/100g in dry weight basis. Total flavanoid of fresh fruit was recorded as 134.3µg g^{-1} whereas blanching increased flavonoid content and steam blanched fruit recorded the highest total flavanoid (198.92 µg g^{-1}) and it was 164.91 µg g^{-1} for hot water blanched bilimbi. Stewart *et al.* (2000) reported that slight heat treatment will increase level of free flavonols and thus total flavanoid increases. Dewanto *et al.* (2002) found that, heating treatment significantly increases the biological activities of fruits and vegetables compared to fresh one and this may be due to the various chemical changes during thermal processing.

Dried bilimbi fruits exhibited higher oxalate content of 31.78 mg g^{-1} whereas osmodehydrated bilimbi recorded a lower value of 24.34 mg g^{-1} (Fig 9 d).. Thus osmodehydration of bilimbi helped in reducing the oxalate content. This was in line with the observations of Pragathi *et al.* (2003) who observed that osmo air drying treatment reduced anti nutritional factors in aonla fruit compared to other drying because of leaching. Blanching treatment significantly reduced the oxalate content and water blanched bilimbi fruit recorded the lowest oxalate content (8.08 mg g^{-1}) as compared to steam blanched bilimbi (9.02 mg g^{-1}) whereas fresh bilimbi recorded an oxalate content of 9.44 mg g^{-1}. Hence blanching treatments of bilimbi significantly reduced the oxalate content and water blanching was found more effective than steam blanching for oxalate reduction which might be due to the leaching of oxalates. This was supported by the findings of Gebczynski (2002) who reported that pre-treatment of fruits and

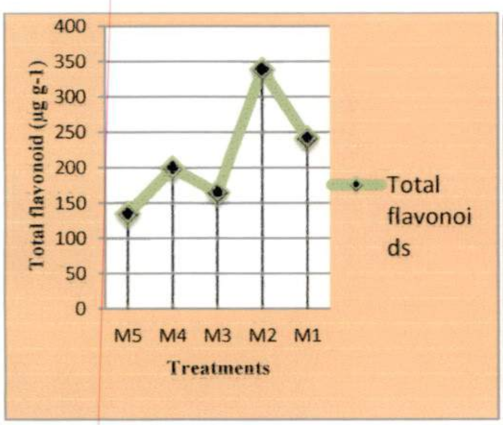


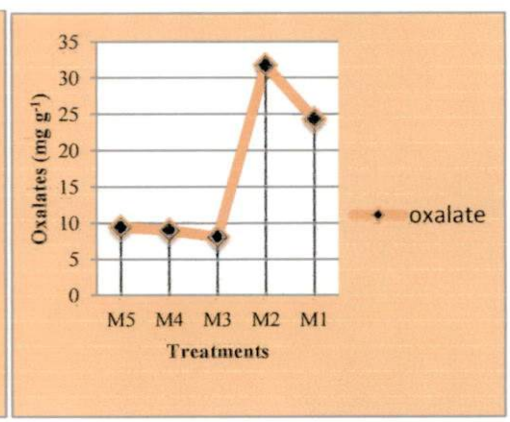


a. Antioxidant activity (%)

b. Phenol content (mg/100g)

M_1–osmodehydrated
M_2–dried
M_3–hot water blanched
M_4–steam blanched
M_5–fresh bilimbi





c. Total flavonoids ($\mu g\ g^{-1}$)

d. Oxalate ($mg\ g^{-1}$)

Fig. 9. Effect of primary processing methods on bioactive compounds of bilimbi

vegetables such as washing, blanching etc. usually reduces the content of nitrates, nitrites and oxalates.

Summary

6. SUMMARY

The present study entitled "Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compounds" was carried out in the Department of Post Harvest Technology of College of Agriculture, Vellayani during the period 2015-2017, with the objective to standardize process variables for osmodehydrated bilimbi and to assess the retention of bioactive compounds

The study was carried out as two separate experiments

1. Development of osmodehydrated bilimbi

2. Assessment of bioactive compounds in bilimbi

Major findings of the study are summarized as below.

Bilimbi fruits of uniform size and maturity were harvested, blanched and subjected to osmotic treatments. Bilimbi fruits were osmosed in three different osmotic concentrations of 40, 60 and 80^0B for an immersion time of 60, 120, and 180 minutes. Osmosed bilimbi was analyzed for mass transfer characters *viz.,* solid gain, water loss, percentage weight reduction, rate of water loss to solid gain. Biochemical parameters such as free acids, vitamin C, reducing sugar, total sugar and antioxidant activity and sensory analysis was conducted for all osmodehydrated bilimbi treatments.

Bilimbi fruits osmodehydrated in 80^0B for 180 minutes recorded highest values for all mass transfer charcters *viz.,* solid gain (5.10%), water loss (16.72%), percentage weight reduction (22.57 %), ratio of water loss to solid gain (3.25) which was followed by 80^0B for 120 minutes and 60^0B for 180 minutes. Bilimbi osmodehydrated in 80^0B for 180 minutes also recorded highest values for total sugar (18.53%), reducing sugar (8.24 %) and lowest values for free acid (2.31%), vitamin C (21.66 mg/100g) and antioxidant activity (47.81%).

The sensory analysis of all osmodehydrated bilimbi fruits with respect to taste, colour, flavour, texture and overall acceptability was conducted. Bilimbi osmodehydrated in 80^0 B for 180 minutes immersion time recorded the highest mean score of for taste (8.43), flavour (8.27), texture (8.47) and overall acceptability (8.43) which was followed by 80^0 B for 120 minutes and 60^0B for 180 minutes. The treatment 60^0B for 180 minutes recorded the highest mean score (8.23) for colour followed by 80^0B for 120 minutes (8.17) and 80^0B for 180 minutes (8.13).

Mass transfer characters, biochemical parameters and sensory analysis of osmodehydrated bilimbi revealed that osmotic treatment 80^0B for 180 minutes yielded the best osmodehydrated bilimbi followed by 80^0B for 120 minutes and 60^0B for 180 minutes immersion time with good retention of nutritional parameters and acceptability and were selected for storage studies.

The selected osmodehydrated bilimbi was stored at room temperature for four months and was analyzed for biochemical, sensory and microbial qualities at monthly intervals. During storage, reducing sugar and total sugar increased while ascorbic acid, antioxidant activity and free acids decreased. Osmodehydrated bilimbi in 80^0B for an immersion time of 180 minutes recorded 2.06 % free acid content, 19.55% total sugar, 8.75% reducing sugar, 19.29% vitamin C and 44.59% antioxidant activity at the end of four months storage with highest sensory score.

All the osmodehydrated bilimbi fruits were microbiologically safe till the end of storage. The storage study revealed that all the three treatments were safe and acceptable during the storage period and the treatment 80^0B for 180 minute considered as the best treatment which exhibited highest acceptability during storage with a mean score of 8.17 for taste, 7.97 for flavour, 8.17 for texture and 8.17 for overall acceptability.

Biochemical parameters such as TSS, free acids, pH, total sugar, reducing sugar vitamin C, carotenoids, phenols, total flavanoid, antioxidant activity and oxalate content present in primary processed bilimbi *viz.* osmodehydration, drying, hot water blanching, steam blanching and fresh bilimbi were assessed. Osmodehydrated bilimbi fruits recorded the highest TSS (19.32 ^{0}B), total sugar (18.73 %), reducing sugar (8.22%), carotenoids (0.46 mg/100g) and lowest oxalate content (24.34 mg/g) whereas dried bilimbi showed highest ascorbic acid (43.18 mg/100g), total phenols (694.60 mg/100g), antioxidant activity (56.23%), total flavonoid content (338.03 μgg^{-1}) and highest oxalate content of 31.78 mg/g. Blanching treatments was found to reduce TSS, free acids, vitamin C and oxalate content of fruits. Hot water blanched fruits exhibited lowest oxalate content (8.08 mg g^{-1}) and TSS (3.82 ^{0}B) whereas steam blanched fruits recorded the highest antioxidant activity (74.83%), total phenol (1067.31 mg/100g) and total flavanoid content (198.32 $\mu g\ g^{-1}$). Fresh bilimbi recorded the lowest phenol (975.67 mg/100g), total flavanoid (134.38 $\mu g\ g^{-1}$) with 68.35% antioxidant activity.

Osmotic treatment at 80 ^{0}B for 180 minutes was found as the best treatment for development of osmodehydrated bilimbi and the product was organoleptically acceptable and microbiologcally safe for a period of four months. Bioactive compounds in bilimbi were significantly influenced by the primary processing methods. Dried bilimbi exhibited highest antioxidant activity, phenols and total flavonoids when compared with osmodehydrated bilimbi. Whereas blanching treatment increased antioxidant activity, total phenols and flavonoids of bilimbi fruits. Hot water blanched bilimbi and osmodehydrated bilimbi significantly reduced the oxalate content when compared to other treatments.

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DEVELOPMENT OF OSMODEHYDRATED BILIMBI (*Averrhoa bilimbi* L.) AND ASSESSMENT OF BIOACTIVE COMPOUNDS

by

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ABSTRACT

The present study entitled "Development of osmodehydrated bilimbi (*Averroha bilimbi* L.) and assessment of bioactive compounds" was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellayani during 2015-17 with the objective to standardize the process variables for osmodehydrated bilimbi and to assess the retention of bioactive compounds.

Harvested mature bilimbi fruits of uniform size were washed, surface dried, pricked and blanched in hot water for one minute. Blanched fruits were subjected to osmotic treatment, with sucrose solution of 40, 60 and 80^0B for 60, 120 and 180 minutes.

The osmodehydrated bilimbi fruits were analyzed for mass transfer, biochemical and sensory qualities. Mass transfer characters *viz*., solid gain, water loss, percentage weight reduction, yield and biochemical parameters such as reducing sugar and total sugar increased with increase in osmotic concentration and immersion time whereas free acids, ascorbic acid and antioxidant activity were decreased. The osmotic treatment of 80 ^{0}B for 180 minutes recorded the highest value for solid gain (5.10 %), water loss (16.72%), weight reduction (22.57%), ratio of water loss to solid gain (3.25%) and yield (21.13%) with a free acid content of 2.32 %, 21.66 mg/100g vitamin C, 47.81% antioxidant activity, 8.24% reducing sugar and 18.53% total sugar which exhibited superior sensory scores for taste (8.43), flavor (8.27), texture (8.46) and overall acceptability (8.43). The best three treatments selected based on sensory analysis (80 ^{0}B for 180 minutes, 80 ^{0}B for 120 minutes and 60 ^{0}B for 180 minutes) were subjected to storage stability studies under room temperature for four months.

The stored osmodehydrated bilimbi fruits were analyzed for biochemical, sensory and microbial qualities at monthly intervals. During storage, reducing sugar and total sugar increased while ascorbic acid, antioxidant activity and free acids decreased. Osmodehydrated bilimbi in 80^0B for an immersion time of 180 minutes recorded 2.06 % free acid content, 19.55% total sugar, 8.75% reducing sugar, 19.29% vitamin C and 44.59% antioxidant activity at the end of four month

storage with highest sensory score. All the osmodehydrated bilimbi fruits were microbiologically safe till the end of storage.

Bioactive compounds *viz.* vitamin C, phenols, total flavonoids, antioxidant activity, carotenoids, free acids, and oxalate content of osmodehydrated, dried, hot water blanched, steam blanched and fresh bilimbi fruits were assessed. Osmodehydrated bilimbi fruits recorded the highest TSS (19.32 ^{0}B), total sugar (18.73 %), reducing sugar (8.22%), carotenoids (0.46 mg/100g) and lowest oxalate content (24.34 mg/g) whereas dried bilimbi showed highest ascorbic acid (43.18 mg/100g), total phenols (694.60 mg/100g), antioxidant activity (56.23%), total flavonoid content (338.03 $\mu g\ g^{-1}$) and highest oxalate content of 31.78 mg/g. Blanching treatments was found to reduce TSS, free acids, vitamin C and oxalate content of fruits. Hot water blanched fruits exhibited lowest oxalate content (8.08 mg/g) and TSS (3.82 ^{0}B) whereas steam blanching recorded the highest antioxidant activity (74.83%) total phenol (1067.31 mg/100g) and total flavanoid (198.32 $\mu g\ g^{-1}$) whereas fresh bilimbi recorded 975.67 mg/100g phenols, 134.38 $\mu g\ g^{-1}$ total flavanoid with 68.35% antioxidant activity.

Osmotic treatment at 80 ^{0}B for 180 minutes was found as the best treatment for development of osmodehydrated bilimbi. Bioactive compounds in primary processed bilimbi are greatly influenced by the processing methods.

സംഗ്രഹം

ഓസ്മോ ഡീഹൈഡ്രേറ്റഡ് പുളിഞ്ചിയുടെ പ്രക്രിയ ഘടകങ്ങൾ ക്രമീകരിക്കുകയും ബയോ-ആക്ടിവ് പദാർത്ഥങ്ങളുടെ നിലനിർത്തൽ കണക്കാക്കുകയും എന്ന ലക്ഷ്യത്തോട് കൂടി വെള്ളായണി കാർഷിക കോളേജിലെ പോസ്റ്റ് ഹാർവെസ്റ്റ് ടെക്നോളജി വിഭാഗത്തിൽ 2015-17 കാലയളവിൽ "ഓസ്മോ ഡീഹൈഡ്രേറ്റഡ് പുളിഞ്ചി (*അവെറോഹ ബിലിമ്പി*) നിർമാണവും കൂടാതെ ബയോആക്ടിവ് പദാര്ത്ഥങ്ങൾ കണക്കാകുകയും" ചെയ്യുന്നതിനുള്ള പഠനം നടത്തി.

ഒരേ വലുപ്പവും മൂപ്പെത്തിയതുമായ പുളിഞ്ചി ഫലങ്ങൾ കഴുകി തുടച്ചതിനു ശേഷം തുളകളിട്ട് ഒരു മിനിറ്റ് നേരം തിളച്ച വെള്ളത്തി ബ്ലാൻച് ചെയ്തെടുത്തു. ബ്ലാൻച് ചെയ്തെടുത്ത ഫലങ്ങൾ 40, 60, 80 °B ഗാഢതയിലുള്ള സുക്രോസ് ലായനിയിൽ 60, 120, 180 മിനിറ്റ് നേരം മുക്കിവെച്ചു.

ഓസ്മോ ഡീഹൈഡ്രേഷൻ ചെയ്തെടുത്ത പുളിഞ്ചി ഫലങ്ങളുടെ ഘനകൈമാറ്റ തോത്, ബയോ-കെമികൽ ഗുണങ്ങൾ, സെൻസറി ഗുണങ്ങൾ എന്നിവ കണക്കാക്കി. ഘന-കൈമാറ്റ പ്രക്രിയകളായ സോളിഡ് ഗയിൻ, ജലനഷ്ടം, ഭാരനഷ്ടം, ഉണക്കിയ വിളവ്, കൂടാതെ, റെഡ്യൂസിംഗ് ഷുഗർ എന്നിവ ഒസ്മോടിക് ദ്രാവകത്തിന്റെ ഗാഢതയും മുക്കിവെയ്ക്കുന്ന സമയവും കൂടുന്നതിനനുസരിച്ച് വർദ്ധിച്ചു. എന്നാൽ, ഫ്രീ - അമ്ലത്വവും അസ്കോർബിക് ആസിഡിന്റെ അളവും നിരോക്സീകരണ പ്രവർത്തനവും കുറഞ്ഞു. 80°B ലായനിയിൽ 180 മിനിട്ട് മുക്കിവെച്ച ഫലങ്ങൾക്കാണ് ഏറ്റവും കൂടുതൽ സോളിഡ് ഗയിൻ (5.10%), ജലനഷ്ടം (16.72%), ഭാരനഷ്ടം (22.57%), ഉണക്കിയ വിളവ് (21.13%), ജലനഷ്ടവും സോളിഡ് ഗയിനും തമ്മിലുള്ള അനുപാതം (3.25%), കൂടാതെ, ഫ്രീ-അമ്ലത്വം (2.32%), 21.66 mg/100g അസ്കോർബിക് ആസിഡ്, 47.18% നിരോക്സീകരണ പ്രവർത്തനം, 8.24% റെഡ്യൂസിംഗ് ഷുഗർ, 18.5 3% ടോട്ടൽ ഷുഗർ എന്നിവയും ഏറ്റവും ഉയർന്ന സെൻസറി ഗുണങ്ങളും രേഖപ്പെടുത്തിയത്. ഇതിൽ നിന്നും തെരഞ്ഞെടുത്ത 3 മികച്ച ട്രീറ്റ്മെന്റ്കൾ 4 മാസത്തെ സൂക്ഷിപ്പ് കാലാവധി പഠനങ്ങൾക്കായി അന്തരീക്ഷ താപനിലയിൽ സൂക്ഷിച്ചു. സൂക്ഷിച്ചു വെച്ച ഓസ്മോ ഡീഹൈഡ്രേറ്റഡ് ഫലങ്ങൾ ഒരുമാസത്തെ ഇടവേളയിൽ മൈക്രോബിയൽ, ബയോ-കെമികൽ, സെൻസറി പഠനങ്ങൾക്ക് വിധേയമാക്കി. സൂക്ഷിപ്പ് കാലവധിയ്ക്ക് അനുസരിച്ചു റെഡ്യൂസിംഗ് ഷുഗർ, ടോട്ടൽ ഷുഗർ എന്നിവയുടെ അളവ് കൂടുകയും ഫ്രീ – അമ്ലത്വം അസ്കോർബിക് ആസിഡ് നിരോക്സീകരണ പ്രവര്ത്തനം എന്നിവ കുറയുകയും ചെയ്തു. 80°B ലായനിയിൽ 180 മിനിറ്റ് ട്രീറ്റ് ചെയ്തെടുത്ത പുളിഞ്ചി ഫലങ്ങൾ നാലാം മാസത്തിന്റെ അവസാനത്തിൽ ഏറ്റവും ഉയർന്ന സെൻസറി ഗുണങ്ങൾ കാഴ്ചവെക്കുകയും ഫ്രീ- അമ്ലത്വം (2.06%), 19.29mg/100g അസ്കോർബിക് ആസിഡ്, 44.59% നിരോക്സീകരണ പ്രവർത്തനം, 8.75% റെഡ്യൂസിംഗ് ഷുഗർ, 19.55% ടോട്ടൽ ഷുഗർ എന്നിവയും രേഖപ്പെടുത്തി. എല്ലാ ഒസ്മോ

ഡീഹൈഡ്രാറ്റഡ് പുളിഞ്ചി ഫലങ്ങളും സൂക്ഷിപ്പ് കാലാവധി തീരുന്നത് വരെ മൈക്രോ-ബയോളജിക്കൽ പരമായി സുരക്ഷിതമായിരുന്നു.

തിളച്ച വെള്ളത്തിൽ മുക്കിയെടുത്തതും, ആവിയിൽ ബ്ലാൻച് ചെയ്തെടുത്തതും, ഉണക്കിയതും, ഒസ്മോ ഡീഹൈഡ്രാഷൻ ചെയ്തെടുത്തതുമായ പുളിഞ്ചി ഫലങ്ങളുടെ ബയോ-ആക്ടിവ് പദാർത്ഥങ്ങൾ (അസ്കോർബിക് ആസിഡ്, ഫീനോൾ, ടോട്ടൽ ഫ്ലാവനോയിഡ്, നിരോക്സീകരണ പ്രവർത്തനം) എന്നിവ പരിശോധിച്ചു. ഒസ്മോ ഡീഹൈഃഡ്രഷൻ ചെയ്തെടുത്ത ഫലങ്ങൾക്കാണ് ഏറ്റവും കൂടുതൽ TSS (19.32°B) റെഡ്യൂസിംഗ് ഷുഗർ (8.22%) ടോട്ടൽ ഷുഗർ (18.73%), കരോട്ടിനോയിഡ് (0.46 mg/100g) എന്നിവയും ഏറ്റവും കുറവു ഒക്സലെറ്റ് (24.34mg/g) എന്നിവയും രേഖപ്പെടുത്തി. എന്നാൽ ഉണക്കിയെടുത്ത ഫലങ്ങൾക്കാണ് ഏറ്റവും കൂടുതൽ അസ്കോർബിക് ആസിഡ് (43.18mg/100g), ടോട്ടൽ ഫീനോൾ (694.60mg/100g), നിരോക്സീകരണ പ്രവർത്തനം (5 6.2 3%), ടോട്ടൽ ഫ്ലാവനോയിഡ് (338.03 മൈക്രോ ഗ്രാം/ഗ്രാം), ഒക്സലെറ്റ്(31.78 മി. ഗ്രാം/ഗ്രാം) എന്നിവ രേഖപ്പെടുത്തിയത്. ബ്ലാന്ച് പരിചരണ പ്രവർത്തനം ചെയ്യുന്നത് വഴി TSS, ഫ്രീ-അമ്ലത്വം, അസ്കോർബിക് ആസിഡ്, ഒക്സലെറ്റ് അളവുകൾ കുറഞ്ഞു. ആവിയിൽ ബ്ലാൻച് ചെയ്തെടുത്ത ഫലങ്ങൾ ഏറ്റവും ഉയർന്ന ടോട്ടൽ ഫീനോൾ (1067.31 mg/100g), നിരോക്സീകരണ പ്രവർത്തനം (74.83%), ടോട്ടൽ ഫ്ലാവനോയിഡ് (198.32 മൈക്രോ ഗ്രാം/ഗ്രാം) എന്നിവയും തിളച്ച വെള്ളത്തിൽ ബ്ലാന്ച് ചെയ്തെടുത്ത ഫലങ്ങൾ ഏറ്റവും കുറഞ്ഞ ഒക്സലെറ്റ് (8.08 മി. ഗ്രാം/ഗ്രാം), TSS (3.82 °B)എന്നിവയും രേഖപ്പെടുത്തി.

80 °B ലായനിയിൽ 180 മിനിറ്റ് മുക്കിവെച്ച പുളിഞ്ചി മികച്ച ട്രീറ്റ് മെന്റ് ആയി തെരഞ്ഞെടുത്തു. പ്രഥമ പരിചരണ പ്രവർത്തനങ്ങൾ പുളിഞ്ചിയുടെ ബയോ-ആക്ടിവ് പദാർഥങ്ങളെ കാര്യമായി സ്വാധീനിച്ചു.

Appendices

APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Title: Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compounds

Score card for assessing the organoleptic qualities of osmo dehydrated bilimbi

Sample: **Osmodehydrated bilimbi**

Instructions : Your are given 9 osmo dehydrated bilimbi samples. Evaluate them and give scores for each criteria

Criteria	Samples								
	1	2	3	4	5	6	7	8	9
Taste									
Colour									
Flavour									
Texture(hard/firm/soft)									
Overall acceptability									
Any other remarks									

<u>Score</u>

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

Date :

Name :

Signature :

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Dept. of Post Harvest Technology

Title: Development of osmodehydrated bilimbi (*Averrhoa bilimbi* L.) and assessment of bioactive compounds

Score card for assessing the organoleptic qualities of stored osmodehydrated bilimbi

Sample: Osmodehydrated bilimbi

Instructions: You are given 3samples. Evaluate them and give scores for each criteria

Criteria	Samples		
	1	2	**3**
Taste			
Colour			
Flavour			
Texture			
Overall accepatability			

<u>Score</u>

Like extremely -9

Like very much -8

Like moderately -7

Like slightly -6

Neither like or dislike -5

Dislike slightly -4

Dislike moderately -3

Dislike very much -2

Dislike extremely -1

Date : Name :

Signature :