Studies on Optimization of Processing and Storage Conditions of Some Underutilized Fruits for Better Retention of Nutritional Quality

Thesis submitted by:
Ipsita Banerjee

(Index No. 181/11/E)

Doctor of Philosophy (Engineering)

Department of Food Technology & Biochemical Engineering

Faculty Council of Engineering & Technology

Jadavpur University

Kolkata, India

2018

JADAVPUR UNIVERSITY
KOLKATA – 700032, INDIA

INDEX NO. 181/11/E

Title of the Thesis:

Studies on Optimization of Processing and Storage Conditions of Some Underutilized Fruits for Better Retention of Nutritional Quality

Thesis submitted by: **Ipsita Banerjee**

Name, Designation & Institution of the Supervisor:

Uma Ghosh

Professor

Department of Food Technology & Biochemical Engineering
Jadavpur University, Kolkata

List of Publications:

Journal publications:

1. **Ipsita Banerjee and Uma Ghosh "Effect of pretreatment and concentration of sugar solution on nutritional parameters of osmodried whole amla (*Phyllanthus emblica* L)"; IJLTET, 5(3), 64-67, 2015.**

2. **Ipsita Banerjee, Uma Ghosh "Effect of pretreatments on nutritional quality of minimally processed jackfruit bulbs during storage" International journal for science and advance research in technology. 4(4), 579-582, 2018.**

3. **Ipsita Banerjee, Uma Ghosh "Effect of thermal treatment on phenolic and antioxidant content of fresh bael juice" International Journal of Agricultural Engineering. 11 (2),282-288, 2018.**

4. **Ipsita Banerjee, Uma Ghosh" Effect of pretreatments on drying attributes and quality assessment of bael powder" International Journal for Research in Engineering Application & Management (IJREAM). 4(8),176-182, 2018.**

Manuscript Communicated:

1. **Ipsita Banerjee, Uma Ghosh, "DRYING CHARACTERISTICS AND MATHEMATICAL MODELING OF DRYING OF PRETREATED AMLA SLICES" Journal of Food Science and Technology (Communicated).**

List of Presentations in National / International / Conferences / Workshops:

1. Poster presented "Effect of Different Treatments on Nutritional Quality of Osmodried amla (*Phyllanthus emblica* L.) fruits" at national seminar on "Non thermal processing techniques:Emerging Inovation for Sustainable,safe and Healthy Foods (NTPT-2014)" at Haldia Institute of Technology,Haldia,West Bengal 2014

2. **2nd prize** in poster presentation on "Statistical approach for optimization of processing parameters for osmodried amla". International seminar on Recent Advances in Food Processing and Biotechnology. BHU, 2016.

3. Oral presentation on " Retention on nutritive quality of amla juice by thermal treatment" International seminar on Contemporary development on nutritional research, Barrackpore Rastraguru Surendranath College, 2017

4. **2nd prize** in Oral presentation on "Effect of pretreatments on nutritional quality of Jackfruit (*Artocarpus heterophyllus* L.) bulbs during storage" at national seminar on "Health and Ecology: the interaction and interdependence" Kankabati Rishi Arabinda Rural Development and Social welfare Institute, 2017

DECLARATION

I hereby declare that this thesis entitled **"Studies on Optimization of Processing and Storage Conditions of Some Underutilized Fruits for Better Retention of Nutritional Quality"** is the bonafide report of original research work carried out by me under the guidance of Dr Uma Ghosh, Department of Food Technology and Biochemical Engineering, Jadavpur University and no part thereof has been included in any other thesis submitted previously for the award of any degree.

Place: Jadavpur University, Kolkata ……

Ipsita Banerjee

Date:

ACKNOWLEDGEMENT

I express my sincere gratitude to my supervisor Dr.Uma Ghosh for her continuous support, guidance and encouragement throughout my Ph.D study.

I would like to utilize this opportunity to express my sincere gratitude to all the professors and staff members of the Department of Food Technology and Biochemical Engineering,Jadavpur University, for their encouragement and support during my research work.

I also thankfully acknowledge the cooperation and encouragement that I received form my fellow lab mates Priyanka Ghosh, Tapasi Polley, Atreyi Sarkar, Soumik Banerjee, Arjuma Sultana and friends.

I am indebted to my family members and to my in-laws for everything what they did to facilitate me in all aspects of life. Words cannot express how grateful I am to my parent for all of their sacrifices that they have made on my behalf during my course of study.

And finally, special and profound thanks to my younger sister Sudeshna Banerjee and my Husband Subhasis Mukherjee for their love, encouragement, and concern for me.

I dedicate my thesis to my parents Nemai Banerjee and Sarbani Banerjee for their unconditional love and support.

CERTIFICATE FROM THE SUPERVISORS

This is to certify that the thesis entitled "**Studies on Optimization of Processing and Storage Conditions of Some Underutilized Fruits for Better Retention of Nutritional Quality**" submitted by Ms.Ipsita Banerjee, who got her name registered on 20/5/2011 for the award of Ph. D. (Engg.) degree of Jadavpur University is absolutely based upon her own work under the supervision of Dr. Uma Ghosh, Professor of Department of Food Technology & Biochemical Engineering, Jadavpur University, West Bengal and neither her thesis nor any part of the thesis has been submitted for any degree/diploma or any other academic award anywhere before.

Signature of the Supervisor
and date with Office Seal

17/07/13

DR. UMA GHOSH
HEAD & PROFESSOR
FOOD TECHNOLOGY &
BIOCHEMICAL ENGINEERING
JADAVPUR UNIVERSITY
KOLKATA – 700 032

CONTENT

INTRODUCTION

India has a great agricultural position in world map and has different weather conditions in different season throughout the year. These situations of this country create a preferable environment for growing various fruits and vegetables. Fruits are obtainable in abundance and also in various seasons. India has an enriched genetic diversity of fruits. 68466 thousand metric tons fruits are produced in India and India is a 2nd biggest producer of end result after China within the world[1]. As per National Horticulture Board apple, banana, lemon, grapes, orange, mango and papaya are the main fruits that grow in India. A few percentages of these fruits are grown and acknowledge commercially, at the same time maximum numbers of others fruits are not given same importance nor traded broadly these are referred as underutilized fruit crops. Underutilized fruits are the ones which might be neither cultivated in a prepared farming system nor processed by industrial processing strategies. Those crops have many advantages in phrases of easiness to grow; hardy in nature and production of precise crop even underneath unfavourable conditions. Most of these fruits are rich sources of vitamins, minerals and other nutrients[2]. They have therapeutic properties and use as the source of ayurvedic medicine[3]. They have strong protective effects against major disease risks including cancer and cardiovascular diseases Most of those fruits have an amazing flavour and appealing colour. Those fruit plants have their own history of intake. Local people are aware of their dietary and medicinal values. A large percentage of rural people depend on locally available fruits for their dietary requirement. The popularity of these fruits varies from fruit to fruit and locality to locality which can be enhanced to a greater extent through publicity. The utilization of these fruits not only increase the components of our food basket but also helpful in increasing the beneficial effect of such fruits. However most numbers of underutilized fruit of the tropics are often available in the local markets and are

nearly unknown in other parts of world. Many value added products can be obtained from these indigenous minor fruits also. Today, consumers are becoming very conscious about their health and nutritional aspects of their food basket. In recent times a tendency is developing to avoid chemicals and artificial ingredients and choice for nutrition through natural resources. On the other hand the deterioration of environmental factors and extinction of biodiversity thus warrants sustainable conservation and documentation of indigenous knowledge base. Efforts are required to preserve and document the indigenous knowledge base of local and indigenous communities and its subsequent sustainable utilization. Today almost all modern human food is based on a limited number of crops. Considering food and phyto-assets are shrinking globally with the hike in populace, it is need of the hour to find new options. For this reason those minor indigenous or underutilized fruit species can aid in crop improvement, ecological and meals security. Even though those species continue to be maintained by means of cultural choices and traditional practices but they nevertheless stay inadequately characterised and left out by research and conservation. Inadequate attention indicates that their potential value is under-estimated and under-exploited for which they are in risk of continued genetic erosion and disappearance. Consequently, exploration of these plants with their ethno-biological values is essential for understanding and comparing their financial potential.

Studies at the usage factor will help to pick out new uses, improve production of already recognised products and also promote welfare of the local people. The information available on underutilized fruits is very limited**.** Fortunately scattered reviews do indicate initiation of works on documentation, crop development, agro-approach standardization and value addition of these underutilized crops are available but it still needs thorough nutritional and utilization research. Some potential underutilized fruits are amla, bael and jackfruit etc. These fruits have enormous medicinal value and are used in curing numerous diseases. So, there's

an excellent scope for the processed products from those fruits not only because of their exclusive flavour but additionally due to their neutraceutical significance and therapeutic value. Processing of these underutilized fruits in to value added products effects in an extensive kind of exotically flavored products with higher nutritional and sensory characteristics which could also unveil new markets for export. Keeping in mind the significance of the underutilized fruits, the present study was proposed with the following objectives.

- **To optimize processing and preservation methods of underutilized fruits.**
- **To Increase shelf life of the products.**
- **To retaining maximum amount of nutrients during storage.**

REVIEW OF LITERATURE

The literature reviews collected on the various aspects of present study are listed below.

Amla (*Phyllanthus emblica* L.) the Indian Gooseberry is an important horticultural crop of India. Amla is one of the vital tropic and sub tropic fruits. This fruit is giving splendid increase to horticultural produce in several areas of India. The main advantage of growing amla than other horticultural crops is that, it can adapted to ecologically poor growing conditions which encounter recurrent crop failure and there by economic crises. Among all fruits amla is second highest source of vitamin C (Shankar, 1969)[4] not only that has also high content of antioxidant properties. The maximum size of amla variety Hathijhool followed by Banarasi, Chakaiya, Bansi Red and Deshi cultivars (Teotia et al 1968)[5]. In other study (Singh et al, 1987)[6] result showed Banarasi variety of amla contain maximum fruit weight (32.65 g), diameter (4.24 cm) and seed weight (3.12 gm). Kalra, 1988[7] noticed that Vitamin C content in the amla pulp varies from 200-900 mg/100 gm of fresh fruit. Barthakur and Arnold, 1991[8] observed in the gooseberry fruits ascorbic acid content was reported to be 160 times more than that of apple. Goyal et al 2008[9] stated that amla is rich source of pectin so it could be

used for preparing jelly, pickles, candy. Edible portion of amla (100 gm) contains 81.8% moisture, carbohydrates (13.7 gm), fibre (3.4 gm), protein (0.5 gm), fat (0.1 gm), calcium (0.05 gm), phosphorous (0.02 gm), 1.2 mg iron, niacin (0.2 mg), thiamine (0.03 g), riboflavin (0.01 mg), carotene (9μ g) and ascorbic acid (600 mg) observed by Swaminathan 1990[10]. Studies on TSS of some important varieties of aonla of Eastern Uttar Pradesh reported that TSS ranged from 9 to 15^0Brix (Teotia et al, 1968)[5]. During study of physico-chemical composition of different cultivars of aonla, Singh et al (1987)[11] noticed that maximum TSS of 14.8^0Brix in Deshi cultivar followed by Harpharori and Banarasi and Chakaiya had minimum TSS of 10.7°B. Ghorai and Sethi (1996)[12] stated that 83.76 and 85.35 % moisture in Deshi and Banarasi variety of amla fruit, respectively whereas 87.17 % moisture for Chakaiya and 80.98 for Deshi variety of fresh amla fruit observed by Premi et al (1999)[13].Gooseberry fruits contain 86.3 percent moisture in Chakaiya, 86.6 % in Krishna variety and87.3 percent in NA-7 obtained by Vijayanand et al (2007)[14]. The acidity of amla fruit ranged from 2.17 to 2.58 % of Deshi variety having maximum acidity followed by Hathijhool, Banarasi, Bansi Red, and Chakaiya varieties noted by Teotia et al (1968)[5]. Ram et al (1983)[15] conducted experiment on composition of amla fruits during growth and development and noticed that acidity increased to 2.73 percent in September from 0.70 in August acquire its peak value of 2.93 percent in November whereas pH value remained almost fixed at 2.5 during fruit growth, also observed that tannins content had been intently related with astringency of the amla fruit which extensively decreased with development of maturity. Authors determined that tannins content confirmed a descending order from 4.68 percent within the initial levels to 0.52 percent throughout month of January. Aonla fruits acquire maturity after mid December had ascorbic acid content of 500.5 mg/100g and ascorbic acid level increased from 57.5 mg/100g in August to 564 mg/100g in 3rd week of January observed by Ram et al (1983)[15]. Singh et al (1987)[11] observed that ascorbic acid content of fruit depends directly with the fruit weight.

Authors also found that weight of Banarasi variety was high and ascorbic acid content (638.8 mg/100g) was also high which was followed by Harpharori (598 mg/100g), Chakaiya (574.5 mg/100g) and Deshi (458.9 mg/100g). The total sugars content in amla fruit varied from 7.0 to 9.6% and reducing sugars from 1.04 - 4.09 percent whereas non reducing sugars varies from 3.05 to 7.23 percent noticed by Kalra (1988)[7].

Singh, 2003[16] noted that amla have high efficiency in curing illnesses inclusive of dysentery, diarrhea, fever, common cold, anemia and jaundice due to acidic, cooling, diuretic and laxative properties of the fruit. Amla fruit is significantly utilized in ayurvedic and unani system of medicine and its beneficial consequences have been ascribed to synergistic action and presence of antracin and phenol observed by Jain et al, 1983[17].

As a result of its sour and extraordinarily acidic nature consumers do not like this fruit as raw, therefore different products are produced from amla via processing. Amla are available only for few months so they require absolute care during post harvest managing. Due to the fact that amla fruit has short shelf life at room temperature, hence to be processed into different products in order that it could be consumed all over the year.

Bael fruit (*Aegle marmelos*) has extended records of use in traditional medicine, much of which is being confirmed by way of scientific research, it is belong to kingdom: Plantae, family Rutaceae, Genus: Aegle and Species: A. Marmelos. This is also referred to as "Bengal quince". A. Marmelos also recognised through various names all over the country and outside of country i.e. Hindi (Bel, bael, sripal); Sanskrit (Bilva, sriphal, shivadruma, Shivapala); Telugu (Maredu); Bengali (Bel); Gujrati (Bil); Kannada (Bilpatra, kumbala, malura); Tamil (Kuvalum); Thai (Matum and mapin); Cambodia (Phneou or pnoi); Vietnamese (Baunau); Malayan (Maja pahit); French (Oranger du Malabar); Portuguese (Marmelos); Java (Modjo) and so on (Chemexcil, 1992)[18]. It has excellent mythological and spiritual importance in Indian cultural history. Bael is a vital tropical medicinal

plant which possesses a variety of medicinal properties. It is native to India having origin from Eastern Ghats and Central India. It is grown during India with altitude 1200 meter also in Sri Lanka, Pakistan, Bangladesh, Burma, Thailand, and most of the Southeast Asian countries. It is native to Indi (Singh and Roy, 1984)[19]. The bael fruit is round, oval, or oblong, 5 to 20 cm in diameter may additionally have a thin, hard, woody shell or a more or less smooth rind, gray-green until the fruit is utterly ripe, when it turns yellowish. The look of yellow or orange edible pulp is like a boiled pumpkin, Possesses a barely sweet taste and a characteristics floral, terpene like aroma and pleasantly flavoured and is surrounded by using slimy transparent mucilage. Gopalan et al., 1954[20] observed that the bael fruit is extremely nutritious. It contains 61.5 g water, 1.8 g protein, 0.39 g fat, 1.7 g minerals, 31.8 g carbohydrates, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1 mg niacin, and 8 mg vitamin C in 100 g of edible portion. Charoensiddhi et al 2008[21] stated that the bael fruit is a superb source of indigenous natural antioxidants and bioactive compounds containing exceedingly excessive content of dietary fiber, carotenoids, phenolics, flavonoids, ascorbic acid and also strong antioxidant sports. Moreover, it also has the appealing yellowish-orange pulp appearance as well as a fragrant and excellent flavor. The main risky compounds are monoterpenes and sesquiterpenes. Nagaraju and Rao, 1990[22] observed that the bael fruit pulp incorporates many useful and bioactive compounds such as carotenoids, phenolics, alkaloids, coumarins, flavonoids, and terpenoids and has innumerable conventional medicinal uses and also isolated phytoconstituents from different portion of Aegle marmelos including Leaf (Skimmianine, Aegeline, Lupeol, Cineol, Citral, Citronella, Cuminaldehyde, Eugenol, Marmesinine); Bark (Skimmianine, Fagarine, Marmin) & Fruit (Marmelosin, Luvangetin, Aurapten, Psoralen, Marmelide, Tannin). Singh et al, 2012[23] observed from their study that bael fruit is highly nutritive with the richest source of riboflavin. It's far richer than most of the reputed fruits like apple, guava and mango because

of the calorific value of bael, apple, guava and mango are 88, sixty four, 59 and 36 calories respectively per 100g. Charoensiddhi and Anprung, 2008[21] stated that the acidity (pH 5.15 to 5.37) of bael fruit contributes by its characteristic flavour. Jauhari and Singh, 1971[24] noticed that bael fruit is also a good source of ascorbic acid 7-21 mg/100g. Mukherjee and Ahm.ad, 1957[25] showed that bael is the richest source of vitamin B_2 and vitamin A and vitamin C are also present. Jauhari and Singh, 1971[24] observed that bael cantain good amount of calcium, phosphorus, potassium and volatile oil. *Marmelosine* is also present renging from 0.03 to 0.37 per cent (Dixit and Dutt, 1932)[26]. Bael fruit contain 61.5 % moisture Gopalan *et: al.* (1978)[27]. Roy and Singh (1978)[28] stated that the moisture content varied from 59.37 to 68.70 per cent in four different locations in India. Bael fruit contain 28-39% T.S.S observed by Jauhari anel Singh , 1971[24]. Singh and Roy (1984)[19] stated that ripe bael fruit contain 33.5% T.S.S on the other hand Ram (1996)[29] noticed that T.S.S of bael fruit varied from 30.5 to 38.5%. Roy and Singh (1978)[28] observed in a study that the pH of bael fruit (5.0 to 5.3) was higher than other fruits. Garg *et al.* 1977[30] measured the total acidity of bael fruit 0.40 % in terms of anhydrous citric acid. Jauhari et al.1969[31] stated the acidity range from0.368 to 0.856 % in bael fruit. Ascorbic acid ranged from 7.86 to 18.2 mg per 100g in bael fruit pulp observed by Roy and Singh (1978)[28]. Singh and Roy 1984[19] reported from Brazil that 65 -to 100 mg ascorbic acid present in 100g of bael pulp. The ripe bael fruit is a cooling tonic, restorative, appetizer, pleasantly laxative, astringent and normally prescribed for diarrhoea and dysentery. In the Ayurvedic, Unani and Siddha systems of medicine in India bael has been used as a herbal medicine for the management of diabetes mellitus stated by Choudhry et al., 2003[32].The Bael is a vital medicinal plant of India. Many research exhibit that consuming various parts of bael such as pulp rich dishes is related with lowering down hazard of diabetes, cardiovascular and anti-inflammatory cancer, hypoglycaemic, hypolipidemic and blood strain diseases (Maity et al., 2009)[33]. Lmbole et al., 2010[34] showed

that bael also contain hypoglycaemic, hypolipidemic and blood pressure lowering property. The various parts of Bael are used for numerous healing purposes, such as for treatment of asthma, Anaemia, Fractures, recovery of Wounds, Swollen Joints, excessive Blood pressure, Jaundice, Diarrhoea observed by Parichha, 2004[35].Alam et *al.,* 1990[36] reported that drugs of Diabetes made from bark and fruit pulp. Agarwal et al., 2009[37] stated that bael is effective in lowering intraocular pressure and decreases intraocular pressure. Hassle related with tooth in kids may be handled by way of the use of bael fruit seem to have a cardiotonic impact at the amphibian and mammalian hearts (Harvey, 1958)[38]. Singh et al., 1983[39] told that bael seed oil contain antimicrobial and antithelminitic properties.

However due to its hard shell, mucilaginous texture and abundant amount of seeds and its perishable nature make it not famous as a dessert fruit. So preservation is needed.

Jackfruit (*Artocarpus heterophyllus* Lam.) is the most important tree borne fruit in the world, attaining up to 50 kg in weight and 60-90 cm in period. It belongs to the family Moraceae. The fruits are pear or barrelshaped borne on a 5-10cm stalk, the thick skin has short protuberances, fleshy, golden yellow, edible perianth that surrounds the seed (the fruit have as much as 500 seed) and the seed surrounded via a attractive endocarp and sub gelatinous exocarp. It's far local to Western Ghats of India and also famous fruit in numerous tropical and sub-tropical international locations. It is appeared as “poor man’s fruit” in eastern and southern parts of India. There are two principal styles of jackfruits: one is small, fibrous, soft, and mushy, and the carpels are sweet, with a texture like that of a raw oyster whereas the opposite range is crisp and crunchy, however now not very sweet. The massive seeds from this non leguminous plant also are fit for human consumption, even though they're difficult to digest (Siddappa, 1957)[40]. Singh *et al*., 1991[41] observed that a single seed is enclosed in a white aril encircling a skinny brown spermoderm, which covers the fleshy white cotyledon. Jackfruit cotyledons are pretty rich in starch and protein. Jackfruit includes

vitamin A, vitamin C, thiamin, riboflavin, calcium, potassium, iron, sodium, zinc, and niacin amongst many other nutrients. Jackfruit has a low caloric content only 94 calories per 100 g jackfruit (Mukprasirt and Sajjaanantakul, 2004)[42]. Brukill, 1997[43] noticed that Jackfruit contain high levels of protein, starch, calcium, and thiamine. Bhatia et al., 1955[44] stated that the bulbs without seeds are rich in sugar, rich in carotene and also contain vitamin C . Hettiarachchi et al., 2011[45] reported that jackfruit is also rich in energy, nutritional fiber which makes it a great bulk laxative. Jackfruit seeds are an excellent source of starch (22%) and nutritional fiber (3.19%). Soobrattee *et al*., 2005[46] showed that jackfruit contain 4 mg niacin /100g. De Faria *et al*., 2009[47] srevealed that jackfruit contains various carotenoids including all-trans-*β*-carotene. All-trans-*β*-carotene is very important antioxidant for human health (Cadenas and Packer, 1996)[48]. Krinsky *et al*., 2003[49] stated that jackfruit containing carotenoids may be vital for the prevention of numerous chronic degenerative diseases, which includes cancer, irritation, cardiovascular ailment, cataract, age-associated macular degeneration. As it is also rich in energy, nutritional fiber which makes it a fantastic bulk laxative so the fiber content facilitates to shield the colon mucous membrane by using decreasing exposure time and in addition to binding to most cancers inflicting chemical substances within the colon (Morton, 1987)[50]. In addition, it's far one of the rare fruit that is wealthy in B-complex group of vitamins. It carries superb quantities of diet B-6 (pyridoxine), niacin, riboflavin, and folic acid. The pulp and seeds of jackfruit are considered as a cooling and nutritious tonic. Siddappa, 1957[40] noticed in experiment that the high fiber content (3.6 g/100 g) in the jackfruit prevents constipation and produces smooth bowel movements due to the presence of it colon mucous membrane protected by getting rid of carcinogenic chemical substances from the big intestine. Jackfruit contain abundant amount of magnesium (27 mg/100 g in young fruit and 54 mg/100 g in seed) (Gunasena *et al.,* 1996)[51]. It contained calcium that help strengthen the bones and prevents bone-related disorders (Singh *et al*.,

1991). Gunasena *et al*., 1996[51] showed it contain Copper (10.45 mg/kg) which helps in hormone production and thyroid gland metabolism.

Because the fruit deteriorates quickly upon ripening, it is acceptable to develop products from bulbs.

Processing and preservations of fruits:

The effect of drying methods on nutritional composition of dehydrated aonla fruit of variety Chakaiya during storage conducted by Pragati *et al* (2003)[52] and observed decrease in ascorbic acid content from 243.74±1.635 mg/100g to 142.46 mg/100g after 90 days of storage of dried aonla fruit.

Vijayanand *et al* (2007)[14] conducted the effect of processing on gooseberry fruits and quality changes in dehydrated powder during storage of 6 months and concluded that Chakaiya variety was having the highest amount of ascorbic acid content (357 mg/100g) which was followed by Krishna (298 mg/100g) and NA-7 (272 mg/100g).

Anand (1970)[53] evaluated the impact of pre-treatments at the loss of tannins and vitamin C in amla preserve and found that during soaking and blanching of fruit a significant share of acids, tannins and vitamin C have been lost. During soaking the acidity, nutrition C and tannins had been discovered to decrease from 2.75 to 0.79%, 460 to 124 mg per 100g of fruit and 3.37 to at 1.31 percent, respectively, after 8 days in Deshi variety. On the other hand, after blanching acidity, tannins and vitamin C decreases from 1.92 to 0.58 percent, 4.06 to 0.81% and 340 to 15.6 mg/100g of fruit, respectively in Banarasi variety wherein as in Deshi range acidity, tannins and nutrition C reduced to 0.45 from 2.75 percent, 0.56 from 3.37 percent and 13 from 460 mg/100g. The impacts of blanching become more extreme and ended in more than ninety five percent loss in nutrition C.

The effect of blanching on drying of amla studied by Sethi (1986)[54] they concluded that fresh amla dried as pulp gave better nutritive value as compared to whole blanched and unblanched

amla fruits. They also stated that blanching of amla for 4 minutes in boiling water prevents non enzymatic browning and retained better colour of the processed product during storage because of higher degree of inactivation of PPO enzyme.

P.K.Wankhadea et al, 2013[55] studied Drying Characteristics of Okra slices on drying in Hot Air Dryer and observed that drying took place in the falling rate period. The sample dried at 40°C was found better in colour, texture and taste as compared to the samples obtained at 60-90°C.

Jain and Khurdiya (2009)[56] evaluated the effect of sulphitation and storage on vitamin C content and non enzymatic browning in stored Indian gooseberry juice and reported that sulphitation (350 ppm SO_2) in aonla juice coupled with storage at low temperature (4±1°C) minimized the loss of vitamin C which can prevent non enzymatic browning even after 6 months of storage.

A.Borah et al., 2015[57], observed during study that drying of sliced rhizomes showed better drying kinetics and effective drying time could be reduced by slicing instead of drying in whole form.

Thankitsunthorn , 2009[58] evaluated the effects of drying temperature on quality of dried Indian Gooseberry powder and observed the moisture content and subsequently the water activity decreased significantly at 0.05 level with increased drying temperature. The increase in drying temperature results in a lower vitamin C content.

V. R. Sagar,2014[59] noticed that maltodextrin and tricalcium phosphate significantly increased the sticky point temperature and also decrease the degree of caking of bael powder which is desirable for efficient handling and storage of fruit powder.

MD. Mizanur Rahman, 2012 [60] observed that Minimum microbial count was recorded for osmosis in 50° Brix sugar solution which was followed by 45° Brix sugar solution. In 45° Brix sugar solution the retention of vitamin A (ß- carotene), vitamin C, total acid and total sugar

were better than 50° Brix sugar solution. The product of 45° Brix solution secured highest score in organoleptic evaluation when stored 8 months at room temperature.

Studies on storage stability of jack fruit RTS beverage conducted by Krishnaveni *et al* (2001)[61] reported TSS 18° Brix in the beverage, which continue throughout the storage period of 180 days.

The results observed Ihediohanma., 2014[62] that jackfruit (*Artocarpus heterophyllus*) is a promising source of pectin and it can be successfully applied in food gel system such as fruit jams, jellies and fillers etc.

REFERENCES

1. Mitra S K, Pathak P K, Chakraborty I (2010) Potential Underutilized Tropical Fruits of India. *Acta Hort.* **864:** 61-67.

2. Genetic Diversity of Underutilized Fruits in India for Environmental Sustainability Volume 3 Issue 1 – (2015). Department of Fruits and Orchard Management, Bidhan Chandra Krishi Viswavidyalaya, India http://medcraveonline.com/APAR/APAR-03-00076.pdf). 3 (1).

3. Mandal U and Bhardwaj R L (2014). The Role of Underutilized Fruits in Nutritional and EconomicSecurity of Tribals: A Review .*Critical Reviews in Food Science and Nutrition*.**54:**880–890.

4. Shankar G (1969) Aonla for your daily requirement of Vitamin C. *J Indian Hort* **13**: 9- 15.

5. Teotia S S, Singh D B, Singh R D and Singh R N (1968) Studies of some important varieties of aonla (*Phyllanthus emblica* L.) of Eastern Uttar Pradesh. *Punjab Hort J* **8**: 241-44.

6. Singh I S and Pathak R K (1987) Evaluation of aonla (*Emblica officinalis* G.) varieties for processing. *Acta Horti* **208**: 173-77.

7. Kalra C L (1988) The chemistry and technology of amla (*Phyllanthus Emblica*)-A Resume. *Indian Food Packer* **42**: 67-83.

8. Barthakur N N and Arnold A P (1991) Chemical analysis of the amla (*Embica officinalis*) and its potential as a food source. *J Sci Hort* **47**: 99-105.

9. Goyal R K, Patil R T, Kingsly A R P, Walia H and Kumar P (2008) Status of post harvest technology of aonla in India-a review. *American J Food Technol* **3**: 13-23.

10. Swaminathan M (1990) *Handbook of Food and Nutrition*. Pp 334. The Banglore Printing and Publication Company Ltd.

11. Singh B P, Singh I P, Singh S P and Kumar K A (1987) Physico-chemical composition of different cultivars of aonla. *Indian Food Packer* **41**: 7-10.

12. Ghorai K and Sethi V (1996) Varietal suitability of amla (Desi and Banarasi) fruits for storage and preservation. *Indian Food Packer* **59**: 54-57.

13. Premi B R, Sethi V and Maini S B (1999) Effect of steeping preservation on the quality of aonla (*Emblica officinalis* G.) fruits during storage. *J Food Sci Technol* **36**: 244-47.

14. Vijayanand P, Kulkarni S G, Reena P, Aksha M and Ramana K V R (2007) Effect of processing on gooseberry fruits and quality changes in dehydrated gooseberry powder during storage. *J Food Sci Technol* **44**: 591-94.

15. Ram H B, Jain S P, Tripathi V K and Singh S (1983) Composition of aonla (*Emblica officinalis* G.) fruits during growth and development. *Indian Food Packer* **37**: 57-60.

16. Singh P, Singh J P and Chopra C S (2003) Techno-economic study on processing of aonla products. *Beverage and Food World* **30**: 68-69.

17. Jain S P, Tripathi V K, Ram H B and Singh S (1983) Optimum stage of maturity for preparation of Aonla (*E. officinallis* Gaerth) preserve. *Indian Food Packer* **37**:85-90.

18. Chemexcil. (1992) Selected medicinal plants of India. Bombay: Bhartiya Vidya Bhavan's Swami Prakashan and Ayurveda Research Centre.

19. Singh R N and Roy S K (1984). The *Bael*: cultivation and processing, New Delhi, India: ICAR.

20. Gopalan and Jain, N.L. (1954). Studies on the preparation of amla syrup. *CFTRI Mysore Bull* **3**:297.

21. Charoensiddhi S, Anprung P. (2008). Bioactive compounds and volatile compounds of Thai *bael* fruit (*Aegle marmelos* (L.) Correa.) as a valuable source for functional food ingredients. *International Journal of Food & Research,* **15(3):** 287-295.

22. Nagaraju N. and RaoK N. (1990). A survey of plant crude drugs of Rayalaseema, Andhra Pradesh, *Indian. J Ethnopharmac* **29(2)**: 137-158.

23. Singh, U., Kochhar, A. and Boora, R. (2012). Proximate Composition, available Carbohydrates, Dietary Fibres and Anti-Nutritional factors in *Bael (Aegle Maemelos L.)* Leaf, Pulp and Seed Powder, *Int J Scient Research Publ*, **2(4)**: 2250-3153.

24. Jauhari O S and Singh R D. (1971). *Bael* a valuable fruit, *Indian Horticulture*, **16(1)**:9-10.

25. Mukharjee B. and Ahmed K. (1957). Riboflavin *Pakist. J. BioI. Agric. Sci.,* **1 :** 47-51.

26. Dixit B B L and Dutt S. (1932). The constitution of marmelosin. *J. Indian Chern. Soc.* **9 :** 271.

27. Gopalan C , B V Sastri R and Balasubrananoum S C (1978). Nutritive value of Indian Foods. National Institute of Nutrition. ICMR. Hyderabad, India.

28. Roy S.K. and Singh R.N (1978). Studles on utilization of bael fruit *(Aegle marmelos* Correa) for processing I. Physico-chemical characteristics of different cultivars. *Indian Fd. Pack.,* **32 (6) :** 3 - 8.

29. Ram D. (1996). Studies on ripening, storage and processing of bael fruit (*Aegle marmelos* Correa) Ph .D. Thesis. N.D. Univ. Of Agric &Tech., Faizabad (U.P.).

30. Garg R.C; Joshi D.P, Ram H.B, Jain Km. S.P. and Tripathi V.K. (1977). Effect of stages of maturity on quality of bael fruit *(Aegle rnarmelos* correa) and its preserve. *Prog. Hart.* **9 :** 18-25.

31. Jauhari O.S, Singh, RooD, and Awasthi R.K. (1969).Survey of some important varieties of Bael *(Aegle marmelos). Punjab Hort. J* . **9 (3):** 48.

32. Choudhry B.K, Kar A. and Bandhopadhyay N.G. (2003) Comparative evaluation of hypoglycemic activity of some Indian medicinal plants in alloxan diabetic rats, *Journal of Ethnopharmacology,* **84**:105-108.

33. Maity P, Hansda D., Bandyopadhyay U. and Mishra D.K. (2009) Biological activity of crude extracts and chemical constituents of *bael*, *Aegle marmelos* (L.) Corr, *Ind J Exp Biol*, **47**: 849-861.

34. Lmbole V B., Murti K, Kumar U, Bhatt S P. and Gajera V. (2010). Phytopharmacological Properties of *Aegle Marmelos* as a Potential Medicinal Tree: An Overview. *International Journal of Pharm Sci Revw and Res* **5(2):** Article-014.

35. Parichha S. (2004). *Bael* (*Aegle Marmelos*): Nature's Most Natural Medicinal Fruit, *Orissa Review*. 16-17.

36. Alam M.M, Siddiqui M.B. and Husain W. (1990). Treatment of diabetes through herbal drugs In rural India, *Fitoterapia,* **61 (3) :** 240-242.

37. Agarwal R., Gupta S K, Srivastava S, Saxena R. and Agrawal S S.(2009) Intraocular pressure-lowering activity of topical application of *Aegle marmelos* fruit extract in experimental animal models. *Ophthalmic Research* **42**:112-116.

38. Harvey S.K. (1958). A preliminary communication of the act ion 0 f *Aegle marmelos* (Bael) on heart. *Indian J. Med. Res* **.56:** 327.

39. Singh I.S. and Pathak R.K. (1983). Rangpur limc a potential fruit for beverage industry second National Citrus Seminar held at New Delhi.

40. Siddappa G.S. (1957). Development of products from jackfruit – canned jackfruit, frozen canned jackfruit and jackfruit jam. *Journal of Science Industrial Research.* **9 (11):**166–99.

41. Singh A, Kumar S. and Singh I.S. (1991). Functional properties of jackfruit seed flour. *Lebensm – Wissu Technology* **24:** 373–374.

42. Mukprasirt A. and Sajjaanantakul K. (2004). Physico-chemical properties of flour and starch from jackfruit seed. *International Journal of Food Science and Technology* **39(3):** 271–276.

43. Burkill H.M. (1997). *The Useful Plants of West Tropical Africa*. Vol. 4, Second Edition. Royal Botanic Gardens: Kew, U.K. pp.160.

44. Bhatia B.S, Lal G. and Siddappa G.S. (1955). Composition and nutritive value of jackfruit. *Indian Journal of Agriculture Science.* **25(4):** 30-36.

45. Hettiarachchi U.P.K., Ekanayake S. and Welihinda J. (2011). Nutritional assessment of jackfruit (*Artocarpus heterophyllus*) meal. *Ceylon Medical Journal.* **56(2):** 54–8.

46. Soobrattee M.A., Neergheen V.S., Luximon-Ramma A., Aruma O.I., Bahorun, T. (2005). Phenolics as potential antioxidant therapeutic agents: Mechanism and action. *Journal of Mutation Research* . **579:** 200–213.

47. De Faria A.F., De Rosso V.V. and Mercadante A.Z. (2009). Carotenoid composition of jackfruit (*Artocarpus heterophyllus*) determined by HPLC-PDA-MS/MS. *Journal of Plant Foods Human Nutrition.* **64:**108–115.

48. Cadenas E. and Packer L. (1996). *Hand book of antioxidants*. Plenum Publishers: New York. pp.602 .

49. Krinsky N.I., Landrum J.T. and Bone R.A. (2003). Biologic mechanisms of the protective role of lutein and zeaxanthin in the eye. *Annual Revision Nutrition* **23:**171–201.

50. Morton J. (1987). Jackfruit: Fruits of warm climates. By Morton Julia F., Miami FL. [http://www.hort.purdue.edu/newcrop/morton/jackfruit_ars.html]. pp 58–64.

51. Gunasena H.P.M., Ariyadasa K.P., Wikramasinghe A., Herath H.M.W., Wikramasinghe P. and Rajakaruna S.B. (1996). Manual of Jack Cultivation in SriLanka. Forest Information Service, Forest Department: pp 48.

52. Pragati K, Dahiya S and Dhawan S S (2003) Effect of drying methods on nutritional composition of dehydrated aonla fruit (*Emblica officinalis* G) during storage. *Plant Foods for Human Nutr* **58**: 1-9.

53. Anand (1970) Effect of pre-treaments on the loss of tannins and vitamin C in amla preserve. *Indian Food Packer.* **24**: 16-18.

54. Sethi V (1986) Effect of blanching on drying of amla. *Indian Food packer* **40**: 446-47.

55. Wankhadea P.K., Sapkala R.S., Sapkal V.S. (2013) Drying Characteristics of Okra slices on drying in Hot Air Dryer; Procedia Engineering. **51 :**371 – 374.

56. Jain S K and Khurdiya D S (2009) Ascorbic acid content and non-enzymatic browning in stored Indian gooseberry juice as affected by sulphitation and storage. *J Food Sci Technol* **46**: 500-501.

57. Borah A., Hazarika K., Khayer S.M. (2015) Drying kinetics of whole and sliced turmeric rhizomes (*Curcuma longa* L.) in a solar conduction dryer *Information Processing in Agriculture.* **2:** 85–92.

58. Thankitsunthorn S., Thawornphiphatdit C., Laohaprasit N. and Srzednicki G. (2009) Effects of drying temperature on quality of dried Indian Gooseberry powder. *International Food Research Journal* **16:** 355-361.

59. Sagar V R. & Kumar R (2014) Effect of drying treatments and storage stability on qualitycharacteristics of bael powder. *J Food Sci Technol* . **51(9):**2162–2168.

60. Rahman M M, MIARUDDIN MD, Ferdous Chowdhury M G F, Haque Khan MD H and Muzahid-E-Rahman MD (2012) Preservation of jackfruit (*Artocarpus heterophyllus*) by osmotic dehydration. Bangladesh. *J. Agril. Res.* **37(1):** 67-75.

61. Krishnaveni A, Manimegalai G and Sarvanakumar R (2001) Storage stablity of Jack fruit (*Artocarpusheterophyllus*) RTS beverage. *J Food Sci Technol* **38**:601-02.

62. Ihediohanma.N.C.,Okafor D.C.and Adeboye, A.S. (2014). Sensory Evaluation of Jam Produced From Jackfruit (*Artocarpus heterophyllus*) *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)* **7(5)** 41-43.

CHAPTER 1

Hot air dehydration of Amla slices

1.1 Introduction

Amla (*Phyllanthus emblica* L) is a wonderful fruit, rich in antioxidant. However it is seasonal and is available only for a short period of time[1, 2]. Therefore processing is very much needed for preservation of amla fruits[3]. Food preservation is the process of treating and handling food in such a way so as to stop or greatly slow down spoilage while maintaining nutritional value, density, texture and flavor. Preservation of foodstuffs through dehydration is an ancient practice[4]. It helps in reducing the moisture content of the produce to a level below which deterioration does not occur for a specific duration[5]. It has great effect on the quality of the dried products. Dehydration has a significant impact on the stability of various health promoting antioxidant components in processed products and is considerably the best and widely used preservative method to extend the shelf life of perishable produces.

Sun drying is the common method of drying in rural areas. However the process is weather dependent, time consuming thus resulting in products of low quality. There is a need for suitable alternatives in order to improve product quality. Hot air dryers give far more hygienic and better quality products. Drying of amla in the form of slice or powder helps to develop food materials for ready to eat products. Drying is the complex thermal process in which heat and moisture transfer occur simultaneously[6]. It is important to develop a better understanding of the controlling parameters of this complex process. Mathematical Modeling of the drying process is an efficient tool for prevention of product deterioration, energy consumption and equipment stress and product yields[7]. Mathematical models of drying processes are used for designing new or improving existing drying systems or even for the control of the drying process. Therefore, validated mathematical drying models are used which enable more detailed explanation of drying [8]. Number of verified equations has been proposed to describe drying process, modeling kinetics and design of drying systems. All these equations obtain a direct relationship between change in moisture content and drying

time, and are strongly related to Fick's second law of diffusion[9]. Among many mathematical models the thin-layer drying models have been widely in use. A number of thin-layer drying models available in the literature for explaining drying characteristics of agricultural products. A number of pre-treatments can be applied depending on the food to be dried and its availability[10].

Blanching as a pre-treatment is used to delay some physiological processes before drying vegetables and fruits. It is a heat pre-treatment that inactivates the enzymes responsible for commercially unacceptable darkening and off-flavours. Blanching of fruits and vegetables is generally carried out by heating them with steam or hot water[11].The objective of this study were (a) to investigate the drying characteristics of amla slices, (b) Mathemetical modeling of the thin-layer drying of amla slices by testing three drying models and (c) to study the effect of pretreatment on quality of hot air dried amla, (d) to estimate retention of ascorbic acid and phenolic content after 3 months storage of dried products.

1. 2 Materials and methods:

1. 2.1 Drying procedure:

Amla fruits were procured from local market. The amla fruits were washed thoroughly with water for removing adhering dust and then sliced by a sharp knife. Untreated samples were used as the control.300 gm of amla slices were divided into three parts and treated accordingly. First part of samples dipped in boiling water (w/v) for 3 minutes and immediately cooled to 30°C (WB). Second part of samples steam blanched for 3minutes and cooled immediately to 30°C (SB). In last part 0.5% Sodium benzoate was mixed with amla slices and then steam blanched followed by immediate cooling to 30°C.

Amla slices were then spread in single layers on trays. Drying of the amla slice was carried out at temperatures of 50°C, 60°C and 70°C[12, 13]. Moisture loss was measured after every 30 mins interval until the material was dried to approximately less than 10% of moisture content.

Samples were packed in polyethylene packets and stored for 3 months for storage study. Ascorbic acid and phenolic content were measured.

1.2.2 Determination of moisture %

The % moisture content of different substrates was measured on the basis of initial weight of the samples[14]. At first weight of previously dried aluminium cup was noted. 50 mg of sample was placed on it and the weight was noted accurately. Then it was placed in a hot air oven at 105°C till constant weight was obtained.

The loss in weight was reported as moisture %.

$$\% \text{ moisture (w.b)} = \frac{\text{loss in weight on drying}}{\text{weight of sample taken}} \times 100$$

$$\% \text{ moisture (d.b)} = \frac{\text{moisture content (w.b)}}{100 - \text{w.b}} \times 100$$

1.2.3 Total phenolic content (TPC):

TPC of the fruit samples were measured by Folin-Ciocalteu method[15]. To 0.25ml of the 10 fold diluted test sample 3.5ml of distilled water and 0.5ml of folin ciocalteu reagent were added. After 3 minutes 1ml of 20% sodium carbonate was added to it and mixed and allowed to stand at 30°c for 2 hours. The absorbance was measured at 765nm against reagent blank. The total phenolic content of the sample was calculated from the standard curve prepared with gallic acid and the value was expressed in terms of mg of gallic acid/ g of amla.

1.2.4 Ascorbic acid content:

Ascorbic acid was determined by titrimetric method [16]. 5 gm of sample was extracted with 50 ml of distilled water. Standard solution was prepared by dissolving 100mg of L-ascorbic acid in 100ml of 3% of metaphosphoric acid. 0.1% L-ascorbic acid solution was prepared with 3% of HPO3 and kept as ascorbic acid stock solution. Then dye solution was prepared by

dissolving 50 mg of sodium salt of 2,6-dichlorophenol indophenol and 42 mg of sodium bicarbonate in 150ml of hot glass distilled water. It was then cooled and diluted with glass distilled water to 250ml.For titration; 5ml of the dye solution was titrated to a colourless end point with ascorbic acid stock solution. In the same process 5 ml dye solution was titrated with samples until colourless. The ascorbic acid content was expressed as mg of ascorbic acid/g of amla.

1.2.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of drying on the sensory quality of untreated and pretreated amla samples. A 10-untrained member sensory panel[17] was used for evaluating colour, aroma, flavour and overall acceptability of dried fruits. Attributes were scored for degree of liking on 9-point hedonic scale of 1 to 9 (9= like extremely,8=like very much,7=like moderately, 6=like slightly, 5=neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much, 1=dislike extremely).

1.2.6 Mathematical modeling of moisture loss:

The decrease of moisture ratio with drying time was used to evaluate the experimental drying data. The moisture ratio (MR) was calculated[18]as follows:

$$MR=\frac{M_t-M_e}{M_i-M_e} \qquad (1)$$

Where MR= Moisture Ratio, M_t= Moisture content in time t (% db), M_e=Equilibrium moisture content (% db), M_i=Initial moisture content (% db)

Various mathematical models have been created to reproduce moisture movement and mass exchange during the drying of agricultural products. Among them the moisture ratio curves obtained were fitted with Page model, Newton model and Henderson and pebis model[6, 13].

Table-1.1 Thin Layer Drying Models Tested for Amla drying

Model name	Model	References
Newton	*MR= exp(-kt)*	*(Mujumder, 1987)*[19]
Page	*MR= exp(-kt^n)*	*(Singh et al., 2008)*[20]
Henderson and Pebis	*MR= a exp(-kt)*	*(Henderson et al., 1961)*[21]

To evaluate the models, a nonlinear regression procedure was performed for three models using SPSS software (Statistical Package for social scientists).The reduced RMSE, χ^2 and increased R^2 were used as the primary criteria to select the best model[22].

Chi-square value (χ^2)[23]:

$$\chi^2 = \frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}{N-z} \qquad (2)$$

Root mean square error[6]**:**

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2} \qquad (3)$$

Where: MR_{exp} = Experimental moisture ratio, MR_{pred} = Predicted moisture ratio, N = Number of observations, z = Number of constants

1. 3 Result and Discussion:

A non linear relationship observed between moisture content and drying time[24]. Moisture content decreases with increasing drying time. Similar observation was reported by Banerjee & Ghosh, 2009[25]. Change in moisture content with time for drying at 50^0-70^0C were shown in figs 1.1.A-1.1.C. The samples dried at 70^0C (Table 1.2) took minimum time to reach the desired final moisture contents.

Table 1.2: Moisture content (d.b) of untreated and pretreated samples

Time (min)	Moisture Content (d.b)											
	50°C				60°C				70°C			
	Untreated	WB	SB	Sodium benzoate+ SB	Untreated	WB	SB	Sodium benzoate+ SB	Untreated	WB	SB	Sodium benzoate+ SB
0	433	455	425	389	400	426.31	389.47	377.25	376.23	366.64	343.05	313
30	344	273.7	182	157.06	305	250.33	174.95	140.56	240.67	151.83	139.98	90.86
60	264.57	202	140.95	106.15	266.74	199.9	128.24	96.33	202.61	135.98	106.79	69.95
90	229.174	87.47	67.48	42.86	109.75	62.86	50.66	29.87	151.41	62.6	45.81	21.43
120	78.94	49.99	40.14	25	78.7	33.33	24.44	17.44	49.99	34.66	21	14.29
150	73.6	25	25.94	12.94	64.25	13.03	12.8	11.64	35.2	16.67	12.5	11.11
180	43.25	13	11.11	8.93	35.5	9.89	8.71	7.69	20	14.19	9.09	7.21
210	39.99	9.89	7.35	7.24	23.46	8.11	7.06	6.96	15.35	7.45	6.99	6.9
240	23.46	8.17	-	-	13.03	7.59	-	-	8.94	-	-	-
270	11	-	-	-	9.09	-	-	-	-	-	-	-

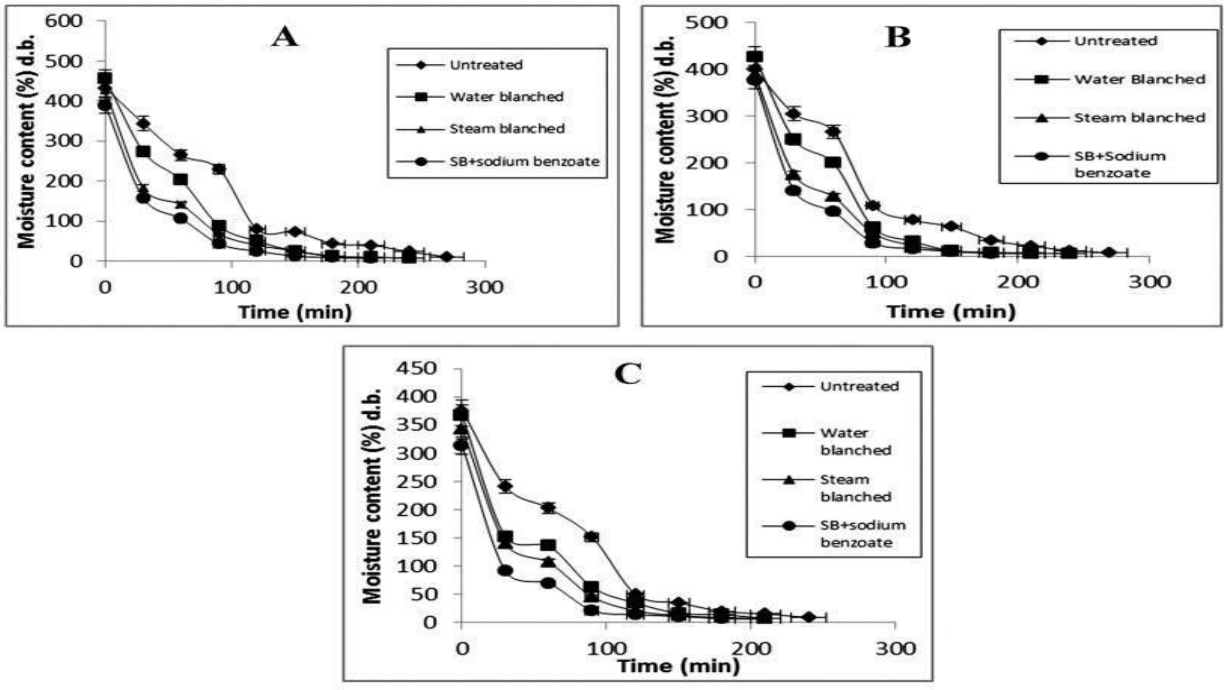


Fig. 1.1: ***Moisture content vs drying time curve of untreated and pretreated amla samples dried at (A) 50, (B) 60 and (C) 70 °C***

It could be seen from fig 1 that the rate of drying was much faster in pretreated samples in comparison to untreated samples. This is an sign of the way that different types of blanching pretreatments increase the drying rate[26]. In 70^0C temperature the time taken by SB+sodium benzoate sample was 210 min to attain 6.9% moisture d.b which is followed by SB and WB (Table 1.2).

Table 1.3: Moisture ratio of untreated and pretreated amla slices

Time (min)	Moisture Ratio											
	50^0C				60^0C				70^0C			
	Untreated	WB	SB	Sodium benzoate+ SB	Untreated	WB	SB	Sodium benzoate+ SB	Untreated	WB	SB	Sodium benzoate+ SB
0	1	1	1	1	1	1	1	1	1	1	1	1
30	0.789	0.594	0.418	0.3924	0.7569	0.5797	0.439	0.36079	0.6309	0.40195	0.3957	0.2742
60	0.6	0.4338	0.3199	0.2591	0.6591	0.4593	0.31688	0.24135	0.5273	0.35785	0.297	0.206
90	0.517	0.1774	0.14397	0.0933	0.2575	0.13199	0.114	0.0618	0.3879	0.15353	0.1155	0.0474
120	0.161	0.0935	0.0785	0.04652	0.178	0.0614	0.0454	0.0283	0.11176	0.07575	0.04168	0.02414
150	0.148	0.03766	0.0445	0.0149	0.1411	0.01299	0.015	0.01577	0.0714	0.02567	0.01639	0.01375
180	0.076	0.0108	0.009	0.0044	0.06756	0.00549	0.00431	0.00197	0.0301	0.01854	0.00624	0.00078
210	0.0686	0.0038	0	0	0.03676	0.00124	0	0	0.01745	0	0	0
240	0.0295	0	-	-	0.01	0	-	-	0	-	-	-
270	0	-	-	-	0	-	-	-	-	-	-	-

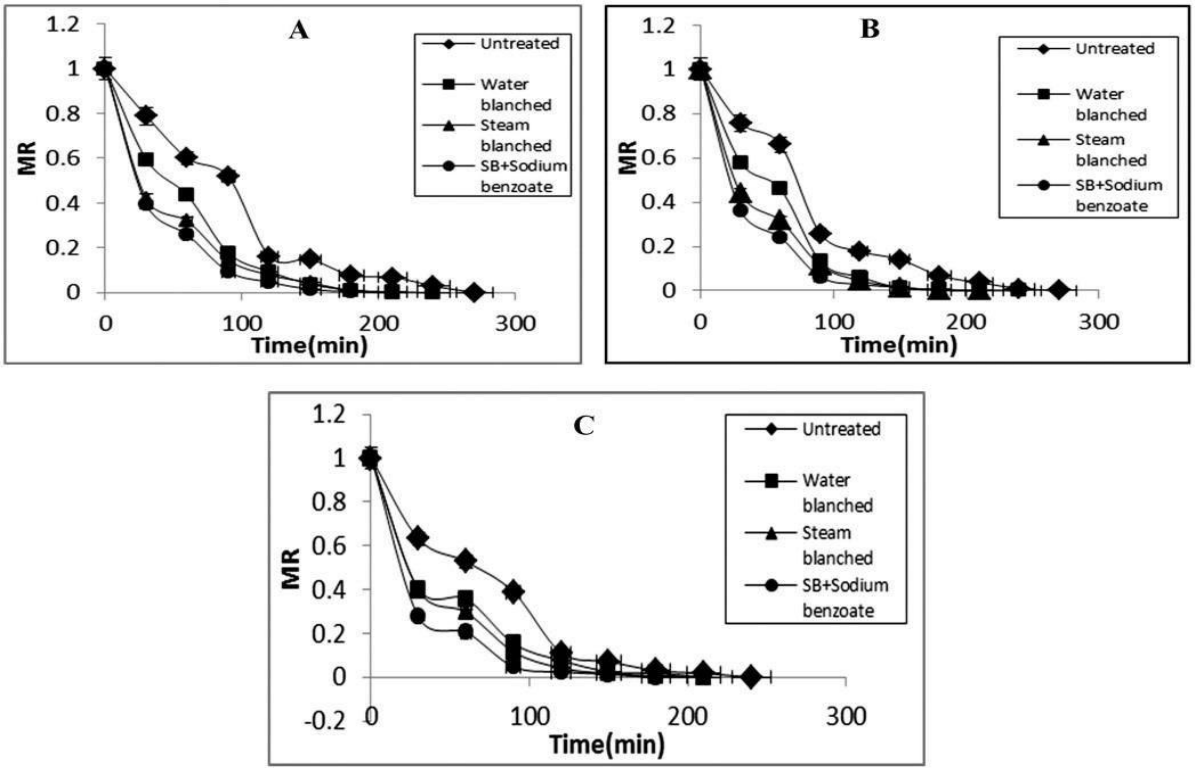


Fig.1. 2*: Moisture ratio of amla slices dried at (A) 50, (B) 60and (C) &70 °C*

The drying rate decreased continuously throughout the drying period. It is obvious from Figure 1.2 that the constant rate period was absent and the drying process of amla slices took place in falling rate period. From fig 1.2 it was observed that moisture ratio decreases exponentially with increasing drying time. Similar results were found by Wankhadea et al. 2013[27]. Continuous decrease in moisture ratio indicates that the major internal mass transfer was occurred by diffusion[13].

Experimental results showed in table 1.3 that drying air temperature and pre-treatment is effective parameter for the drying of amla slices.

Table 1.4: Values of the drying constants of the selected models

Temperature	Sample	Model		
		Newton k(min^{-1})	Page k (min^{-1})	Henderson and Pebis k (min^{-1})
50°C	Untreated	0.011	0.001	0.011
	WB	0.017	0.008	0.018
	SB	0.023	0.050	0.022
	Sodium benzoate+SB	0.027	0.049	0.026
60°C	Untreated	0.012	0.002	0.013
	WB	0.018	0.006	0.019
	SB	0.024	0.032	0.023
	Sodium benzoate+SB	0.029	0.055	0.029
70°C	Untreated	0.014	0.005	0.014
	WB	0.022	0.052	0.022
	SB	0.025	0.048	0.025
	Sodium benzoate+SB	0.036	0.113	0.036

Table 1.5: Curve fitting criteria for the three mathematical models and parameters for pretreated and untreated samples at temperatures of 50, 60 and 70 °C

Temperature	Sample	Model								
		Newton			Page			Henderson and Pebis		
		R^2	Chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE
50°C	Untreated	0.952	0.006143	0.074354	0.979	0.002974	0.04878	0.957	0.006248	0.070699
	WB	0.9876	0.00146	0.036027	0.9917	0.001122	0.029537	0.9886	0.001637	0.035686
	SB	0.9849	0.001779	0.039453	0.9912	0.001239	0.030485	0.985	0.001985	0.038585
	Sodium benzoate+SB	0.992	0.000941	0.028697	0.9951	0.000717	0.023189	0.9927	0.001072	0.028357
60°C	Untreated	0.956	0.005728	0.071802	0.980	0.002875	0.047958	0.960	0.005859	0.068461
	WB	0.9741	0.003271	0.053924	0.9810	0.00271	0.045912	0.9741	0.003685	0.053538
	SB	0.9892	0.001277	0.033425	0.9904	0.00138	0.032174	0.9893	0.00147	0.033203
	Sodium benzoate+SB	0.991	0.001119	0.031296	0.993	0.000944	0.026603	0.991	0.001287	0.0310
70°C	Untreated	0.966	0.004218	0.061235	0.973	0.003846	0.054695	0.967	0.00478	0.060976
	WB	0.9726	0.003124	0.05228	0.980	0.002629	0.044401	0.9738	0.003507	0.051289
	SB	0.986	0.001656	0.03806	0.990	0.001424	0.032677	0.9866	0.001883	0.037583
	Sodium benzoate+SB	0.984	0.001824	0.039952	0.992	0.001043	0.027965	0.984	0.002105	0.039737

Table 1.4 shows values of the drying constants of the selected models. It is clear from table 1.4 that drying constant (k) is temperature function which increased with increasing drying temperature. The k values of untreated samples were lower than that of pretreated samples for all the drying temperatures (Table 1.4). This affirms the way that the different types of blanching expanded the rate at which drying occurred.

The high R^2 and low χ^2 and RMSE value used to determine the goodness of fit of the models are shown in table 1.5. Among all three model Page model gave the highest R^2 value which varied from 0.973 to 0.995 for experimental conditions considered in this study. The values of χ^2 and RMSE for the Page model which varied from0.003846 to 0.000717 and 0.0546 to 0.02318 respectively were the lowest for all the models measured. From the tables (1.4 and 1.5), it is obvious that the Page model therefore represents the drying characteristics of pre-

treated amla (for individual drying runs) better than the other models in this experiment. This is similar to the observations of Lavanya K. et al. (2016)[13] for drying of amla at different temperatures.

Table 1.6: Sensory analysis of untreated and pretreated samples

Samples	Colour	Aroma	Taste	Overall acceptibility
Untreated (50^0 C)	3	1.67	2.83	1.16
WB (50^0 C)	5.16	4.83	5.2	6
SB (50^0C)	5.6	5.3	5.2	6.16
SB + NaB (50^0C)	6	5.5	5.3	6.5
Untreated (60^0C)	4.3	3.17	3.5	2.67
WB (60^0C)	6.16	6	5.2	6.67
SB (60^0C)	6.3	6.17	5.8	7.16
SB+NaB (60^0 C)	7	5.8	6	7.5
Untreated (70^0C)	5.16	4.3	3.2	3.83
WB (70^0C)	7.17	5.3	6.67	7.16
SB (70^0C)	7.2	5.6	7	7.5
SB + NaB (70^0C)	8	5.5	7.16	8.2

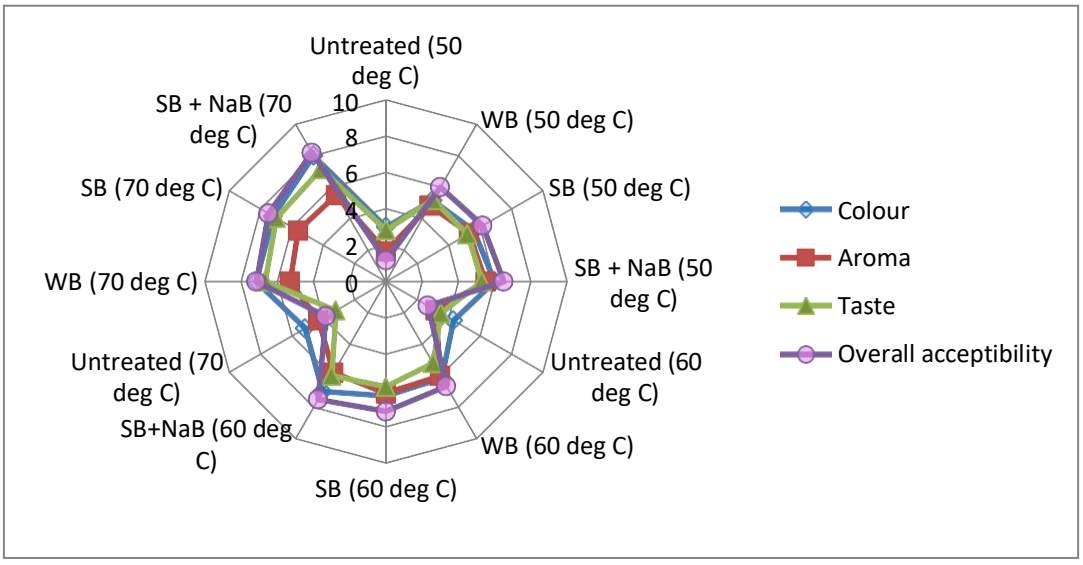


Fig: 1.3 Descriptive analysis on sensory score on dehydrated amla slices

Sensory attributes are very important factors for acceptability of dehydrated products by the consumer In addition to visual appearance, colour, aroma and flavour attributes are critical in determining their degree of acceptance. From table 1.6 and fig 1.3 it was observed that pretreated samples scores better than untreated samples for all temperature. Best colour, taste

and overall acceptability were obtained with steam blanched with 0.5% sodium benzoate at 70^0C might be due to preservative action of sodium benzoate and faster drying of material[17].

Table 1.7: Changes in ascorbic acid and phenolic content of dehydrated amla slices during storage

Temp.	Sample	Retention of Ascorbic acid (%) Time(month)					Retention of Total phenolic content (%) Time(month)				
		0	1	2	3	6	0	1	2	3	6
50^0C	Untreated	44	40	35	25.7	8.54	46.57	40.27	35.97	27.75	10.88
	Water Blanched	67	64	60.4	56	18	56	50.82	47.12	41.63	29.6
	Steam Blanched	69	65.77	62.68	58.76	18.4	57.5	52.98	49.53	45.26	33.21
	SB+sodium benzoate	70	67.42	64.5	61	19.5	60.4	54.37	50.98	48	35.68
60^0C	Untreated	38	34.4	30	22.9	9.56	35.6	31.80	28.85	25.13	10.54
	Water Blanched	60.8	58.14	55.26	51.96	17.34	49.3	46.57	44.13	39.8	28.68
	Steam Blanched	63	60.82	57.94	56.7	17.9	50.25	46.17	44	39.72	29.94
	SB+sodium benzoate	65.97	63.9	61.24	58.35	19	54	49.32	47.89	42.8	33.3
70^0C	Untreated	31.5	27	22	19	9.12	27.39	24	19.35	15.85	10.21
	Water Blanched	55.6	54	51.34	48	16.92	46.6	43.4	40.96	35.91	28.7
	Steam Blanched	58.56	56	54.22	52.5	17.3	46.8	44.24	41.09	38.41	28.22
	SB+sodium benzoate	62.9	60.8	58.55	55.67	18.74	51	48	45.5	42	32.08
Fresh amla		4.85 mg/g					73 mg/g				

Phenolic content decreases with increasing temperature[28]. Phenolic compounds Degradation could be results of polyphenol oxidase (PPO) enzymatic activity[29]. Thermal treatment can

affect the polyphenols by thermal breakdown that affect the cell structure which then resulted in the relocation of components, leading to losses by leakage or breakdown by various chemical reactions involving enzymes, light and oxygen[30]. Total phenol content also decrease during storage[31]. This degradation of total phenol content was described through research that demonstrated that polyphenols were utilized as substrates for the PPO protein Janovitz-Klapp et al. (1990)[32]. Ascorbic acid content degraded during drying involves oxidation and hydrolysis[33]. Loss of ascorbic acid, also occur by chemical degradation during preparation time. Because ascorbic acid is highly soluble in aqueous solution so there was potential for significant losses by leaching from freshly cut fruit. The loss also occurs during storage[1]. The retention of ascorbic acid and phenolic compound (Table 1.7) was highest in steam blanched with 0.5% sodium benzoate in all three temperature followed by steam blanched and water blanched after 6 months storage.

1.4 Conclusion:

The effect of temperature and pre-treatments on thin layer drying of amla in dryer was investigated. Increase in drying temperature from 50 to 70 °C decreased the drying time for all the samples considered. The pretreated samples dried faster than the untreated samples. Samples pretreated with steam blanching with 0.5% sodium benzoate had shorter drying times (hence higher drying rates) compared to steam blanched, water blanched and control samples The entire drying process occurred in falling rate period. Ascorbic acid and phenolic compound decreases with increasing temperature and during storage. Maximum retention of ascorbic acid and phenolic compound observed in steam blanched with 0.5% sodium benzoate after 6 months storage.

REFERENCES

1. Pragati, Dahiya S and Dhawan S S (2003) Effect of drying methods on nutritional composition of Dehydrated aonla fruit (*Emblica officinalis* Garten) during storage. *Plant Foods for Human Nutrition*. **58**: 1–9.

2. Sajith K G C and Muraleedharan (2013) A Study on drying of amla using a hybrid solar dryer. *International Journal of Innovative Research in Science, Engineering and Technology.* **2**: Special Issue 1: 794-799.

3. Mishra P, Verma M, Mishra V and Rai K G (2011) Studies on Development of Ready to Eat Amla (*Emblica officinalis*) Chutney and its Preservation by using class one Preservatives. *Am. J. Food Technol.* **6(3)** 244-252.

4. Verma C R and Gupta A (2004) Effect of pre-treatments on quality of solar-dried amla. *Journal of Food Engneering*. **65**: 397-402.

5. Prasad J, Vijay V K, Tiwari G N and Sorayan V P S (2006) Study on performance evaluation of hybrid drier for turmeric (*Curcuma longa* L.) drying at village scale. *J Food Eng*. **75**:497–502.

6. Akoy E O M (2014) Experimental characterization and modeling of thin-layer drying of mango slices. *International Food Research Journal.* **21(5)** 1911-1917.

7. Oliva A, Torralba A B, Guerin-Dugue A and Herault J (1999) Global semantic classification of scenes and power spectrum templates. In: Proceedings of Challenge of Image Retrieval, Electronic Workshop in Computer Series, Newcastle.

8. Waananen K M, Litchfield J B and Okos M R **(**1993) Classification of drying models for porous solids.*Drying Tech.* **11 (1)** 1-40.

9. Akpinar E K (2006) Determination of suitable thin layer dring curve model for some vegetables and fruits. *Journal of Food Engineering.* **73**: 75–84.

10. Doymaz I (2010) Effect of citric acid and blanching pre-treatments on drying and rehydration of Amasya red apples. *Food Bioproducts Processing*. **88**: 124–132.

11. Tembo L, Chiteka Z A, Kadzere I, Akinnifesi F K and Tagwira F (2008) Blanching and drying period affect moisture loss and vitamin C content in *Ziziphus mauritiana* (Lamk.). *Afric J Biotech.* **7**: 3100–3106.

12. Aregbesola, O A, Ogunsinaa,B.S., Sofolahan, A.E., Chime, N.N., (2015) Mathematical modelling of thin layer drying characteristics of dika (*Irvingia gabonensis*) nuts and kernels. *Nigerian FoodJourna*l. **33**:83–89.

13. Lavanya K, Kothakota A, Pandiselvam R and Rajesh G K (2016) A study on drying kinetics of Indian Gooseberry – AONLA (*Phyllanthus emblica* Linn.*). International Journal of Agriculture Sciences.* **8(52)** 2446-2449.

14. AOAC. (1990) Official Methods of Analysis. Trends Food Science Technology. Association of Official Analytical Chemists, Washington DC, USA.

15. Singleton V L and Rossi J A (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am J Enol Viticult.* **16**: 144-153.

16. Rangana S (1986) Handbook of analysis and quality control for fruit and vegetable products. 105-106.

17. Suresh K P & Sagar V R (2014) Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions. *J Food Sci Technol* **51(8)** 1540-1546.
.

18. Tunde-Akintunde T Y and Ogunlakin G O (2013) Mathematical modeling of drying of pretreated and untreated pumpkin. *J Food Sci Technol.* **50(4)** 705-713.

19. Mujumdar A S (1995) *Handbook of industrial drying* (second ed. New York): Marcel Dekker.

20. Singh S, Sharma R, Bawa A S and Saxena D C (2008) Drying and rehydration characteristics of water chestnut (*Trapa natans*) as a function of drying air temperature. *J Food Eng.* **87**: 213-221.

21. Henderson S M, and Pabis S (1961) Grain drying theory. I: Temperature effect on drying coefficient. *Journal of Agricultural Engineering Research.* **6(3)** 169-174**.**

22. Goyal R K, Kingsly A R P, Mannikantan M R and Ilyas S M (2007) Mathematical modeling of thin layer drying kinetics of plum in a tunnel dryer. *Journal of food Engineering*. **79**: 176-180.

23. Qing-An Zhang, Yun Song, Xi Wang, Wu-Qi Zhao and Xue-Hui Fan (2016) Mathematical modeling of debittered apricot (*Prunus armeniaca* L.) kernels during thin-layer drying. *CyTA - Journal of Food*. **14(4)** 509-517.

24. Aregbesola, O A, Ogunsinaa,B.S., Sofolahan, A.E., Chime, N.N., (2015) Mathematical modelling of thin layer drying characteristics of dika (*Irvingia gabonensis*) nuts and kernels. *Nigerian FoodJourna*l **33:**83–89.

25. Banerjee I and Ghosh U (2009) Effect of drying temperature on quality of dehydrated amlaki (*Phyllanthus emblica* Linn.). *J.Botan.Soc. Bengal.* **63(2)** 111-114.

26. Goyal R K, Mujjeb O and Bhargava V K (2008) Mathematical modeling of thin layer drying kinetics of apple in tunnel dryer. Int *J Food Eng.* DOI: https://doi.org/10.2202/1556-3758.1233.

27. Wankhadea P K, Sapkala R S, and Sapkalb V S (2012) Drying Characteristics of Okra slices on drying in Hot Air Dryer. *Procedia Engineering.* **51**: 371-374.

28. Paul R and Ghosh U (2012) Effect of thermal treatment on ascorbic acid content of pomegranate juice. *Indian journal of Biotechnology*. **11**: 309-313.

29. Sonawane S K and Arya S S (2015) Effect of drying and storage on bioactive components of jambhul and wood apple. *J Food Sci Technol.* **52(5)** 2833-2841.

30. Youssef KM, Mokhtar SM (2014) Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of Portulaca oleracea L. Leaves. *J Nutr Food Sci* 4:322. doi: 10.4172/2155-9600.1000322.

31. Serea C, Barna O, Manley M and Kidd M (2014) Effect of storage temperature on the ascorbic acid content, total phenolic content and antioxidant activity in Lettuce (*Lactuca sativa* L.). *The Journal of Animal & Plant Sciences.* **24(4)** 1173-1177.

32. Janovitz-Klapp A H, Richard F C, Goupy P M and Nicolas J J (1990) Inhibition studies on apple polyphenol oxidase. *J. Agric. Food Chem*. **38(4)** 926-931.

33. Thankitsunthorn S, Thawornphiphatdit C, Laohaprasit N and Srzednicki G (2009) Effects of drying temperature on quality of dried Indian Gooseberry powder. *International Food Research Journal.* **16**: 355-361.

CHAPTER 2

OSMOTIC DEHYDRATION OF AMLA

2.1 Introduction

The Osmotic dehydration has received larger attention in recent years as an effective method for preservation of fruits and vegetables. Osmotic drying is a partial dehydration process for giving the product a quality improvement over the conventional drying process. It is less energy intensive than hot air or vacuum drying processes because it can be conducted at low or ambient temperature. The process take place by two counter current mass transfers, a loss of water from the food to the solution and the simultaneous migrates of solids of solids from solution to the food. These mass transfer phenomena get affected by pretreatments, osmotic solution, product and osmotic environment related factors. It involves dehydration of fruits in two steps, removal of water using as an osmotic agent (osmotic concentration) and subsequent dehydration in a dryer where moisture content is further reduced to make the product shelf stable[1, 2]. After the osmotic treatment, the moisture content of fruits and vegetables are usually lower by 30-50% (wet basis). The residual moisture in the product determines the energy required to dry it to achieve the desired product quality. Moisture removal by segment change is an energy intensive process because of high latent heat of vaporization of water. However, there is no phase transition for osmotic dehydration process and requires minimum amount of energy compared to other conventional drying methods like convective, freeze, microwave and hot air drying processes. Osmotic dehydration allows development of new products storable in room temperature with minimum contribution of energy. Sugar, glucose, fructose, corn syrup and sodium chloride are the common osmotic agents and out of this sodium chloride solution is commonly used for vegetables and sucrose solution for fruits. Only limited efforts have so far been made to process amla into osmodehydrated product[3]. Osmotic dehydration is largely affected by pretreatment of samples. Mass transfer during osmotic drying depends on permeability of cell membrane. Any pretreatment such as blanching prior to osmotic water removal was detrimental to the

product quality. Therefore, the objective of our study was to evaluate the quality of osmodried whole amla and its storage at room temperature.

Very few attempt has been made to optimize the osmotic process parameters for osmoconvectively dehydrated product of amla[4, 5].Response surface methodology (RSM) is a group of statistical and mathematical techniques that has been successfully used for developing, improving and optimising processes[6]. RSM enables a reduction in the number of experimental trials required to evaluate multiple parameters and their interactions, thus, requiring less time and effort. RSM has been widely applied for optimising processes in the food industry[7, 8]. Response surface methodology was used for optimization of osmodried amla.

Thus the purpose of the present work was to study the effect of osmotic process parameters on nutritional quality responses and also to optimize these parameters for developing an effective osmotic dehydration system to obtain higher quality end product.

2.2 Materials and methods:

2.2.1 Osmodehydration of whole amla

Fresh amla fruits were purchased from local market. The amla were cleaned thoroughly with distilled water to remove adhering dust, foreign matter and wiped with a muslin cloth. The treatments prior to osmodehydration consisted of

(a) Whole fruits without any blanching were considered as control

(b) Water Blanching prior Pricking

(c) Pricking prior water Blanching

(d) SteamBlanching

2.2.1.1 Whole amla fruits were dipped in boiling water for 2-3 mins followed by cooling with cold water. Then amla fruits were pricked with the help of a needle. A portion of sample was first pricked with needle and then dipped in boiling water for 2-3 mins and immediately cooled by cold water. Steam Blanching was done in autoclave at 15 p.s.i pressure for 10 mins. The samples were separately dipped in sugar solution of 30^0B. The concentration of sugar syrup increased upto 60^{0B}. After 60^0 B samples were dried at 50^0c temperature for 7 hours and packed in glass container for storage study. Samples were collected and analysed for Vitamin C, naringin and total phenol content.

2.2.1.2 Total phenolic content (TPC)

Total phenolic content was determined by folin-ciocalteu method[9] at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit as described in chapter 1 (1.2.1.2).

2.2.1.3 Ascorbic acid content

Ascorbic acid was determined by titrimetric method[10] and the value expressed as mg of ascorbic acid /g fruit as described in chapter 1 (1. 2.1.3).

2.2.1.4 Naringin content

Naringin content was measured by the method of Davis[11]. 5 gm of sample was extracted with 50 ml of distilled water. Then 0.1ml of this sample was taken in a test tube and 5ml of 90% diethylene glycol (v/v) and 0.1ml of 4N NaOH was added to it and kept at room temperature for 10 minutes. Then the OD value was taken at 420nm. The flavonoid content of the test samples were determined from the standard curve prepared with naringin and expressed in terms of mg of naringin / g.

2.2.1.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of drying on the sensory quality of untreated and pretreated amla samples. A 10-untrained member sensory panel[12]

was used for evaluating colour, aroma, flavour and overall acceptability of dried fruits described in chapter 1 (1.2.1.4).

2.2.1.6 Total soluble solid:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B.

2.2.2 Statistical optimization of osmodried amla slices

2.2.2.1 Sample preparation:

After collection Amla (*Phyllanthus emblica* L) fruits were sorted for uniform size, colour and physical damage, washed with distilled water and wiped with muslin cloth. Then amla were cut into slices of same thickness.

2.2.2.2 Osmotic agent concentrations:

Sugar was purchased from local market. The osmotic solutions of different concentrations (45, 55and 60 °Brix) were prepared by dissolving required amounts of sugar in distilled water using magnetic stirrer. Concentrations (TSS) were checked by hand refractrometer.

2.2.2.3 Osmotic dehydration:

For each experiment, known weight of amla slices (40 g) were put in the stainless steel containers having calculated volume (as per solution : fruit ratio) of osmotic solutions of different concentrations preset at the desired temperature by water bath. During experimentation, it was assumed that the solid leaching out of amla slices during osmosis was negligible[13]. The amla slices were removed from the osmotic solutions at the specified times and rinsed with distilled water to remove surplus solvent adhering to the surfaces. These

osmotically dehydrated amla slices were then wiped with the absorbent paper to remove free water present on the surface. Each sample was dried at 60^0C after cooling used for analysis.

2.2.2.4 Total soluble solid:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, japan) and expressed in terms of ^{0}B.

2.2.2.5 Total phenolic content (TPC)

Total phenolic content was determined by Folin-Ciocalteu method[9] at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit as described in chapter 1 (1.2.1.2).

2.2.2.6 Ascorbic acid content

Ascorbic acid was determined by titrimetric method[10] and the value expressed as mg of ascorbic acid /g fruit as described in chapter 1 (1.2.1.3).

2.2.2.7 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of drying on the sensory quality of osmodried amla samples. A 10-untrained member sensory panel[12] was used for evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, appearance, taste, flavour and overall acceptability (OA). OA was considered as an average of colour, appearance, taste and flavour.

2.2.2.8 Experimental design: Response Surface Methodology or RSM is a set of mathematical and statistical techniques that are helpful for modelling and analysis of problems in which the response is influenced by several variables. It is reported to be an efficient tool for optimizing a process when the independent variables have the united effect on the responses[14]. Several investigators has been applied it in optimizing food-processing

operations by several investigators[15, 16]. Therefore, response surface methodology (RSM) was used to design the experiments. In the Box- Behnken design four variables and three levels each with three-center point combination was used[17].This design was taken as it fulfills most of the criteria needed for optimization of the pretreatment (osmotic dehydration) process prior to convective drying. In this design A, B, C, D are the coded variables, which are related to un-coded variables using the following relation

$$X_i = 2(\zeta i - \zeta_i')/ d_i \qquad (1)$$

Where, ζ_i is variable value in actual units of the i^{th} observation. The difference between the highest and lowest variable value of ζ_i is d_i and ζ_i' is the mean of highest and lowest variable value of ζ_i . Based on the above equation, the independent osmotic process variables and their levels in the form of coded variables for four-factor three level response surface analyses are given in Table 2.1. The independent process variables were sugar concentration, osmotic solution temperature, solution: fruit ratio and immersion time. The low level and high level in the actual (un-coded) form were 45-65^{0}B sugar, 30-50^{0}C, 5-15 and 2-6 hours for osmotic solution concentration, temperature, solution**:**fruit ratio and immersion time, respectively[18,19].Mainly sucrose is used as osmotic agent for fruits and salt for vegetables.

The experiment was conducted according to the requirements of RSM for analyzing the data. A second order Box-Behnken design was used to work out the range of osmotic process variables for optimization of osmotic dehydrated amla slices.

Table 2.1: The range and levels of experimental variables

Independent variables	Symbols		Levels	
	Coded	Un-coded	Coded	Un-coded
Sugar Concentration	A	^{0}B	1 0 -1	65 55 45
Immersion time (Hour)	B	t	1 0 -1	6 4 2
Temperature (^{0}C)	C	T	1 0 -1	50 40 30
Solution : Fruit	D	SL: FR	1 0 -1	15 10 5

2.2.2.9 Optimization of process parameters: Response surface methodology was applied to the experimental data using a commercial statistical package, Design-Expert version 7.0.0 (Statease Inc, Minneapolis, USA). The same software was used for the production of

response surface plots, superimposition of contour plots and optimization of process variables. The response surface and contour plots were generated for different interaction for any two independent variables, whereas holding the value of other two variables as constant (at the central value). Such three-dimensional surfaces could give accurate geometrical representation and provide valuable information about the behavior of the system within the experimental design[20, 21]. The optimization of the osmotic dehydration process aimed at finding the levels of independent variables such as osmotic solution concentration, immersion time, temperature, and solution**:**fruit ratio, which could give maximum overall acceptability, maximum Vitamin C and maximum total phenol content.

2.3 Result and discussion:

2.3.1Osmodehydration of whole amla

Initial vitamin C content of amla was 4.7±0.14 mg/g fruit. The pretreatments given to the amla fruit before osmotic drying effects the retention of vitamin C. From the table 2.2 it is clear that retention of vitamin C in the control sample was minimum, retained only 0.5±0.02 mg/g fruit. While maximum retention of vitamin C shows in the prickling after water blanching sample (2.1±0.15 mg/g fruit) followed by prickling before water blanching (1.3±0.03 mg/g fruit).

Table 2.2: Effect of concentration of sucrose solution on vitamin C, naringin and total phenol of whole amla

Sample	Vitamin C(mg/g)				Naringin(mg/g)				Total Phenol(mg GAE/g)			
	Sucrose solution (^{0}B)				Sucrose solution (^{0}B)				Sucrose solution (^{0}B)			
	30	40	50	60	30	40	50	60	30	40	50	60
Control	4± 0.25	2.85± 0.08	1.5± 0.03	0.5± 0.02	2.5± 0.12	2.3± 0.05	1.5± 0.03	1.5± 0.06	66.67± 0.42	45.83±0 .44	35.42± 0.34	33.33±0 .24
WB+P	2.85± 0.12	2.8± 0.08	2.7± 0.07	2.1± 0.15	2.5± 0.07	2.16± 0.07	2.16± 0.03	1.9± 0.11	47.93± 0.72	43.75±0 .86	41.66± 0.74	37.5± 1.11
P+WB	1.7± 0.03	1.4± 0.02	1.35±0 .03	1.3± 0.03	2.3± 0.07	2±0.1	1.67±0 .04	1.5±0. 03	47.08± 0.39	35.42±0 .98	34.58± 0.66	33.33±0 .47
SB	1.45± 0.15	0.85± 0.016	0.75± 0.007	0.7± 0.015	2.2± 0.02	1.8± 0.02	1.5± 0.01	1± 0.19	40± 0.33	22.5± 1.45	21.25± 0.47	20± 0.64
Fresh	4.7±0.14				3±0.32				75±0.07			

Ascorbic acid being an unstable compound decomposed easily under undesirable conditions[22]. Among treated sample steam blanching results higher loss in Vitamin C retaining (0.7±0.015mg/g fruit). Sagar et al reported thermal degradation of amla during osmotic process[23]. In case of naringin content little change were observed with pretreatments of amla and it was (1 to 1.9 mg/g fruit) for treated samples. Reduction in total phenol content was observed with increase in concentration of sucrose solution and at 60^{0}B total phenol

content (37.5±1.11mg GAE/g fruit) was maximum with blanching prior prickling sample. Retention of total phenol content was minimum in steam blanching (20±0.64 mg GAE/g fruit) followed by prickling before blanching (33.33±0.47 mg GAE/g fruit).

Table 2.3: Sensory analysis of osmodried amla samples

Samples	Colour	Aroma	Flavour	Overall acceptibility
Untreated	4.3	3.5	4.5	2.8
WB+P	8.3	6.8	8	8.33
P+WB	7.16	6.5	7.5	7.7
SB	6.33	5.8	6.7	7

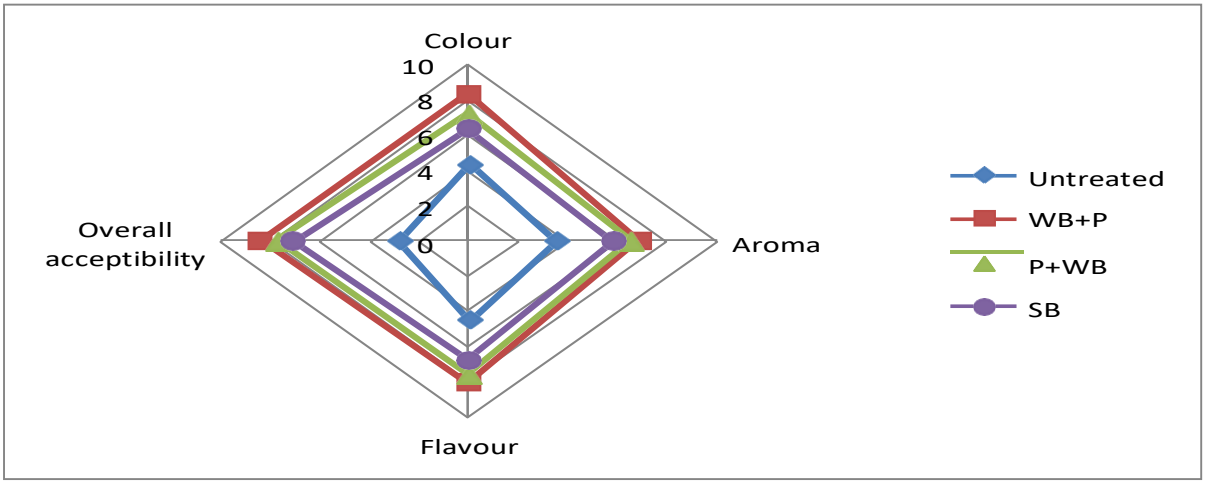


Fig 2.1: ***Descriptive analysis on sensory score on osmodried amla***

Sensory scored for osmosed amla for best colour (Fig 2.1) was obtained with Water Blanching prior Pricking due to prevention of enzymatic and oxidative browning as fruits were surrounded by sugar which making it possible to retain good colour. From table 2.3 it was observed that the overall acceptability of Water Blanching prior Pricking is satisfactory.

Table 2.4: Nutritional parameters of osmodried amla after 6 months of storage

Sample	Vitamin C(mg/g)	Total phenol(mg GAE/g)	Naringin(mg/g)
WB+P	1±0.11 (21.3%)	31.25±0.46 (41.7%)	1.25±0.1 (41.67%)
P+B	0.5±0.02 (10.64%)	29.16±0.3 (38.9%)	0.62±0.03 (20.7%)
SB	0.5±0.01 (10.64%)	12.5±0.24 (16.7%)	0.42±0.03 (14%)

Table 2.4 represents the nutritional parameters of osmodried amla after 6 months of storage. Ascorbic acid content of osmodried amla decreases further when stored for 6 months. The retention of vitamin C was highest in water blanching prior prickling (1±0.11 mg/g fruit). Loss of naringin is highest in steam blanching retained only (0.42±0.03 mg/g fruit). Maximum amount of naringin revealed in blanching prior prickling sample (1.25±0.1 mg/g fruit). Maximum total phenol retained in prickling after water blanching (31.25±0.46 mg GAE/g fruit) and minimum in steam blanching (12.5±0.24 mg GAE/g fruit). In all cases loss in Vitamin C, naringin and total phenol occurs but loss was minimum for water blanching prior prickling samples. Control (Unblanched) samples became unacceptable within 8-9 weeks of storage due to dark brown coloration of amla. This may be due to faster rate of browning reaction of control samples than other pretreated samples.

However retention of nutritional content was not so significant between pretreated samples but better than control sample and can be stored upto 6 months in glass container.

2.3.2 Statistical optimization of osmodried amla slices

Box-Behnken method of RSM was used to optimize the interaction between process variables and response by using Design Expert software. According to this method 29 experiments were carried out and a second order polynomial model describing the relation between experimental variables and the response was developed and represented by the following equation:

$$y_k = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \beta_{ij} x_i x_j \quad \textbf{(2)}$$

Where y is the response, Where β_i, β_{ii}, β_{ij} are constant coefficient and χ_i χ_j are coded independent variables. This equation use to describe the response surface and from this R_2 values were calculated.

The value of different responses at different experimental combination for coded variables is given in Table 2.5. A wide variation in all the responses was observed for different experimental combinations i.e. 1.250 mg/g to 9.390 mg/g for vitamin C, 72 to 89.80 % for overall acceptability and 2.225 mg GAE/g to 68.5 mg GAE/g for total phenol.

Table 2.5: Experimental data for the four-factor three level response surface analyses

Std	Run	Factor A: Brix(°)	Factor B: Time(h)	Factor C: Temparature(°C)	Factor D: (SL:FR)	Response 1: Vit C (mg/g)	Response 2 :OA%	Response 3: Total phenol(mg GAE/g)
19	1	45	4	50	10	2.72	77.18	7.99
23	2	55	2	40	15	5.31	84.3	35.42
10	3	65	4	40	5	2.8	80.3	7.5
9	4	45	4	40	5	1.25	74.81	42.5
20	5	65	4	50	10	1.69	87.87	7.45
17	6	45	4	30	10	2.68	72	32.67
29	7	55	4	40	10	2.35	79.5	13.54
11	8	45	4	40	15	3.25	76.2	12.82
18	9	65	4	30	10	4.05	72.7	2.225
5	10	55	4	30	5	7.22	73.4	20.64
22	11	55	6	40	5	6.98	88.9	21.47
24	12	55	6	40	15	4.6	85.7	14.675
1	13	45	2	40	10	1.42	78	68.5
25	14	55	4	40	10	4	79.9	8.5
21	15	55	2	40	5	3.65	84.58	40.5
6	16	55	4	50	5	3.65	88.9	3.2
26	17	55	4	40	10	4	81.6	8.5
12	18	65	4	40	15	2.5	80.3	10.85
15	19	55	2	50	10	5.88	89.8	31.4
4	20	65	6	40	10	2	86.6	24
27	21	55	4	40	10	4	79.9	13.98
28	22	55	4	40	10	4	79.9	8.5
8	23	55	4	50	15	5.5	81.9	6.78
13	24	55	2	30	10	3	76.13	35
16	25	55	6	50	10	3.3	86.6	5.75
7	26	55	4	30	15	6.42	79.18	10.62
3	27	45	6	40	10	3.05	78.9	14.16
14	28	55	6	30	10	9.39	85.2	27.89
2	29	65	2	40	10	1.94	81	12.4

The three outputs, namely vitamin C, overall acceptability and total phenol of the product were given as polynomials in equations (3), (4) and (5) respectively

$$\text{Vitamin C} = 3.67+0.051*A+0.68*B-0.84*C+0.17*D-0.39*A*B-0.60*A*C-0.57*A*D-2.24*B*C-1.01*B*D+0.66*C*D-2.09*A^2+0.55*B^2+1.18*C^2+0.88*D^2 \quad (3)$$

$$\text{Overall acceptability} = 80.16+2.64*A+1.51*B+4.47*C-0.28*D+1.18*A*B+2.50*A*C-0.35*A*D-3.07*B*C-0.73*B*D-3.20*C*D-3.12*A^2+4.37*B^2+8.750E-003*C^2+0.96*D^2 \quad (4)$$

Total phenol=10.60-9.52*A-9.61*B-5.54*C-3.72*D+16.48*A*B+7.48*A*C+8.26*A*D-4.63*B*C-0.43*B*D+3.40*C*D+4.40*A^2+15.41*B^2-2.03*C^2+2.39*D^2 (5)

The sign of the coefficients indicate the effect of the variable on the response. Negative sign of the coefficient means decrease in response while the level of the variable is increased when positive sign indicated increase in the response. Significant interaction suggests that the level of one of the interactive variable can be increased that of other decreased for constant value of the response[5].

Table 2.6: Analysis of Variance (ANOVA) for the quadratic polynomial model for the optimization of Vitamin C of osmodried amla

Source	Sum of Squares	df	Mean Square	F value	P-value Prob>F	
Model	98.05	14	7.00	22.46	< 0.0001	Significant
A-Brix	0.031	1	0.031	0.099	0.7571	
B-Time	5.49	1	5.49	17.62	0.0009	
C-Temperature	8.37	1	8.37	26.84	0.0001	
D-Ratio	0.34	1	0.34	1.10	0.3117	
AB	0.62	1	0.62	1.98	0.1816	
AC	1.44	1	1.44	4.62	0.0496	
AD	1.32	1	1.32	4.24	0.0585	
BC	20.12	1	20.12	64.52	< 0.0001	
BD	4.08	1	4.08	13.09	0.0028	
CD	1.76	1	1.76	5.63	0.0325	
A^2	28.42	1	28.42	91.17	< 0.0001	
B^2	1.98	1	1.98	6.36	0.0244	
C^2	8.96	1	8.96	28.74	0.0001	

D^2	5.01	1	5.01	16.08	0.0013
Residual	4.36	14	0.31		
Lack of Fit	2.19	10	0.22	0.40	0.8897 Not Significant
Pure error	2.18	4	0.54		
Cor Total	102.41	28			

The probability (p- value) is commonly applied to test the significance of each coefficient[24]. Normally values of "Prob > F" (p-value) less than 0.05 indicate model terms are significant and values greater than 0.1 indicate the model terms are not significant. In table 2.6 B, C, AC, BC, BD, CD, A^2, B^2, C^2, D^2 are significant model terms. The resulted values give factor wise analysis of variance, the contribution of each independent variable to the total sum of squares are separated. The results revealed that the higher influence of temperature and time in comparison to SL:FR and ^{0}brix on vitamin C of sample. Model significance was evaluated by the F-test of ANOVA table. The Model F-value of 22.46 implies the model is very significant (p <0.0001) and accurately predicted the Vitamin C content of the samples. The F value of Lack of Fit, 0.40 denote that the Lack of Fit was not significant relative to the pure error. There was a 88.97% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good for fit the model.

Table 2.7: Analysis of variance (ANOVA) for response-surface quadratic fitted model

Standard deviation	0.56
Mean	3.88
Press	16.00
R^2	0.9574
Adjusted R^2	0.9148
Predicted R^2	0.8438
Adequate Precision	20.278

The R^2 (0.9574) for this model implied that 95.74% of the sample variation for vitamin C retention was attributed to the independent variables , and only about 4.26% of the total variation was not explained by the model.

The value is closer to 1.0 suggested that model represents better correlation between experimental and predicted values. As adequate Precision measures the signal to noise ratio and a ratio greater than 4 is desirable. An adequate precision of 20.278 indicated low signal to noise ratio. On the basis of results obtained from ANOVA (table 2.6 and 2.7) it can be concluded that the model is highly significant and sufficient to represent the actual relationship between the response and the significant variables and can be used successfully to navigate the design space. The 3D surface and contour plots usually represent the pair wise interaction of two factors on the response[25], keeping other factors at a fixed level (centre point).

2.3.2.1Effect of solution concentration (^{0}Brix) vs solution temperature on vitamin C content

The interaction between solution concentration (^{0}Brix) and solution temperature on vitamin C was represented by figure 2.2.A and 2.2.B when time and SL: FR ratio was constant. Vitamin C content decreases with increasing temperature and increases with solution concentration. The maximum value of vitamin C 5.9 mg/g content was observed below 40^{0}C solution temperature and 55^{0}B sugar concentration.

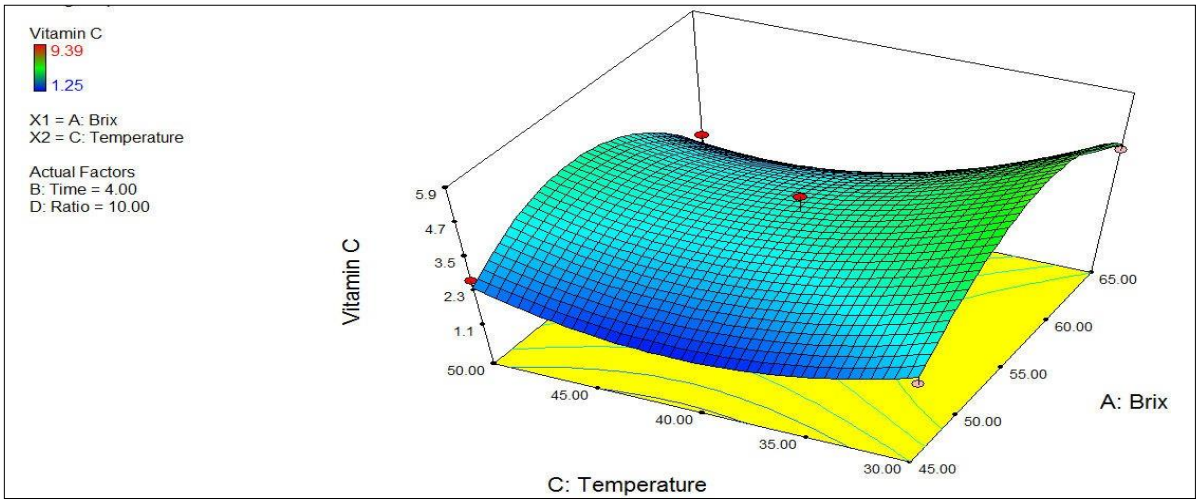


Fig 2.2 A*: Response surface plots ^{0}Brix vs temperature for vitamin C*

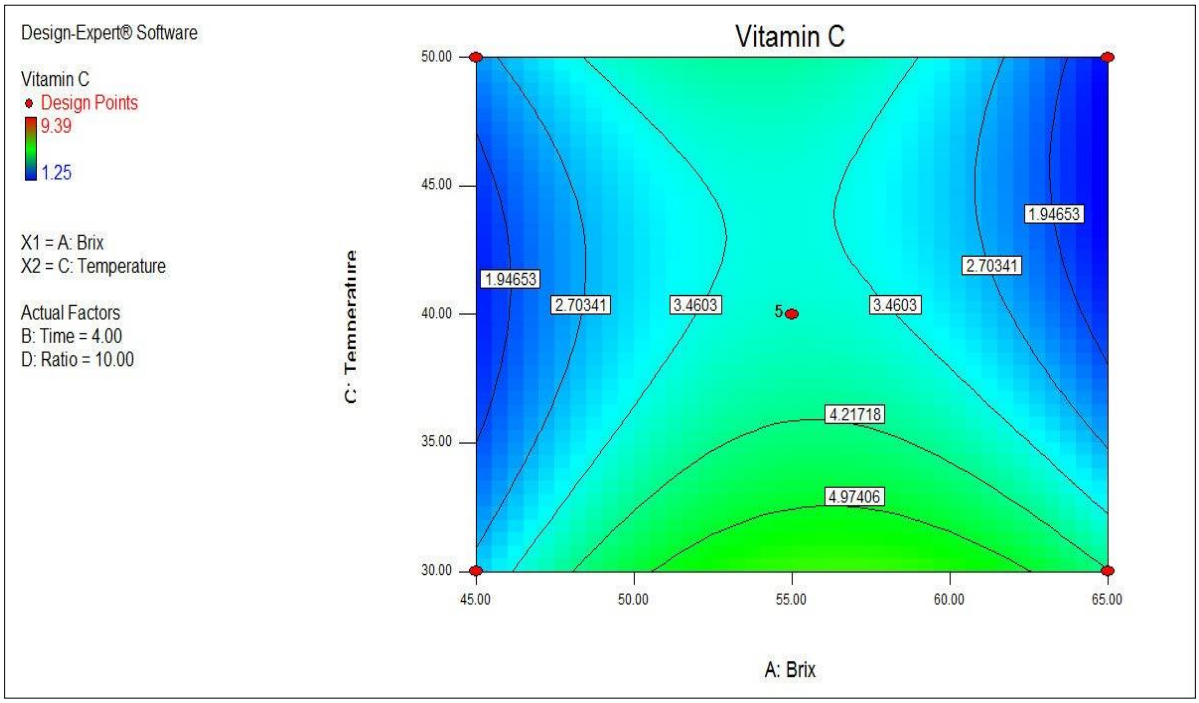


Fig 2.2 B: *Contour plots brix vs temperature for vitamin C*

2.3.2.2 Effect of time vs solution temperature on vitamin C content

Figure 2.3.A (3D surface plot) and 2.3.B (contour plot) represented the combined effect of temperature and time on vitamin C content. The other two factors (solution concentration and Solution: fruit ratio) were maintained at centre point. The 3D surface and contour plot indicated that vitamin C content was maximum (9.4 mg/g) below 40^0C solution temperature when immersion time was above 4 hours. Vitamin C decreases with increasing temperature

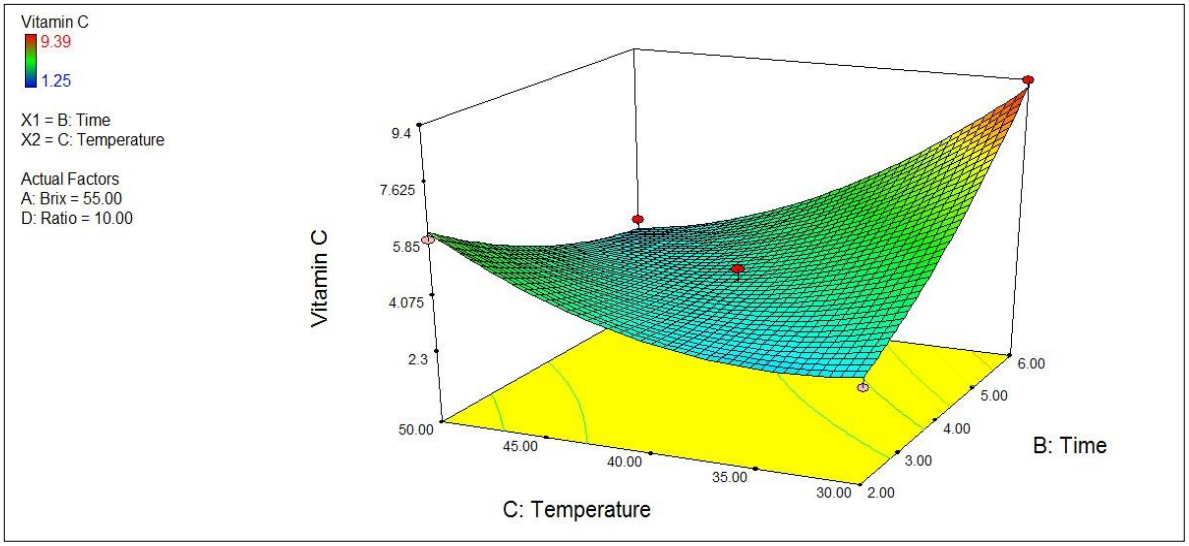


Fig 2.3A: ***Response surface plots of time and temperature for vitamin C***

up to 45^0C above that temperature Amount of vitamin C increased when immersion time was 2 hours.

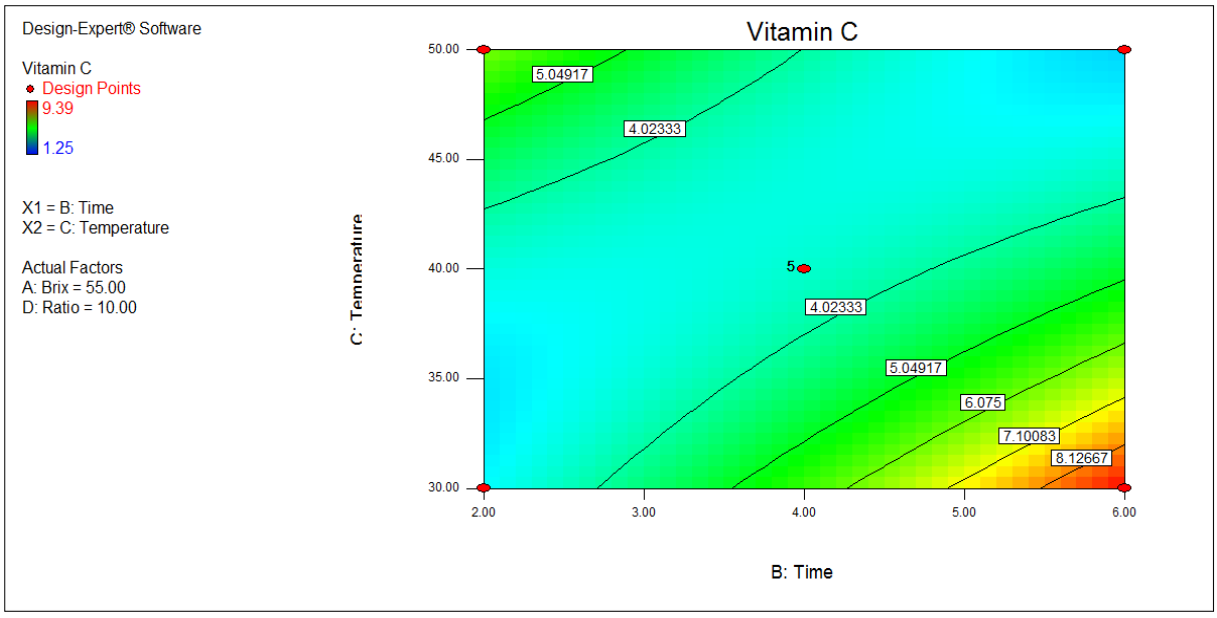


Fig 2.3 B: ***Contour plots of time and temperature for vitamin C***

2.3.2.3 Effect of immersion time vs SL: FR ratio on vitamin C content

The combined effect of solution: fruit ratio and immersion time on vitamin C content was represented in figure 2.4 A (3D surface plot) and 2.4 B (contour plot). These experiments were done by keeping the other parameters that were solution concentration and temperature at the centre points. The vitamin C gradually increased with immersion time and solution to fruit ratio.

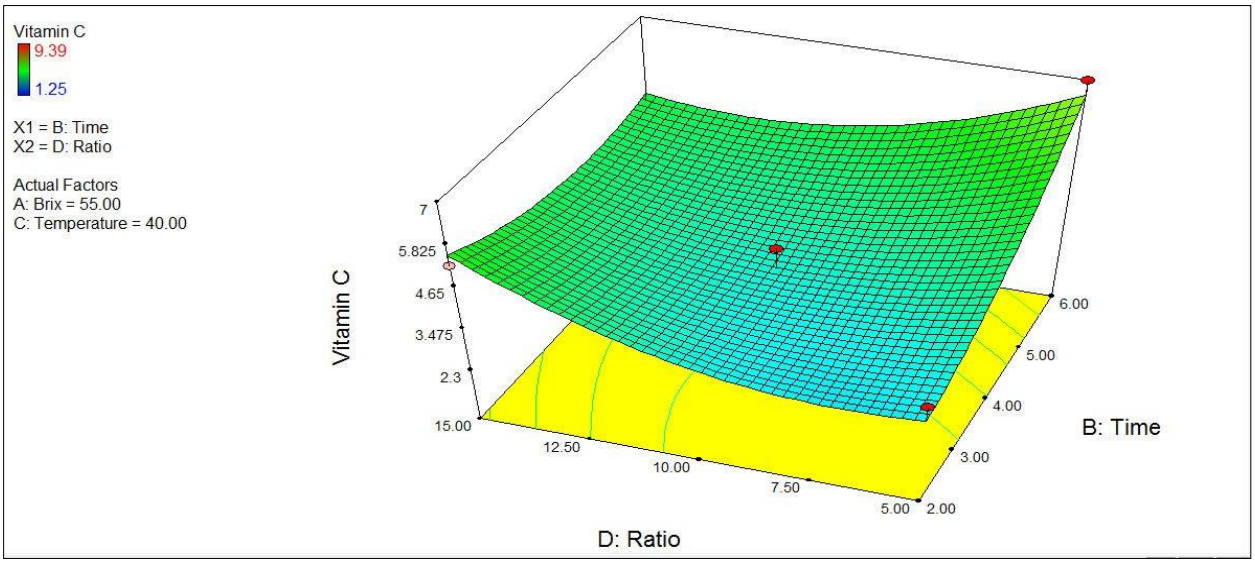


Fig 2.4 A: ***Response surface plots of ratio vs time for vitamin C***

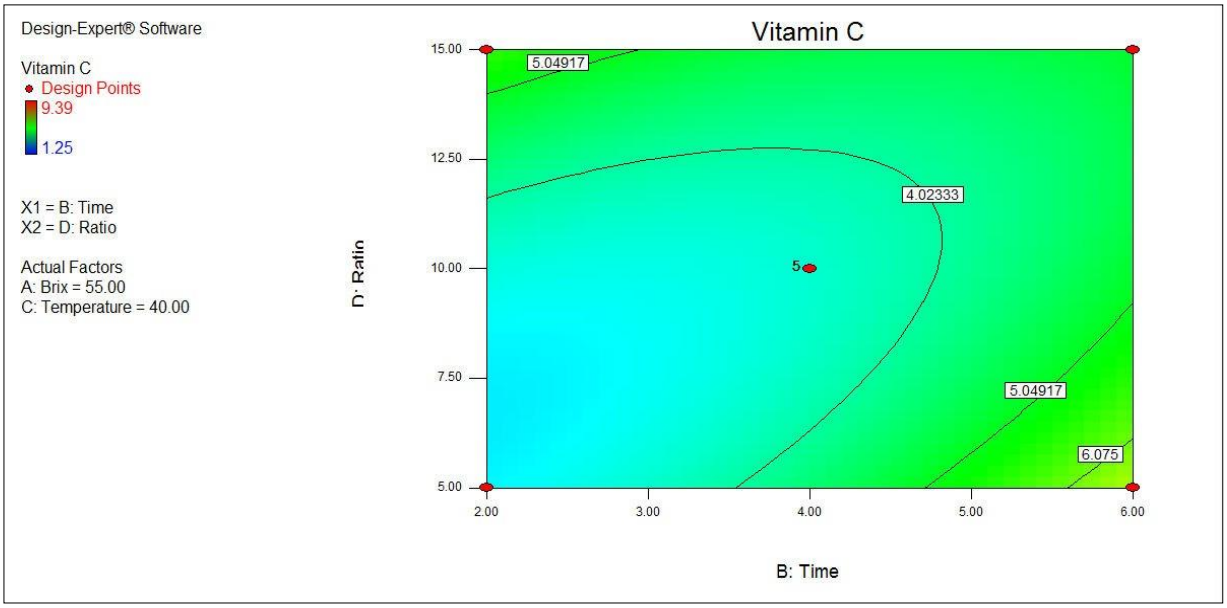


Fig 2.4 B*: Contour plots of ratio vs time for vitamin C*

2.3.2.4 Effect of solution to fruit ratio and temperature on vitamin C content

Figure 2.5 A (3D surface) and 2.5 B (contour) represented the interaction between SL: FR ratio and solution temperature on vitamin C content. Vitamin C content maximum at 30^0C when solution to fruit ratio was 5 again retention was maximum at 30^0C when solution to fruit ratio was 15 with increasing temperature.

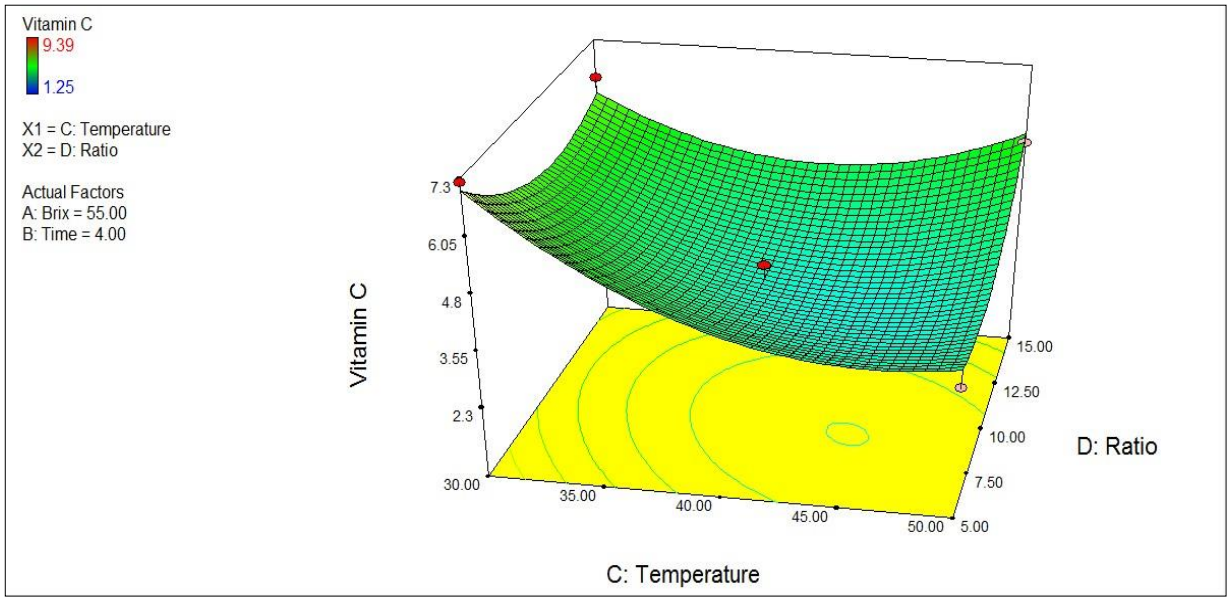


Fig 2.5 A: ***Response surface plots of ratio vs temperature for vitamin C***

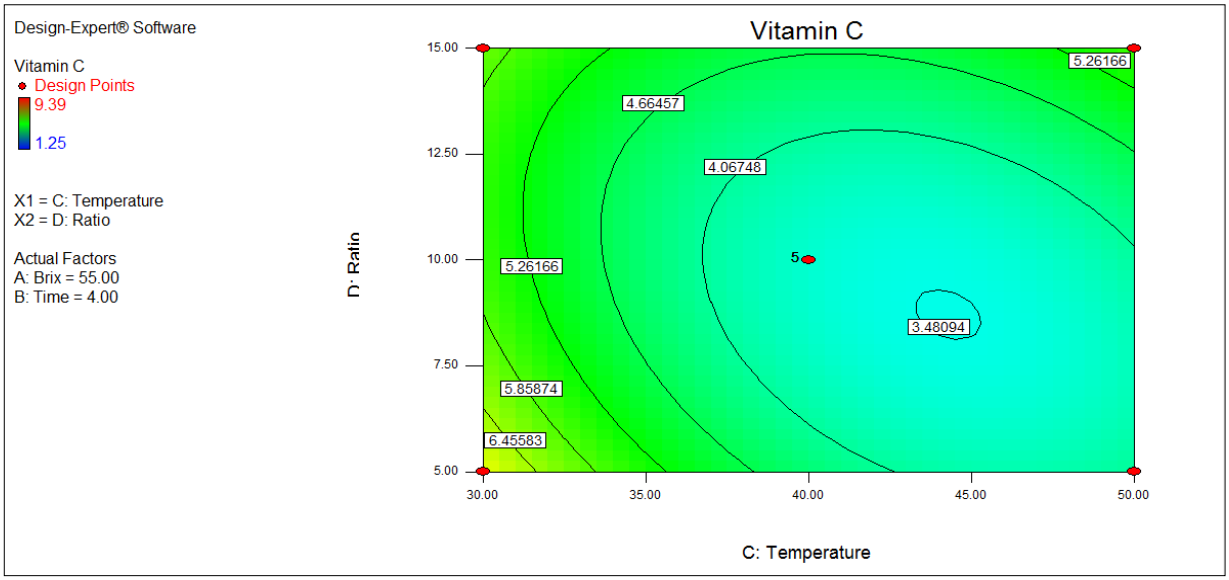


Fig 2.5 A: ***Contour plots of ratio vs temperature for vitamin C***

It was obtained from fig 2.2 to 2.5 that the higher influence of temperature, concentration and time in comparison to solution to fruit ratio irrespective of the responses. The temperature

showed most significant effect on vitamin C content. Maximum retention of vitamin C observed when solution temperature was below 40^0 C, higher solution concentration, immersion time above 4 hours and solution to fruit ratio was higher. Also good retention of vitamin C showed at 50^0 C temperatures when immersion time was 2 hours.The rate of osmosis increased with temperature which was limited up to 60^0C as higher temperature destroyed the cell membranes but vitamin C is very unstable[22] during heat treatment it degraded at high temperature. Vitamin C is highly soluble in aqueous solution so there was potential for significant losses during longer immersion time. Increase in osmotic solution concentration increases water loss to equilibrium level and drying rate. This could be described by the greater concentration gradient between the fruit and the solution led to a greater dehydration driving force[26]. The rate of osmosis increase with increase of solution to fruit ratio[27].

Table 2.8: Analysis of Variance (ANOVA) for the quadratic polynomial model for the optimization of overall acceptability of osmodried amla

Source	Sum of Squares	df	Mean Square	F value	P-value Prob>F	
Model	695.89	14	49.71	59.89	< 0.0001	Significant
A-Brix	83.64	1	83.64	100.77	< 0.0001	
B-Time	27.27	1	27.27	32.86	< 0.0001	
C-Temperature	239.77	1	239.77	288.89	< 0.0001	
D-Ratio	0.91	1	0.91	1.10	0.3120	
AB	5.52	1	5.52	6.65	0.0218	
AC	24.95	1	24.95	30.06	< 0.0001	
AD	0.48	1	0.48	0.58	0.4582	
BC	37.64	1	37.64	45.35	< 0.0001	
BD	2.13	1	2.13	2.57	0.1313	
CD	40.83	1	40.83	49.20	< 0.0001	
A^2	62.99	1	62.99	75.89	< 0.0001	
B^2	123.59	1	123.59	148.90	< 0.0001	
C^2	4.966E-004	1	4.966E-004	5.984E-004	0.9808	
D^2	5.98	1	5.98	7.20	0.0178	
Residual	11.62	14	0.83			
Lack of Fit	8.91	10	0.89	1.31	0.4263	Not Significant
Pure error	2.71	4	0.68			
Cor Total	707.51	28				

From the Table 2.8 the magnitude of P and F values indicates the maximum positive contribution of all the four variables namely temperature, sugar concentration immersion time & solution to fruit ratio on the overall acceptability during osmotic dehydration. The sum of square showed that osmotic solution temperature had a more pronounced effect (239.77) on sensory score than did osmotic solution concentration (83.64), process time (27.27) and solution to fruit ratio (0.91). The F-value (59.89) for the present model implies that the model was highly significance. $p< 0.05$ indicate model terms are significant and values greater than 0.1 indicate the model terms are not significant. In table 2.8 A, B, C, AB, AC, BC, CD, A^2, B^2, D^2 are significant model terms. The *F*-values for the lack of fit were non-significant ($p < 0.01$) which confirmed that the validity of the models.

Table 2.9: Analysis of variance (ANOVA) for response-surface quadratic fitted model

Standard deviation	0.91
Mean	81.08
Press	55.55
R^2	0.9836
Adjusted R^2	0.9672
Predicted R^2	0.9215
Adequate Precision	27.661

The R^2 was found to be 0.9836 for this model, greater than 90%, indicating the significant relationship between the independent variable and the response value. The value is closer to 1.0 suggested that model represents better correlation between experimental and predicted values. An adequate precision of 27.661 indicated low signal to noise ratio. On the basis of results obtained from ANOVA (table 2.8 and 2.9) it can be concluded that the model is highly

significant and sufficient to represent the actual relationship between the response and the significant variables and can be used successfully to navigate the design space.

2.3.2.5 Effect of immersion time vs ^{0}Brix on overall acceptability

Fig 2.6 A (3D surface) and 2.6 B (contour) shows the significant interaction between solution concentration and immersion time when solution temperature and solution fruit ratio were constant. At the initial stage the overall acceptability increased with time further decreased with increase of time. After 4 hours immersion time overall acceptability increased with increasing time. Overall acceptability gradually increased with increasing solution concentration. The maximum value of overall acceptability was observed at 65^0 B and 6 hours immersion time.

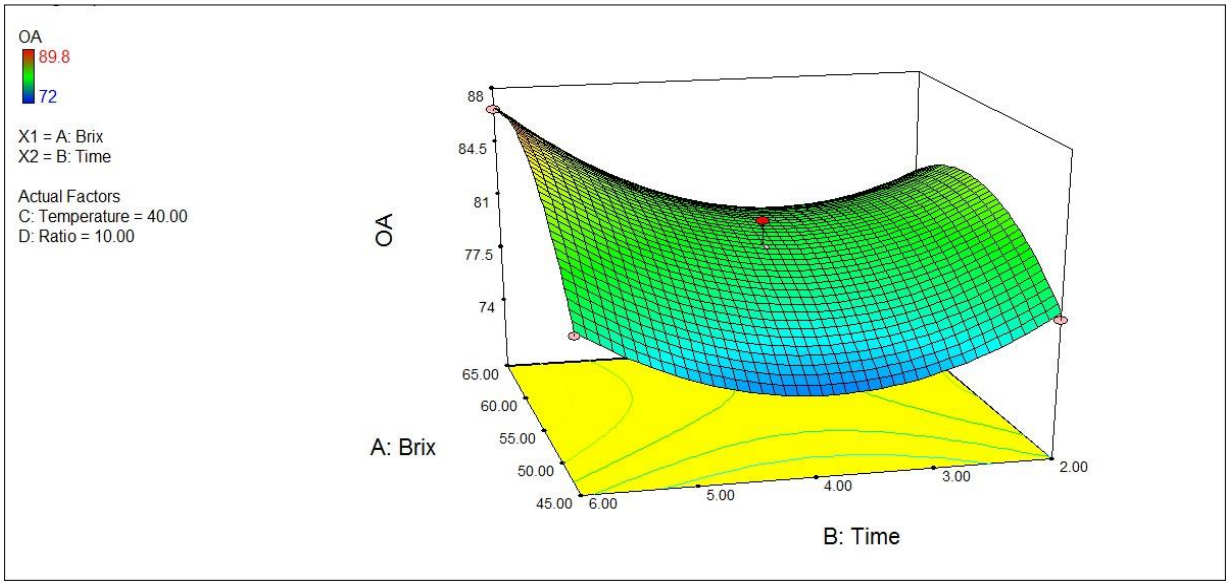


Fig 2.6 A: ***Response surface plots of ^{0}Brix vs time for overall acceptability***

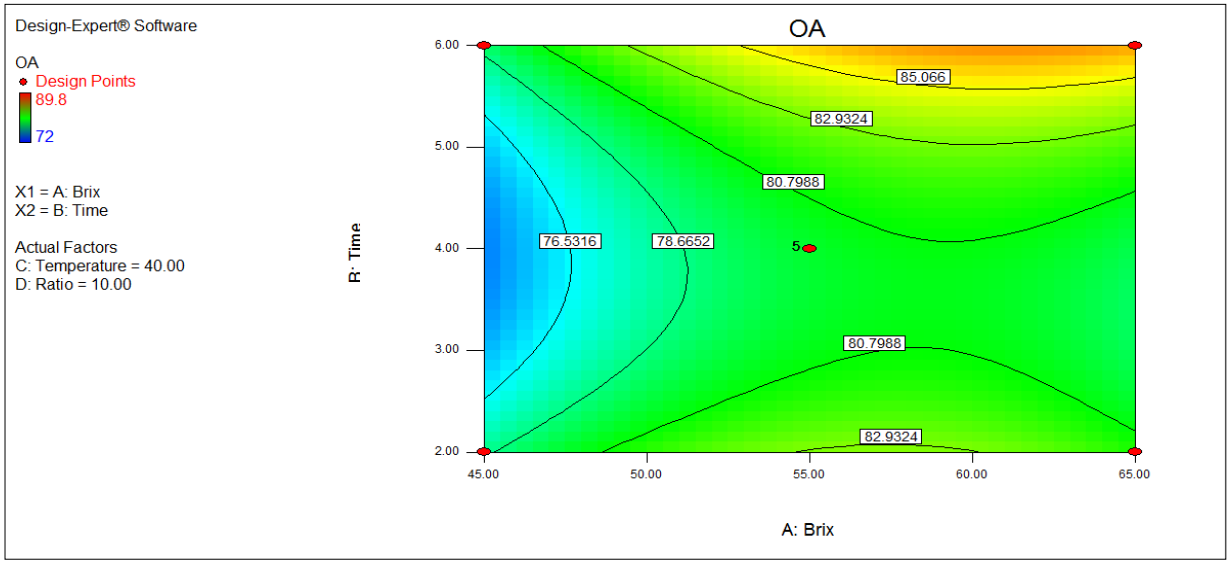


Fig 2.6 B: ***Contour plots of ^{0}Brix vs time for overall acceptability***

2.3.2.6 Effect of solution temperature vs ^{0}Brix on overall acceptability

The combined effect of solution temperature and solution concentration on overall acceptability was represented in figure 2.7.A (3D surface plot) and 2.7.B (contour plot). These experiments were done by keeping the other parameters that were immersion time and solution to fruit ratio at the centre points. Overall acceptability increased with increasing temperature. Maximum amount of overall acceptability was observed with increasing solution temperature and solution concentration.

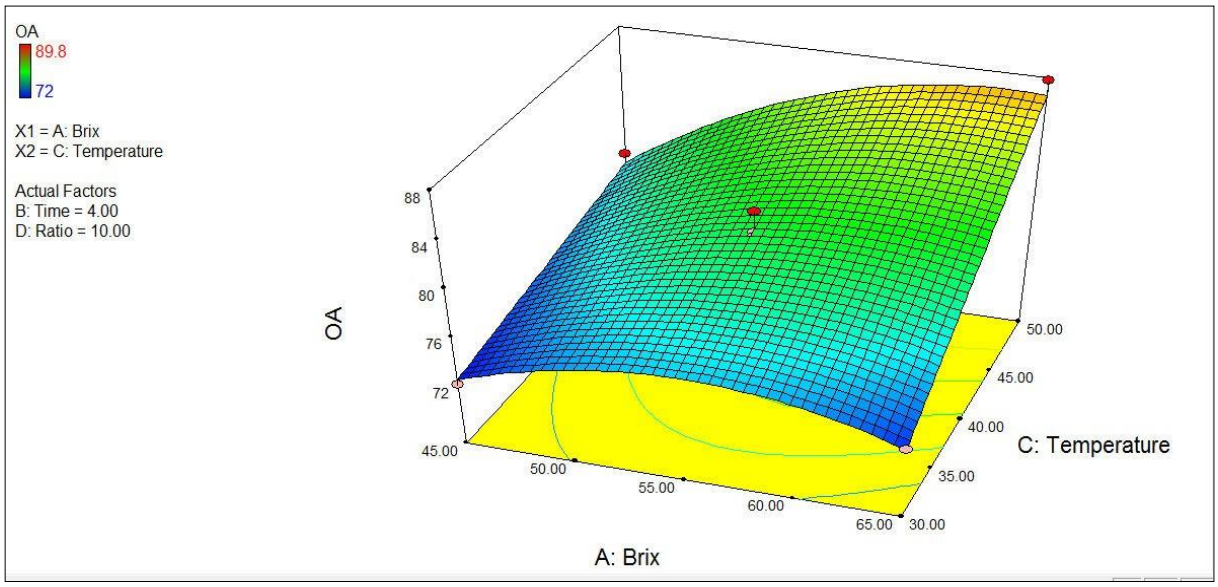


Fig 2.7 A: ***Response surface plots of ^{0}Brix vs temperature for overall acceptability***

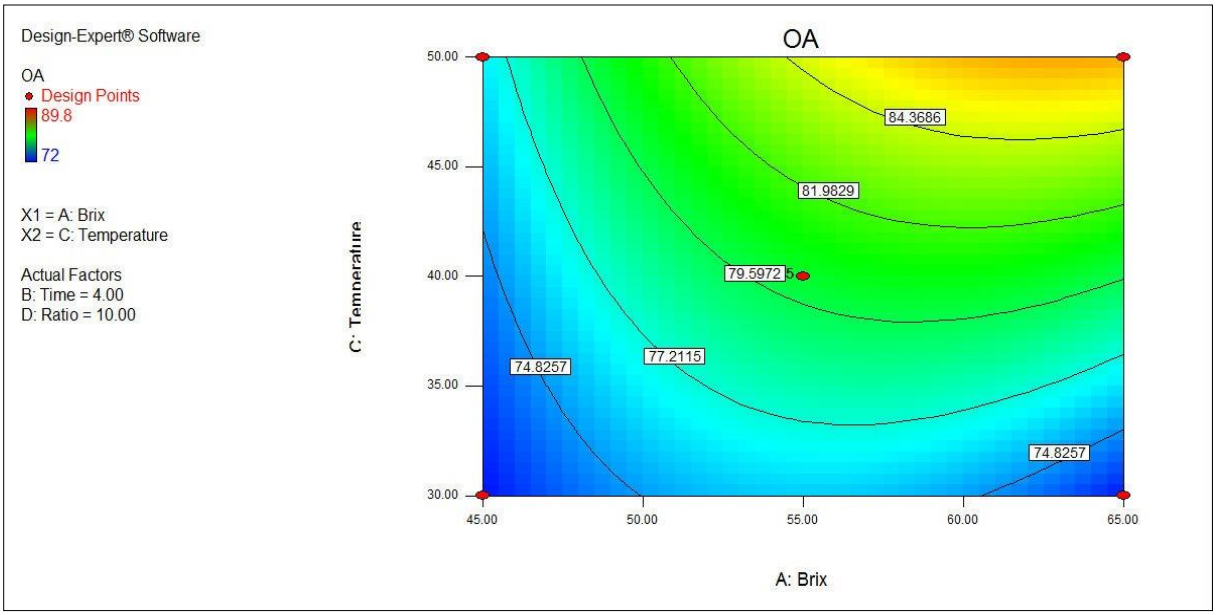


Fig 2.7 B: ***Contour plots of ^{0}Brix vs temperature for overall acceptability***

2.3.2.7 Effect of solution temperature vs immersion time on overall acceptability

Figure 2.8.A (3D surface) and 2.8.B (contour) represented the interaction between solution temperature and immersion time. The overall acceptability gradually increases with increasing temperature and immersion time but the maximum overall acceptability (89.8%) observed at 50^0C temperature and 2 hours immersion time combinations.

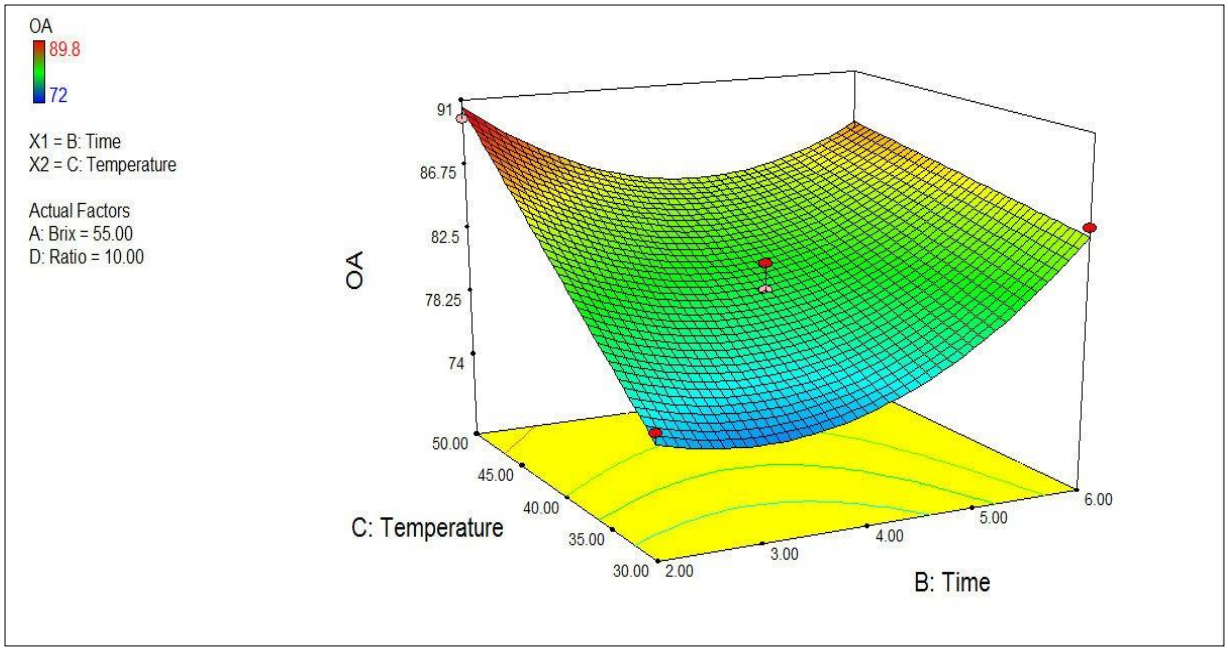


Fig 2.8 A: ***Response surface plots of time vs temperature for overall acceptability***

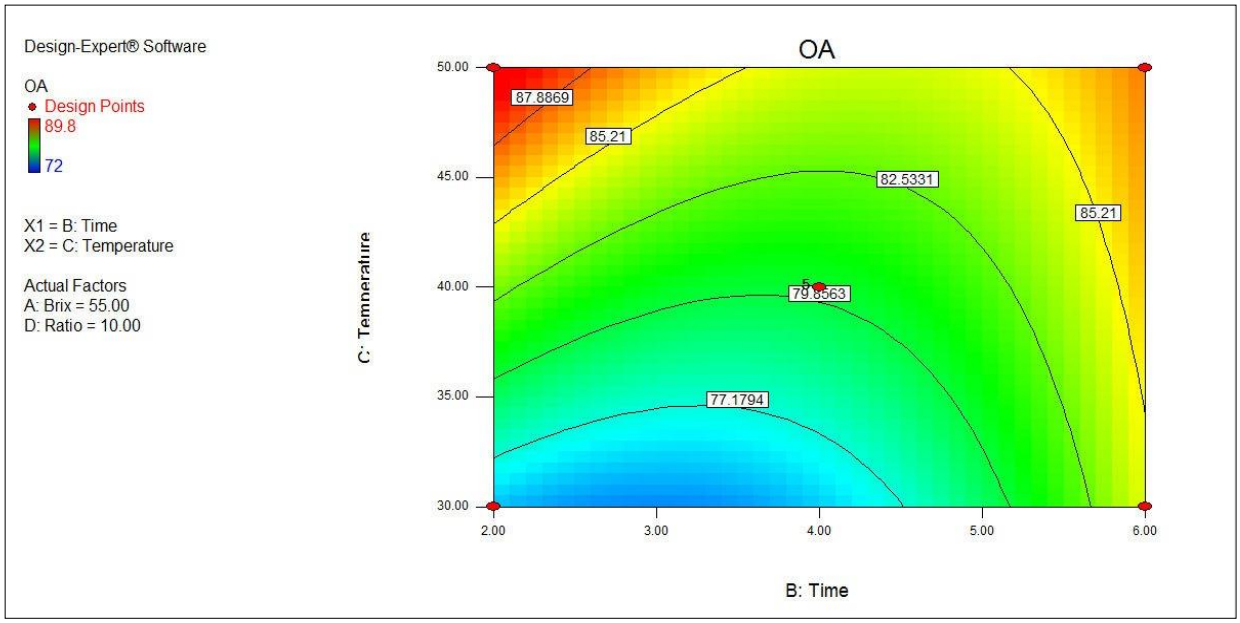


Fig 2.8 B: Contour plots of time vs temperature for overall acceptability

2.3.2.8 Effect of solution temperature vs sl: fr ratio on overall acceptability

Figure 2.9.A (3D surface plot) and 2.9.B (contour plot) represented the combined effect of solution temperature and sl: fr ratio on overall acceptability. The other two factors (immersion time and brix) were maintained at centre point. Overall acceptability increases

with increasing temperature and solution to fruit ratio. In 50^0C temperature overall acceptability became maximum when solution to fruit ratio was low.

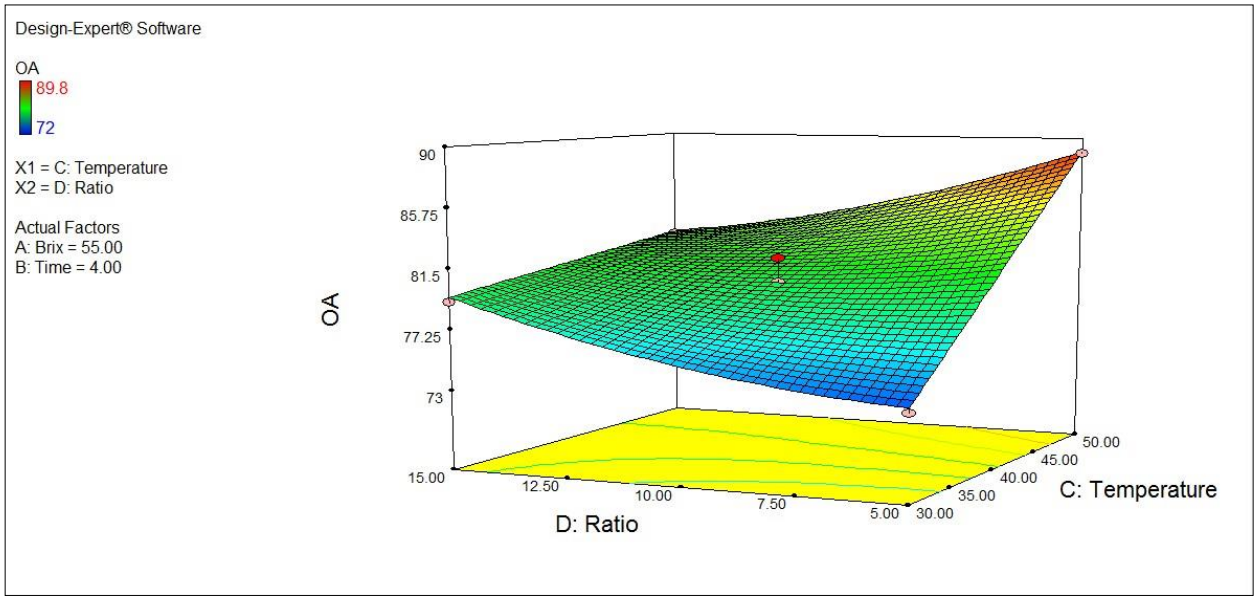


Fig 2.9 A: ***Response surface plots of ratio vs temperature for overall acceptability***

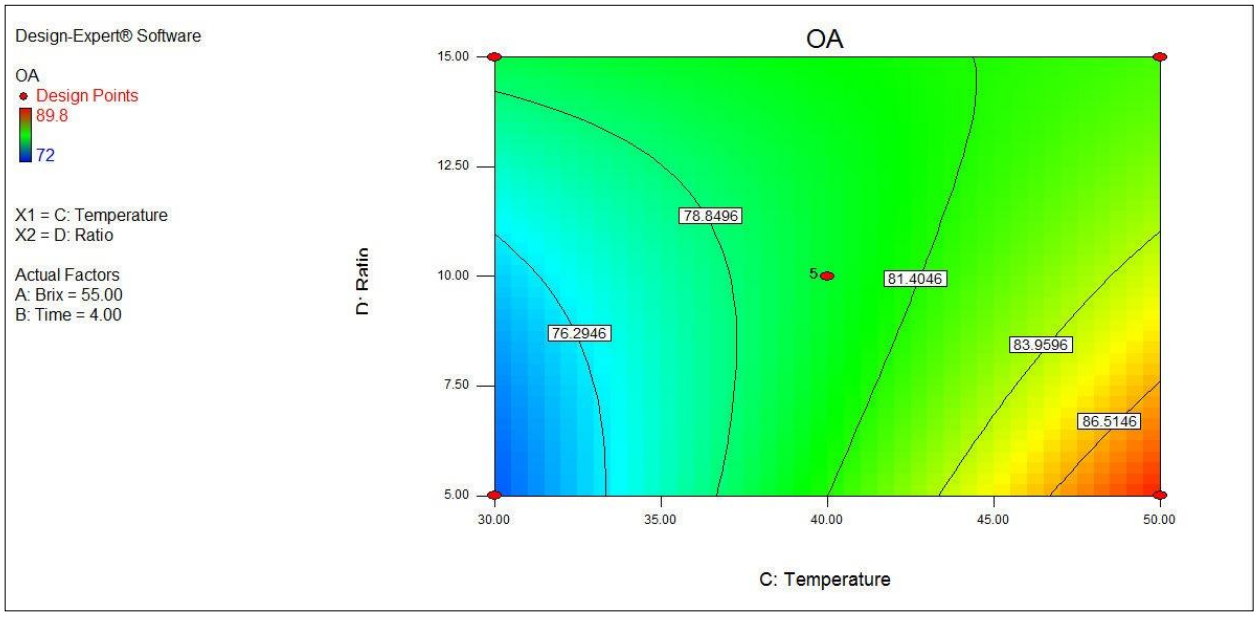


Fig 2.9 B: ***Contour plots of ratio vs temperature for overall acceptability***

The overall acceptability of the osmo-dehydrated product increased with increase in all the process variables except with the increase of solution to fruit ratio. The maximum acceptance was noticed for the product under process condition of high temperature, high concentration

and low solution to fruit ratio with the condition that immersion time should be either less than 3 hours or more than 4 hours. The solution temperature showed significantly higher affect on overall acceptability in comparison to other process variables. The osmosis rate increased with high temperature. At high temperature solute did not diffuse as easily as water through the cell membrane[28]. Thus the concept of osmotic equilibrium was achieved primarily by flow of water from the cell resulting in a lower solute gain by the food material.Higher temperatures uphold faster water loss through swelling and plasticizing of cell membranes as well as the better water transfer characteristics on the product surface due to lower viscosity of the osmotic medium[29]. Higher osmotic solution concentration increases the drying rate. At the surface of the food material a dense solute-barrier layer formed when the solution concentration increased. This layer enhanced the dewatering effect and reduced the loss of nutrients during the process[28]. Therefore at increasing temperature and solution concentration the overall acceptability was high.

Table 2.10 shows that all linear terms of process variables have significant effect ($P < 0.05$) on total phenol content.The model F-value 42.04 implies that the model is highly significant. Chance of noise is only 0.01%. $p<0.05$ indicate model terms are significant. In table 2.10 A, B, C, D, AB, AC, AD, BC, A^2, B^2 are significant model terms. It was observed from resulted sum of squares that the higher influence of immersion time, brix and solution temperature in comparison to SL: FR on total phenol content of sample. The lack of fit test of ANOVA indicates that the model could satisfactorily fit the experimental data ($p < 0.05$).

Table 2.10: Analysis of Variance (ANOVA) for the quadratic polynomial model for the optimization of total phenol of osmodried amla

Source	Sum of Squares	df	Mean Square	F value	P-value Prob>F	
Model	6185.70	14	441.84	42.04	< 0.0001	Significant
A-Brix	1087.09	1	1087.09	103.44	< 0.0001	
B-Time	1107.36	1	1107.36	105.37	< 0.0001	
C-Temperature	368.24	1	368.24	35.04	< 0.0001	
D-Ratio	166.10	1	166.10	15.81	0.0014	
AB	1087.02	1	1087.02	103.44	< 0.0001	
AC	223.58	1	223.58	21.27	0.0004	
AD	272.75	1	272.75	25.95	0.0002	
BC	85.93	1	85.93	8.18	0.0126	
BD	0.74	1	0.74	0.070	0.7952	
CD	46.24	1	46.24	4.40	0.0546	
A^2	125.43	1	125.43	11.94	0.0039	
B^2	1540.31	1	1540.31	146.57	< 0.0001	
C^2	26.83	1	26.83	2.55	0.1324	
D^2	36.93	1	36.93	3.51	0.0819	
Residual	147.13	14	10.51			
Lack of Fit	113.83	10	11.38	1.37	0.4091	Not Significant
Pure error	33.30	4	8.32			
Cor Total	6332.83	28				

Table 2.11: Analysis of variance (ANOVA) for response-surface quadratic fitted model

Standard deviation	3.24
Mean	18.95
Press	707.68
R2	0.9768
Adjusted R_2	0.9535
Predicted R_2	0.8883
Adequate Precision	27.668

The R^2 (0.9768) for this model implied that 97.68% of the sample variation for overall acceptability was attributed to the independent variables , and only about 2.32 % of the total variation was not explained by the model. The value is closer to 1.0 suggested that model represents better correlation between experimental and predicted values. An adequate precision of 27.668 indicated lower signal to noise ratio. On the basis of results observed from ANOVA (table 2.10 and 2.11) it can be concluded that the model is highly significant and sufficient to represent the actual relationship between the response and the significant variables.

2.3.2.9 Effect of immersion time vs ^{0}Brix on total phenol content

Figure 2.10 shows the response surface plot and contour plot of total phenol content under the effects of input parameters, solution concentration and immersion time. Total phenol content decreased with increasing solution concentration and increasing immersion time. Maximum total phenol content 68.5 mg GAE/g obtained with 45^0B and 2 hours immersion time.

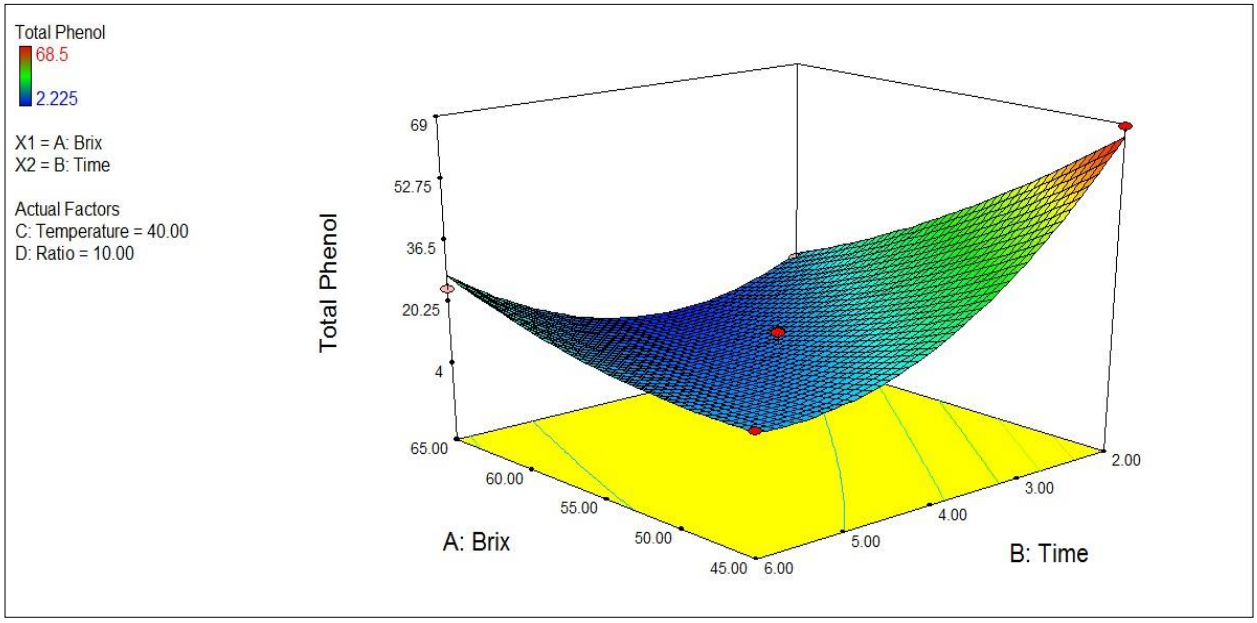


Fig 2.10 A: ***Response surface plots of brix vs time for total phenol content***

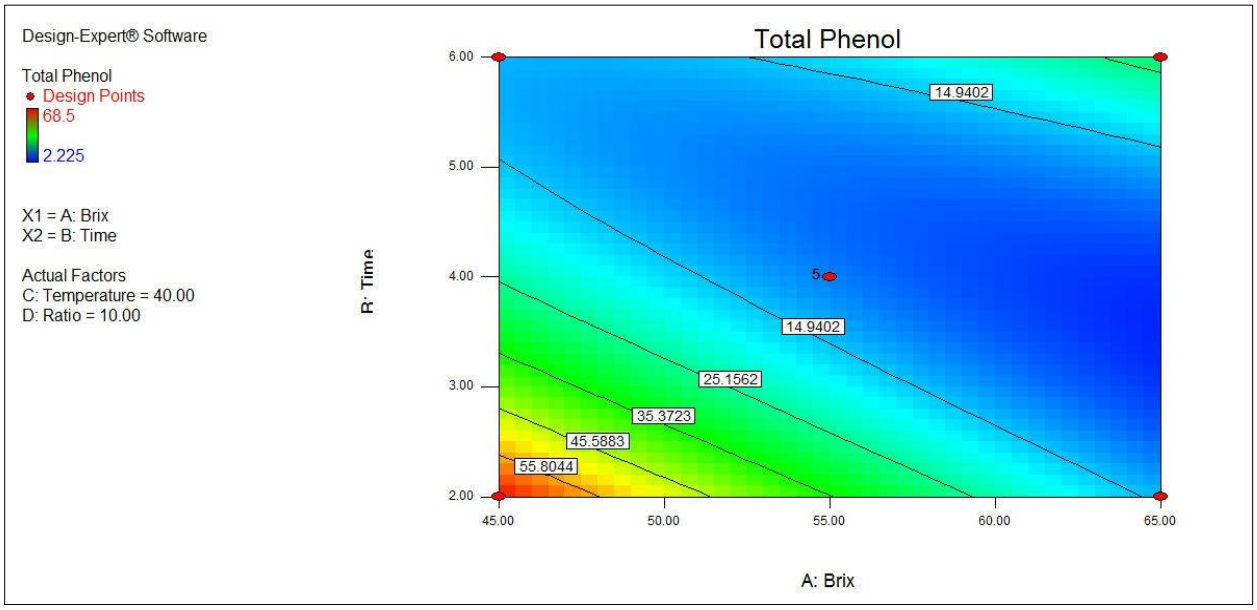


Fig 2.10 B: ***Contour plots of ^{0}Brix vs time for total phenol content***

2.3.2.10 Effect of solution temperature vs ^{0}Brix on total phenol content

From fig 2.11 A (3D surface plot) and fig 2.11 B (contour plot) it was observed that the of total phenol content decreases with increasing temperature and increasing solution concentration. The highest amount of total phenol content was resulted in 45^0B solution concentration and 30^0 C temperature.

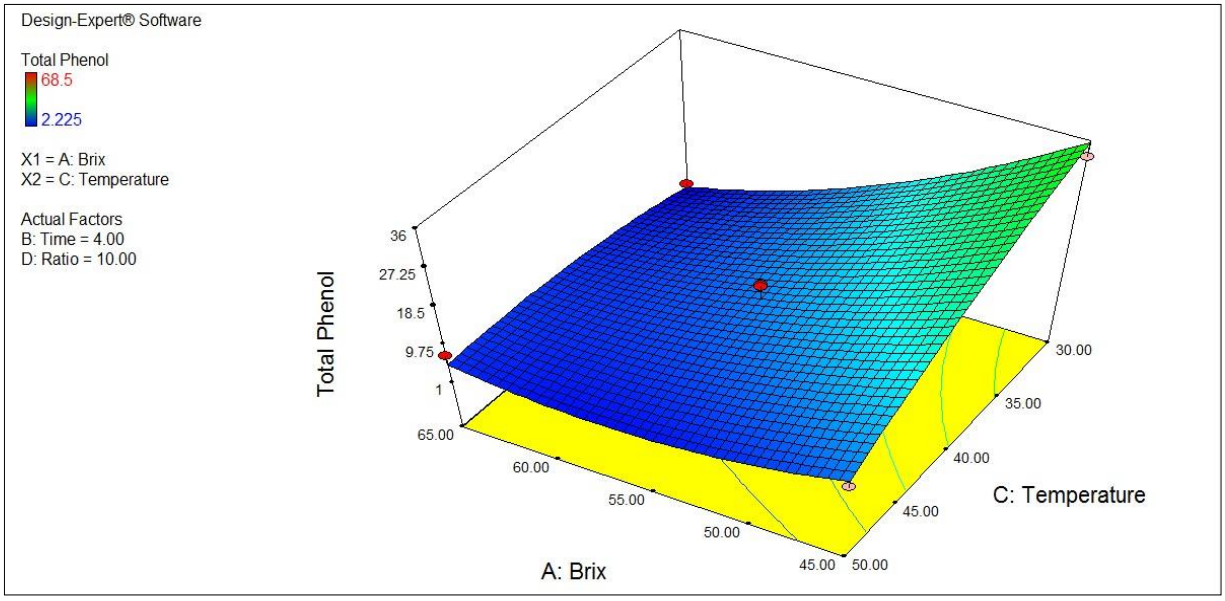


Fig 2.11 A: ***Response surface plots of ^{0}Brix vs temperature for total phenol content***

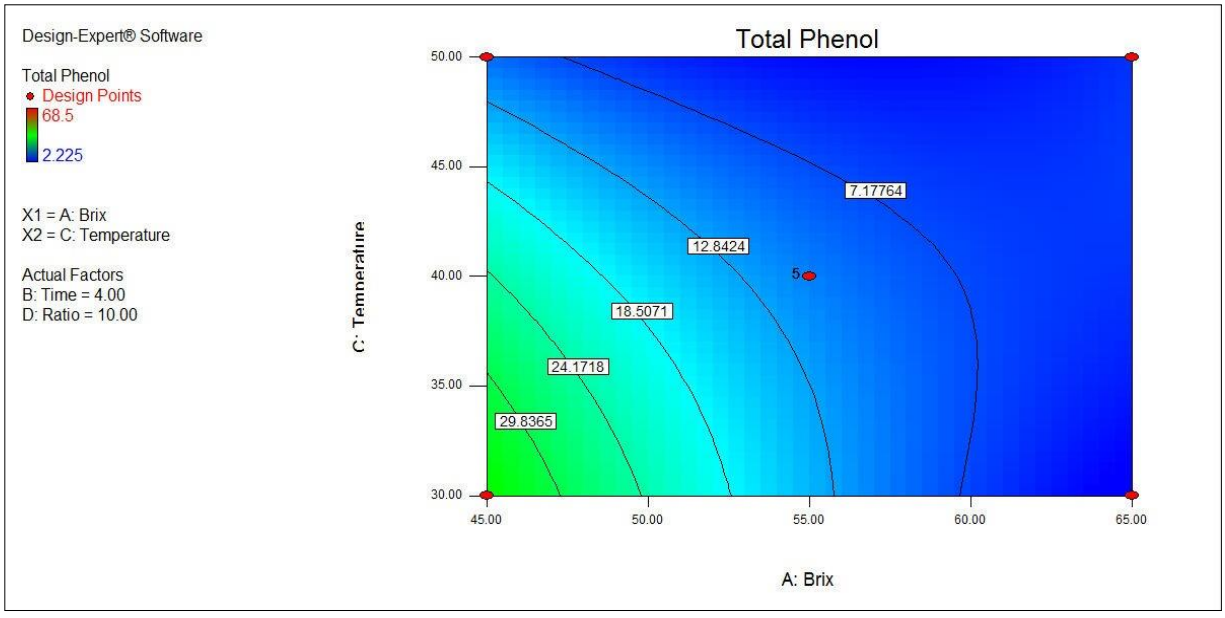


Fig 2.11B: ***Contour plots of brix vs temperature for total phenol content***

2.3.2.11 Effect of solution concentration vs solution to fruit ratio on total phenol content

Figure 2.12.A (3D surface) and 2.12.B (contour) represented the interaction between solution concentration and solution to fruit ratio on total phenol content. Total phenol content constantly decrease with increasing ^{0}B and solution to fruit ratio. Maximum amount of total phenol content retained with 45^{0}B solution concentration and 5:1 solution to fruit ratio.

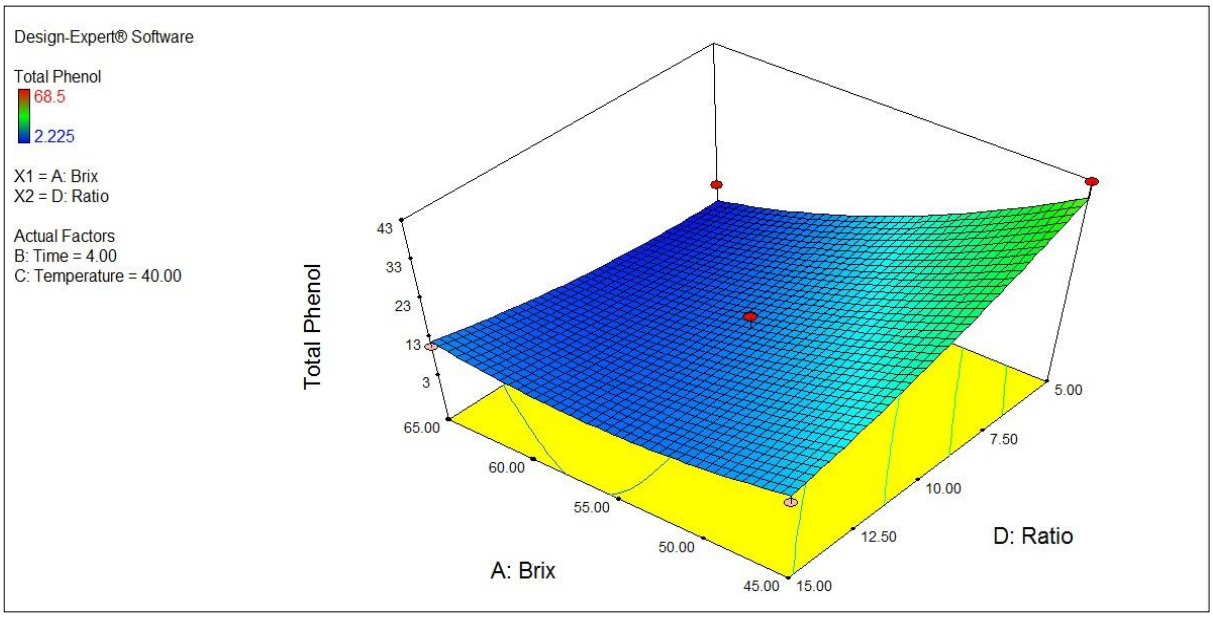


Fig 2.12 A: ***Response surface plots of brix vs solution to fruit ratio for total phenol content***

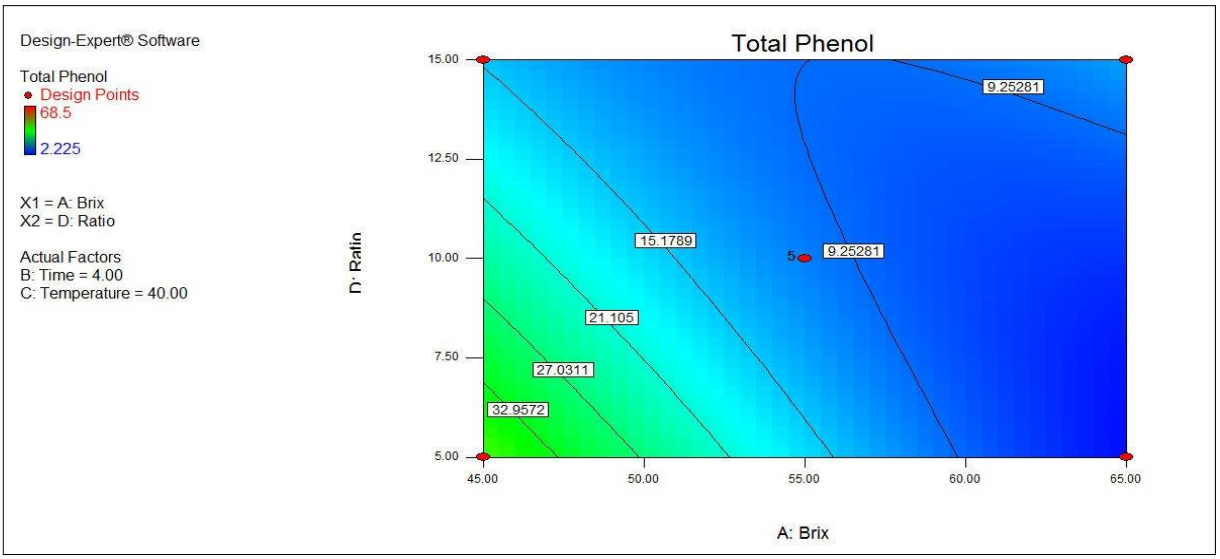


Fig 2.12 B: ***Contour plots of brix vs solution to fruit ratio for total phenol content***

2.3.2.12 Effect of solution concentration vs solution to fruit ratio on total phenol content

In Figure 2.13.A (3D surface) and 2.13.B (contour) it was observed that total phenol content decreases continuously with increasing temperature. At the initial stage total phenol content increased with immersion time up to 3 hours after that total phenol content decreased and again increased at 6 hours only when the solution temperature was 50^0C.

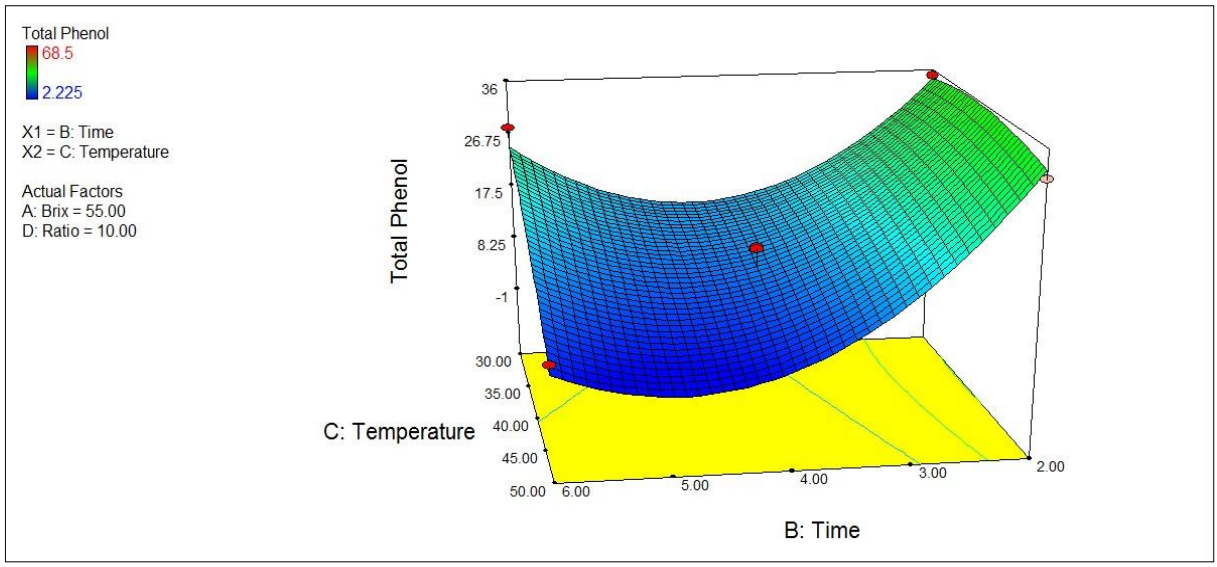


Fig 2.13 A: ***Response surface plots of time vs temperature for total phenol content***

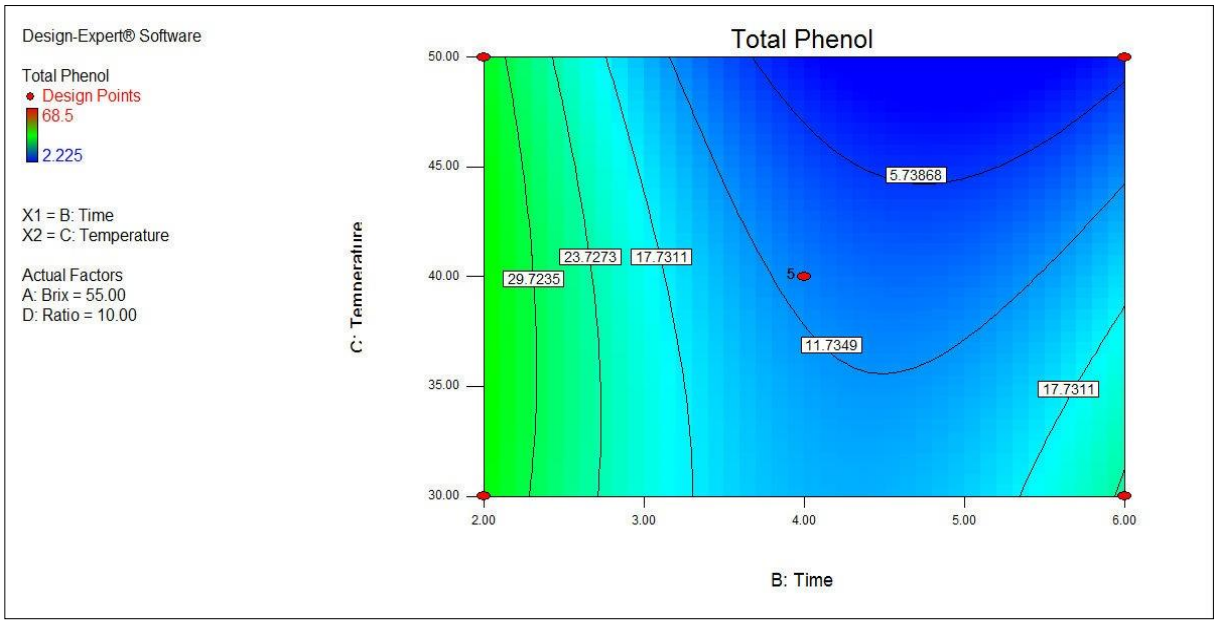


Fig 2.13 B: ***Contour plots of time vs temperature for total phenol content***

From fig 2.10 to fig 2.13 it was observed that the total phenol content decreases with increase in all the process variables. The solution concentration and immersion time showed significantly higher affect on total phenol content in comparison to other process variables. At high solution concentration, immersion time and solution to fruit ratio the rate of solid uptake is maximum that resulted loss of phenolic contents. Phenol content decreases at higher temperature [30]. Degradation of phenolic compounds could be results of polyphenol oxidase (PPO) enzymatic activity[31]. High temperature can affect the polyphenols by thermal breakdown that affect the cell structure [32].

2.3.2.13 Optimization of osmo dehydration process*:* Optimum response along with the optimum values of the experimental variables was obtained by the point prediction tool of this software. According to this, maximum vitamin C content was 8.88 mg/g, overall acceptability 88.48% and total phenol content was 35.93 mg GAE/g with 54.25^0B solution concentration, 2 hours immersion time, 50^0C solution temperature[4] and 15:1 solution to fruit ratio. The desirability of the process was found to be 0.810.

2.3.2.14 Validation of the model

An experiment was set up with the optimum values predicted by the software to find the accuracy of the model. Maintaining the experimental variables at the predicted levels, the response was found to be 8.34 mg/g vitamin C, 88.3 % Overall acceptability and 35.67 mg GAE/g total phenol content. From this validation result it was clear that experimental value of responses was very closer to the predicted response and the predicted model fitted well.

2.4 Conclusion

2.4.1

Whole amla can be preserved by osmotic dehydration process. Results showed that pretreatment enhanced quality of osmodried samples. Retention of nutritional parameters was maximum for amla fruits pricked after blanching followed by pricking prior water Blanching and steam blanching. Samples were successfully stored up to 6 months at room temperature. Osmotic dehydration reduced drying time without any significant changes in colour and flavor.

2.4.2

The work has demonstrated the use of a Box-Behnken design by determining the conditions leading to the optimum yield of nutritional quality. This methodology could therefore be successfully employed to any process (especially with three levels), where an analysis of the effects and interactions of many experimental factors are referred. Box-Behnken designs maximize the amount of information that can be obtained, while limiting the number of individual experiments required. Response surface plots are very helpful in visualizing the main effects and interaction of its factors. Thus, smaller and less time consuming experimental designs could generally suffice the optimization of many fermentation processes. Response surface methodology was effective in optimizing process parameters for osmotic dehydration of aonla slices in osmotic solution of sugar having concentration in the range of 45 to 65^0B sugar, temperature 30 to 50^0C, solution to fruit ratio 5:1 to 15:1 and immersion time 2 to 6 hours. Optimum osmodrying condition obtained was 54.25^0B sugar solution concentration, 50^0C osmotic solution temperature, and 15:1 solution: fruit ratio and 2 hour of immersion time to get maximum possible vitamin C, overall acceptibility and total phenol.

REFERENCES

1. Pointing J D (1973) Osmotic dehydration of fruits, recent modifications and applications. *J. Process Bio Technology*. **12 (8)** 8-20.

2. Chavan U D and R. Amarowicz (2012) Osmotic dehydration process for preservation of fruits and vegetables. *Journal of Food Research*. **1(2)** 202-207.

3. Palodkar D M, Rodge B M and Patil M B (2003) Studies on drying and dehydration of aonla fruits*". J Maharashtra Agric Univ* . **28**:81–83.

4. Alam S Md, Singh A and Sawhney B K (2010) Response surface optimization of osmotic dehydration process for aonla slices. *J Food Sci Technol* . **47(1)** 47–54.

5. Alam S Md, Singh A (2010) Optimum process parameters for development of sweet aonla flakes. *IJRRAS* **3 (3)** 323-333.

6. Myers R H, Montgomery D C and Anderson-Cook, C M (2009) Response Surface Methodology: Process and Product Optimization Using Designed Experiments. *John Wiley & Sons, Inc., Hoboken, New Jersey, USA.*

7. Kumar Y S, Prakasam R S and Reddy O V S (2009) Optimisation of fermentation conditions for mango (*Mangifera indica* L.) wine production by employing response surface methodology. *International Journal of Food Science and Technology.* **44**: 2320-2327.

8. Mercali G D, Marczak L D F, Tessaro I C and Norena C P Z (2011) Evaluation of water, sucrose and NaCl effective diffusivities during osmotic dehydration of banana (*Musa sapientum, shum.*). *LWT – Food Science and Technology.* **44**: 82-91.

9. Singleton V L and Rossi J A (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am J Enol Viticult.***16:** 144-153.

10. Rangana S (1986) *Handbook of analysis and quality control for fruit and vegetable products*. 105-106.

11. Davis D W (1947) *Anal Chem*. **19**:4-48.

12. Suresh K P and Sagar V R. Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions. *J Food Sci Technol. DOI* 10.1007/s 13197-012-0658-3

13. Lazarides H N, Katsanidis E, Nickolaides A (1995) Mass transfer kinetics during osmotic pre concentration aiming at minimal solid uptake. *J Food Eng.* **35**:151–166.

14. Mudahar G S, Toledo R T, Floros J D and Jen J J (1989) Optimization of carrot dehydration process using response surface methodology. *J Fd Sci*. **54**: 714-719.

15. Dhingra D and Paul S (2005) Optimization of drying conditions of garlic slices. *J Fd Sci Technol*. **42**:348-352.

16. Rai P, Majumdar G C, Dasgupta S and De S (2004) Optimizing pectinase usage in pretreatment of mosambi juice for clarification by response surface methodology. *J Fd Eng*. **64**: 397-403.

17. Box G E and Behnken D W (1960) Some new three level designs for the study of quantitative variables. *Technometrics* 2(4): 455-475.

18. Kar A and Gupta D K (2003) Air drying of osmosed buttons mushrooms. *J Fd Sci Technol*. 40:23-27.2003

19. Ozen B F, Dock L L, Ozdemir M and Floros J D (2002) Processing factors affecting the osmotic dehydration of diced green peppers. *Int J Fd Sci Technol*. **37**:497-502.

20. Montgomery D C (2004) Designs and analysis of experiments. *New York: John Wiley & Sons.*

21. Cox G M and Cochran W G (1964) Experimental designs. *New York: John Wiley & Sons, Inc.*

22. Lee H S and Coates G A (1999) Vitamin C in frozen, fresh, squeezed, unpasteurized, polyethylene bottled orange juice: A storage study. *Food Chemistry*. **65**:165-168, 1999.

23. Sagar V R and P Suresh Kumar (2009) Involvement of some process variables in mass transfer kinetics of osmotic dehydration of mango slices and storage stability". *Journal of Scientific & Industrial Research.***68**:1043-1048.

24. Box G E P, Behnken D W (1960) *Technometrics* . **2**:455-475.

25. Bas D and Boyaci I H (2007) *J Food Eng.* **78**:836–845

26. Campos C D M, Sato A C K , Tonon R V, Hubinger M D , CUNHA R L (2012) Effect of process variables on the osmotic dehydration of star-fruit slices *Cienc. Tecnol. Aliment., Campinas.* **32(2)** 357-365.

27. Chavan U D (2012) Osmotic Dehydration Process for Preservation of Fruits and Vegetables. *Journal of Food Research* . **1(2)** 202-209.

28. Charles T (June 2010) A review of osmo dehydration for food industry. *African Journal of Food Science* Vol. **4(6)** 303 - 324.

29. Sridevi M, Genitha Er TR (2012) Optimization of Osmotic Dehydration Process of Pineapple by Response Surface Methodology. J Food Process Technol 3:173. doi:10.4172/2157-7110.1000173

30. Paul R and Ghosh U (2012) Effect of thermal treatment on ascorbic acid content of pomegranate juice. *Indian journal of Biotechnology*.**11** 309-313.

31. Sonawane S K and Arya S S (2015) Effect of drying and storage on bioactive components of jambhul and wood apple. *J Food Sci Technol.* **52(5)** 2833.

32. Youssef K M and Mokhtar S M (2014) Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of *Portulaca oleracea* L. Leaves. *J Nutr Food Sci*, **4** 322.

CHAPTER 3

Processing of Bael

3.1 Introduction:

The bael (*Aegla marmelos*) is a wellknown fruit found widely throughout India [1]. Every part of the tree,root,bark,leaf,fruit,seed,latex are useful for their medicinal properties[2]. Whereas bael is a seasonal fruit its availability is restricted throughout the year. Post harvest losses and retain of nutrition can be reduced by preservation. Drying is one of the most common methods for preservation of bael fruit pulp for longer time. The dried products have very long shelf-life at ambient temperature. Drying may be defined as the application of heat under controlled conditions to eliminate the majority of the water normally present in a food by evaporation. In drying heat penetrates into the product and moisture is eliminated by evaporation. Among different types of drying tray drying is the most cost effective method.

However the high moisture content of bael can cause rapid deterioration after cropping. Thus, the dehydration is used to improve fruits stability by decreasing the water activity to minimize physical and chemical reactions that may occur during storage. However thermal treatments result degradation reaction and are believed to cause destruction of natural antioxidants in food[3,4,5].Two important variables to be controlled are temperature of treatment and its duration[6]. There is also economic importance of dehydrated bael powder which used in formulated drinks, baby foods and other products. Very limited works have been done on bael powder. The objective of this study is to investigate effect of temperature and pretreatment on quality of bael powder.

Due to increaseing demand of health drinks based on indigenous fruits, bael fruit can be processed for making juice,and RTS bevarages. Researcher reported about optimization of juice extraction from bael fruit using commertial and crude pectinase enzyme[7]. A whey protein enriched bael fruit beverage prepared by Singh & Nath[8].Bael juice was used for preparation of RTS drink,nectar,squash[9], and blended beverages[10,11]. However processing of fruit juice affects nutritional quality of the product. Therefore degradation kinetic modelling is important to control changes of physico-chemical parameter during processing[12].Furthermore kinetic models can be used for economic assessments of food quality and to predict the effect of several experimental variables on nutritional values[13].

Therefore the aim of this study is to determine the kinetic parameters for bael juice total phenolic content and antioxidant activity during thermal treatment.

3.2 Dehydration of bael pulp

Materials and Methods:

3.2.1 Mature fruits were procured from local market then fruits were washed under running water and scooped out the pulp after removing its hard shell. After removal of seeds1st part of pulp (200 g) dried without any pretreatment used as control. 2nd part (200 g) steam blanched for 5 min, 1% sugar added in 3rd part (200g) and 1% KMS added with 200 g pulp (4 th part). Samples were dried at 50^0C, 60^0C and 70^0C. Moisture loss was measured after every 30 mins interval until the equilibrium moisture reached.After drying samples were grounded in mixer grinder to produce bael powder and packed in polyethylene packet and stored for further studies.

3.2.1.1 Determination of moisture %

The % moisture content of different substrates was measured on the basis of initial weight of the samples[14]. At first weight of previously dried aluminium cup was noted. 50 mg of sample was placed on it and the weight was noted accurately. Then it was placed in a hot air oven at 105°C till constant weight was obtained.

The loss in weight was reported as moisture %.

$$\% \text{ moisture (d.b)} = \frac{\text{moisture content (w.b)}}{100-\text{w.b}} \times 100$$

3.2.1.2 Total phenolic content

Total phenolic content of bael pulp was determined by folin-ciocalteu method[15] at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit as described in chapter 1 (1.2.1.2).

3.2.1.3 Ascorbic acid content

Ascorbic acid of bael pulp was determined by titrimetric method[16] and the value expressed as mg of ascorbic acid /100 g fruit as described in chapter 1 (1. 2.1.3).

3.2.1.4 Antioxidant content (FRAP)

1g sample diluted in 50 ml distilled water was used for FRAP assay. The reagents required for FRAP assay are 20mM ferric chloride ($FeCl_3$, 6H2O) solution and 10mM TPTZ (2,4,6-tripyridyl-S-triazine) in 40mM HCl.300mM acetate buffer of pH 3.6 (prepared by dissolving 3.1g of Na-acetate and 16ml of acetic acid per liter). FRAP reagent[17] was prepared by the addition of 25ml acetate buffer, 2.5ml TPTZ and and 2.5ml FeCl3.6H2O. 3 ml FRAP mixed with 0.1 ml sample. The O.D was taken at 593nm after 4 minute incubation at ambient temperature. Standard curve was prepared with $FeSO_4$. $7H_2O$.

3.2.1.5 Carotenoid

Total carotenoids of bael pulp were measured according to the method of Talcott and Howard (1999)[18]. β-carotene was used as standard. Total carotenoids were expressed as β-carotene equivalents (µg/g). Two grams of sample were homogenized with 20 mL of acetone/ethanol (1:1 v/v) and 200 mg/L of BHT and centrifuged at 15,000 rpm for 15 min. The supernatant was transferred into a 50 mL volumetric flask and the solvent was added to a final volume of 50 mL. The O.D was taken at 470 nm.

3.2.1.6 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of drying on the sensory quality of bael powder. A 10-untrained member of sensory panel[19] was used for evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, taste, aroma and overall acceptability (OA).

3.2.1.7 Mathematical modeling of moisture loss:

The decrease of moisture ratio with drying time was used to evaluate the experimental drying data. The moisture ratio (MR) was calculated[20]as follows:

$$MR=\frac{M_t-M_e}{M_i-M_e} \qquad (1)$$

Where MR= Moisture Ratio, M_t= Moisture content in time t (% db), M_e=Equilibrium moisture content (% db), M_i=Initial moisture content (% db)

To describe drying behaviour of pretreated bael three different established thin layer drying were used[21, 22, 23]:

Newton model: MR= exp(-kt)

Page model: MR= exp(-kt^n)

Two term model : MR= a exp(-kt)+ b exp (-gt)

Chi-square value (χ^2)[24]:

$$\chi^2 = \frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}{N-z}$$

Root mean square error[25]**:**

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}$$

Where: MR_{exp} = Experimental moisture ratio, MR_{pred} = Predicted moisture ratio, N = Number of observations, z = Number of constants

3.2.2 Effect of thermal treatment on phenolic and antioxidant content of bael juice

3.2.2.1 Preparation of bael juice:

Fresh baels procured from local market were washed under running water and shells were broken to collect pulp. Then water(1:10 w/v) was added to the pulp followed by blending in a juicer and centrifuged at 4000 rpm for 5 mins. The clear centrifugate was used as fresh bael juice.

3.2.2.2 Thermal treatment:

Kinetics of total phenolic content and antioxidant activity were studied by isothermal heating at 55°, 65°, 75° and 85° respectively. 10ml samples were taken in sealed glass tubes and heated by placing them in a thermostatic water bath (Scientific instrument & chemical company, India). At regular time interval of 15 min, the tubes were taken out and rapidly cooled by dipping them into ice water and analyzed for total phenolic content (TPC) and antioxidant activity.

3.2.2.3 Total soluble solid:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B.

3.2.2.4 Total phenolic content

Total phenolic content of bael juice was determined by folin-ciocalteu method[15] at a wavelength of 765 nm using gallic acid standard as described in chapter 1 (1.2.1.2).

3.2.2.5 Ascorbic acid content

Ascorbic acid was determined by titrimetric method[16] as described in chapter 1 (1. 2.1.3).

3.2.2.6 Antioxidant content (FRAP)

Antioxidant activity was measured by FRAP method[17] at a wavelength of 593nm as described in chapter 3 (3.2.1.3).

3.2.2.7 Thermal degradation

Nutrients degradation in foods during their thermal processing has been described in terms of zero, first and second order kinetics[26]. A general reaction rate expression for degradation kinetics can be written as follows[5, 27].

$$d[c]/dt = -k_x[c]^n \quad \ldots (1)$$

Where 'c' is the quantitative value of the degraded product under consideration. 'k_x' is the reaction rate constant and 'n' is the reaction order, 't' is the reaction time (min).

The reaction order was determined through linear regression by graphical analysis, where exponent 'n' in eq. (1) was set to 0, 1, and 2 to compare the coefficients of determination (R^2).The integrated forms of zero, first and second order models are given in equation:-

$$\text{Zero order: } X_t = X_0 - k_x t \quad \ldots (2)$$

$$\text{First order: } \ln([X]_t/[X]_0) = -k_x t \quad \ldots (3)$$

$$\text{Second order: } 1/X_t - 1/X_0 = k_x t \quad \ldots (4)$$

The relationship of reaction rate to temperature was evaluated by the Arrhenius equation[28]:

$$K_x = A_0 \exp^{-(Ea/RT)} \quad \ldots (5)$$

Where 'k_x' is the rate constant (min^{-1}), 'E_a' is the activation energy (kJ mol^{-1}) of the reaction, 'R' is the universal gas constant (8.314 J mol^{-1} k^{-1}), 'T' is the absolute temperature and 'A_0' is a pre exponential constant.

In Eyring-polany model enthalpy of activation (ΔH^*) and entropy of activation (ΔS^*) are the model's parameters.

Entropy (ΔS^*_{xi}) and enthalpy (ΔH^*_{xi}) were obtained from the **Eyring-polany** model:

$$\frac{\ln K_x}{T} = \frac{\Delta H^* xi}{R} \cdot \frac{1}{T} + \frac{\ln K_B}{h} + \frac{\Delta S^* xi}{R}$$

Where k_B is the Boltzmann constant (1.381×10^{-23} J K^{-1}), T is absolute temperature, 'h' is the planck constant (6.626×10^{-34} J s).

Statistical analysis: Data were analysed using student t-test (origin 6.1). Significance of differences was defined at $P \leq 0.05$

3.3 Result and discussion

Table 3.1-Main characteristic of bael

Analysis	Fresh Bael
Juice yield(%)	20±0.26
TSS (^{0}B)	32±0.12
Moisture (%)	66±0.15
Total Phenol(mg GAE/g)	35.08±0.4
Ascorbic acid (mg/100 g)	5.254±0.1
FRAP(mM $FeSO_4$/g)	31±0.2
Carotenoid (µg/g)	12.15±0.33

3.3.1 Dehydration of bael pulp

The initial moisture content of bael pulp was 66% (w.b). The experiments were performed at temperature ranging from 50-70º C until final moisture reached. The moisture content (d.b) against time at different temperature was plotted in fig 3.1-3.3. In the initial stage of drying the decrease of moisture content was high due to the presence of high moisture. The amount of moisture reduction decreases with increasing time. These results were very similar with previous research work[23, 29]. Results showed in table 3.2 that drying time reduced with increasing temperature for all samples may be the result of increasing vapour pressure within the samples with increasing temperature. As a result of it moisture removed quickly from samples.

3.2 Moisture content (d.b) of untreated and pretreated bael pulp

Time (min)	Moisture Content (d.b)											
	50^{0}C				60^{0}C				70^{0}C			
	Control	Steam Blanched	1% sugar	1% KMS	Control	Steam Blanched	1% sugar	1% KMS	Control	Steam Blanched	1% sugar	1% KMS
0	188.85	192.23	188.47	188.9	190	192	190.2	189	188.3	190	188.45	188.4
30	172.84	168.35	165.27	152.56	169.15	163.75	153.62	145.32	166.06	153.39	144.85	135.56
60	150.7	136.22	140.24	121.68	145.05	131.35	117.03	112.57	139.45	128.46	112.16	100.94
90	134.2	102.49	102.2	97.13	118.83	100.2	89.59	85.27	116	97	78	72.89
120	117	84.18	84.11	80.1	100.6	81.6	81.06	65.25	95.11	78.27	64.93	59.04
150	93	68.3	68.23	64.21	88.43	67.57	66	53.79	81.9	62.94	57.66	46.28
180	79.8	66	53.12	41.73	74.65	51.48	50.11	40.69	69.2	48.22	43.13	35.35
210	66	40.8	40.92	30.83	62.13	39.16	37.6	28.13	59.11	37.1	32.96	22.6
240	58.54	31.48	31.52	27.4	54	30.11	23.74	24.48	51.6	27.65	21.88	20.4
270	50.33	26.2	26.22	22	43.22	23.86	22.8	19.08	40.3	22.15	19.52	14.9
300	47.11	24	23.82	19.49	37.8	21.44	20.2	16.48	33.7	19.63	16.79	13.35
330	43.06	20.1	20.13	16	35.1	17.14	16.4	14.22	30.18	15.33	14.97	11.07
360	39.84	15.9	15.78	12.3	31.6	14.81	14.32	11.65	25.85	13	12.25	9.32
390	32.61	13.78	13.55	10.05	29.21	12.6	11.79	9.45	23.5	10.58	10.25	7.8
420	27.11	12	11.6	9.3	25.19	10.8	10.14	8.22	21.07	9.02	8.98	6.53
450	25.05	10	10.03	8.21	22.13	8.78	8.5	7.56	19.05	7.58	7.34	6.2
480	22.53	9.2	9	7.79	17.22	7.98	7.7	7.02	16.34	6.94	6.8	-
510	19.6	8	8	7.21	16.57	7.36	7.28	-	13.02	-	-	-
540	17.5	7.65	7.55	-	13.7	-	-	-	9.2	-	-	-
570	14.56	-	-	-	10	-	-	-	-	-	-	-
600	12.78	-	-	-		-	-	-	-	-	-	-
630	11	-	-	-	-	-	-	-	-	-	-	-

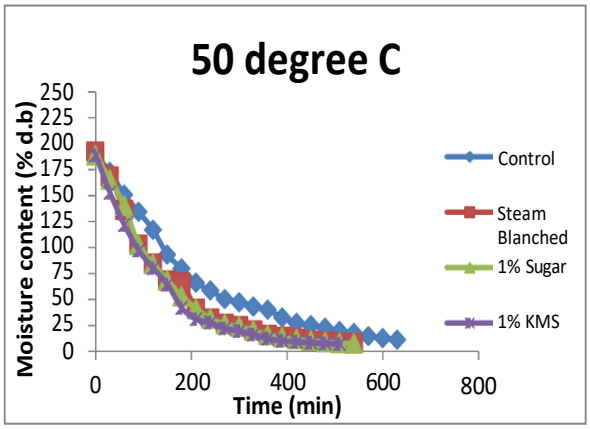


Fig 3.1

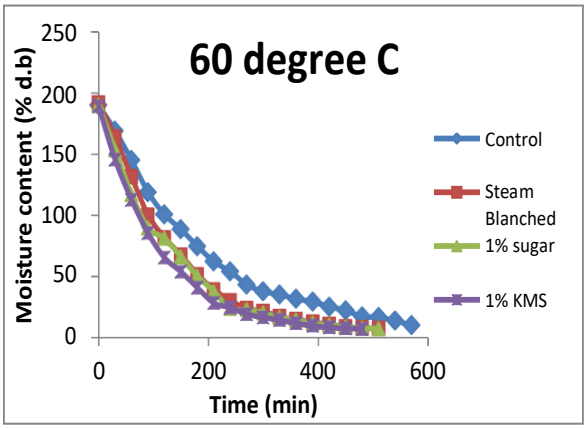


Fig 3.2

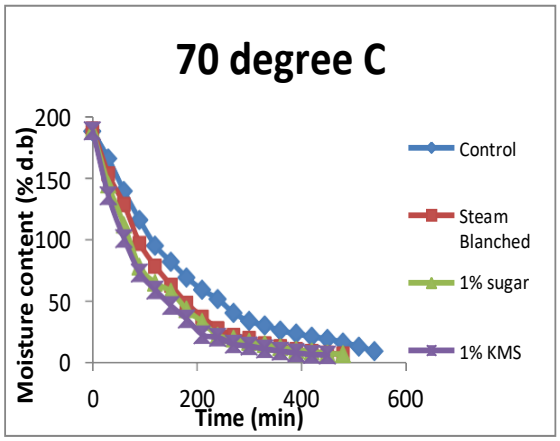


Fig 3.3

Moisture content vs drying time curve of untreated and pretreated bael pulp dried at (Fig 3.1) 50, (Fig 3.2) 60 and (Fig 3.3) 70 °C

It was observed in fig 3.4-3.6 that moisture ratio decreased continuously with drying procedure. Continuous decrease in moisture ratio may be the result of diffusion which has governed the internal mass transfer. Decrease of moisture ratio was faster with increasing temperature[23]. The graph shows falling rate period. Results showed in table 3.3 that pretreatment have positive effect on moisture ratio.

Table 3.3 Moisture ratio of untreated and pretreated bael pulp

Time (min)	Moisture ratio											
	50^{0}C				60^{0}C				70^{0}C			
	Control	Steam Blanched	1% sugar	1% KMS	Control	Steam Blanched	1% sugar	1% KMS	Control	Steam Blanched	1% sugar	1% KMS
0	1	1	1	1	1	1	1	1	1	1	1	1
30	0.91	0.87	0.87	0.84	0.89	0.85	0.8	0.78	0.87	0.8	0.76	0.71
60	0.82	0.697	0.62	0.63	0.78	0.682	0.6	0.58	0.76	0.66	0.58	0.52
90	0.73	0.51	0.523	0.5	0.692	0.5	0.45	0.43	0.672	0.49	0.392	0.366
120	0.596	0.415	0.42	0.4	0.5	0.4	0.4	0.364	0.49	0.39	0.32	0.29
150	0.46	0.33	0.34	0.31	0.44	0.326	0.32	0.277	0.42	0.306	0.28	0.22
180	0.39	0.32	0.252	0.23	0.36	0.272	0.23	0.185	0.35	0.225	0.2	0.16
210	0.3	0.18	0.18	0.12	0.29	0.17	0.16	0.116	0.28	0.16	0.144	0.09
240	0.27	0.13	0.133	0.1	0.26	0.12	0.1	0.096	0.24	0.11	0.083	0.078
270	0.22	0.1	0.103	0.08	0.185	0.09	0.08	0.066	0.17	0.083	0.07	0.05
300	0.2	0.089	0.09	0.067	0.17	0.08	0.06	0.05	0.137	0.069	0.055	0.039
330	0.18	0.067	0.0695	0.048	0.14	0.06	0.049	0.039	0.117	0.046	0.045	0.027
360	0.16	0.045	0.0455	0.028	0.12	0.042	0.038	0.025	0.093	0.033	0.03	0.017
390	0.12	0.033	0.033	0.016	0.107	0.028	0.024	0.01	0.08	0.019	0.019	0.009
420	0.09	0.024	0.022	0.01	0.084	0.02	0.016	0.006	0.066	0.011	0.012	0.002
450	0.08	0.013	0.014	0.006	0.067	0.008	0.006	0.002	0.057	0.003	0.003	0
480	0.065	0.008	0.008	0.003	0.04	0.003	0.002	0	0.04	0	0	-
510	0.05	0.002	0.003	0	0.037	0	0		0.02	-	-	-
540	0.037	0	0	-	0.02	-	-	-	0	-	-	-
570	0.02	-	-	-	0	-	-	-	-	-	-	-
600	0.01	-	-	-	-	-	-	-	-	-	-	-
630	0	-	-	-	-	-	-	-	-	-	-	-

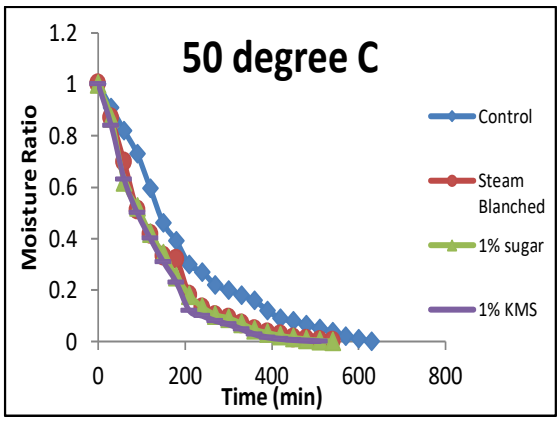


Fig 3.4

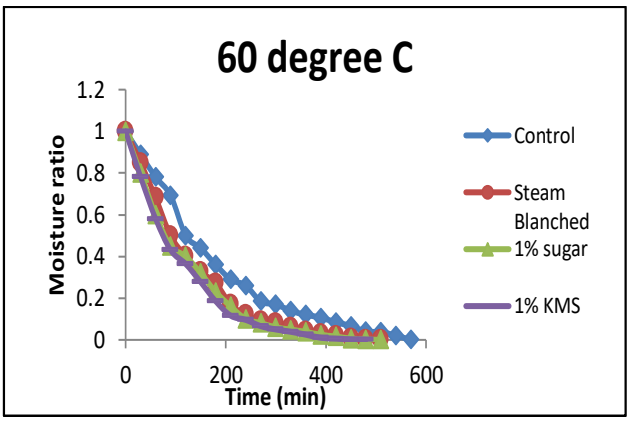


Fig 3.5

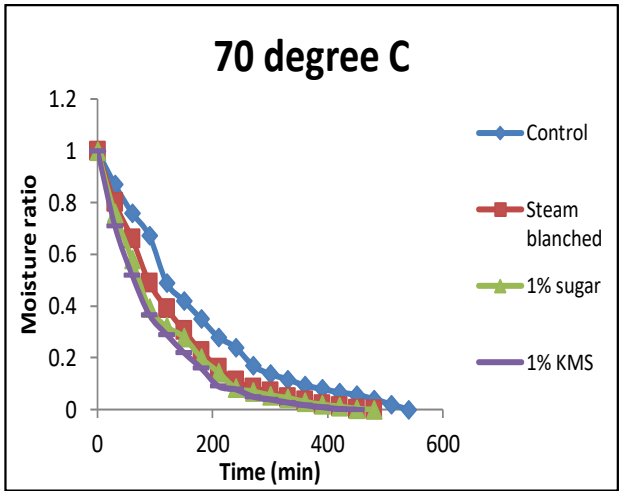


Fig 3.6

(Fig 3.4-3.6) Effect of temperature on moisture ratio during drying at 50- 70ºC temperature

These tables show that the drying constant (k) increased as drying temperature increased for most of the models;

Table 3.4 Values of the drying constants of the selected models

Temperature	Sample	Model		
		Newton $k(min^{-1})$	Page $k\ (min^{-1})$	Two term $k\ (min^{-1})$
50^0C	Control	0.005	0.002	0.006
	Steam Blanched	0.007	0.003	0.009
	1% Sugar	0.008	0.004	0.008
	1% KMS	0.008	0.003	0.013
60^0C	Control	0.006	0.002	0.007
	Steam Blanched	0.008	0.003	0.011
	1% Sugar	0.008	0.006	0.012
	1% KMS	0.009	0.006	0.013
70^0C	Control	0.006	0.002	0.008
	Steam Blanched	0.008	0.004	0.013
	1% Sugar	0.009	0.009	0.012
	1% KMS	0.011	0.012	0.014

In this experiment the most acceptable model was shown by statistical analysis (SPSS) among three drying models suggested by previous researchers[23, 30]. RMSE, chi-square values and R^2 values were given in table 3.5. Depending on lowest RMSE, chi-square value and highest R^2 value the suitable kinetic model was selected. All three models shown high R^2 value (0.984-0.999) which indicate drying characteristics of bael pulp could satisfactorily

describe by these models. Among all models the Two term model gave the highest R^2 (0.999-0.996), lowest RMSE (0.009-0.0188) and χ^2 (0.00008-0.00039).

Table 3.5 Statistical results of three thin-layer drying models

Temperature	Sample	Model								
		Newton model			Page model			Two term model		
		R^2	Chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE
50^0C	Control	0.984	0.00157	0.039	0.995	0.0005	0.0211	0.996	0.00039	0.0188
	Steam Blanched	0.989	0.00104	0.031	0.996	0.0004	0.019	0.996	0.00049	0.0197
	1% sugar	0.993	0.0006	0.024	0.997	0.0003	0.016	0.997	0.0003	0.016
	1% KMS	0.991	0.0008	0.028	0.9975	0.0002	0.014	0.9975	0.0002	0.014
60^0C	Control	0.989	0.0011	0.032	0.996	0.0004	0.0183	0.9966	0.00035	0.01677
	Blanched	0.992	0.0008	0.027	0.998	0.0002	0.013	0.998	0.0002	0.013
	1% sugar	0.995	0.0004	0.02	0.997	0.0003	0.017	0.997	0.0003	0.016
	1% KMS	0.9965	0.0003	0.017	0.9979	0.0002	0.013	0.998	0.0002	0.012
70^0C	Control	0.989	0.0010	0.031	0.9976	0.0002	0.015	0.9976	0.00027	0.014
	Blanched	0.995	0.0005	0.022	0.9986	0.0001	0.0094	0.999	0.00009	0.009
	1% sugar	0.997	0.0003	0.015	0.997	0.0002	0.015	0.997	0.0003	0.015
	1% KMS	0.9984	0.0001	0.01	0.999	0.0001	0.010064	0.999	0.00008	0.009

The most acceptable model for bael pulp drying was estimated by comparing the predicted moisture ratio against experimental moisture ratio in fig 3.7-3.10. It was shown that Two term model was accurate for describing the drying characteristics of bael pulp.

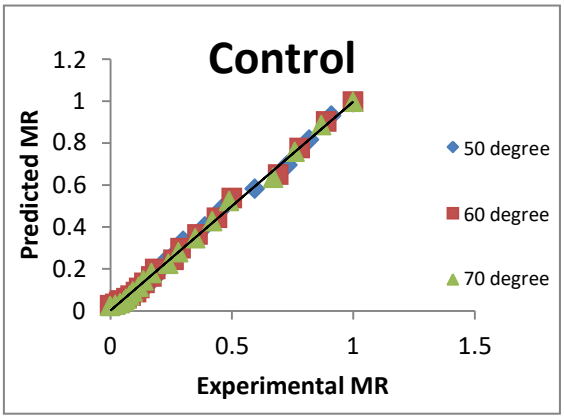


Fig 3.7

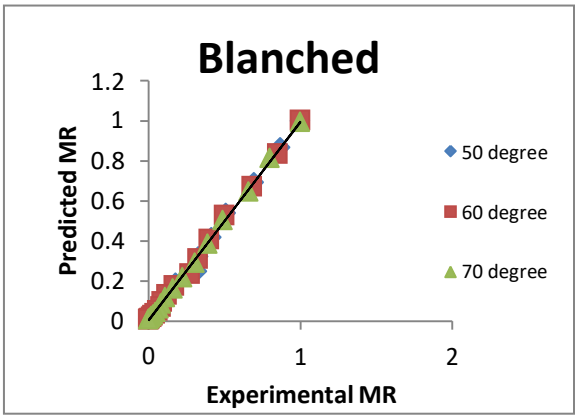


Fig 3.8

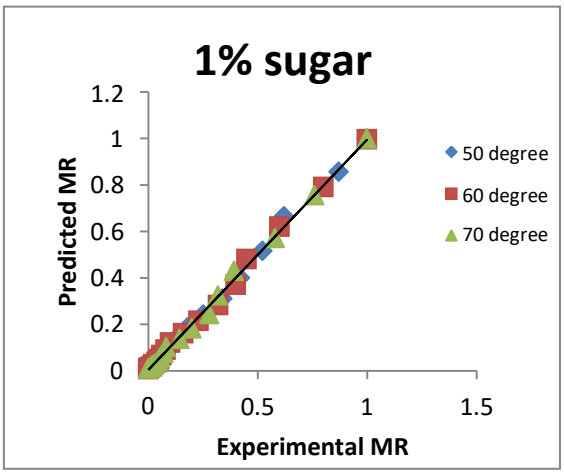


Fig 3.9

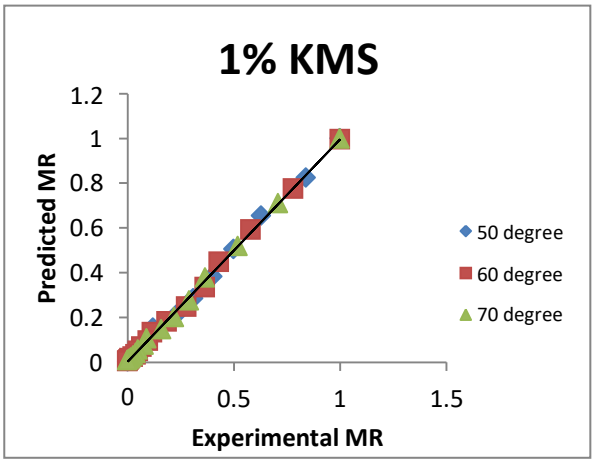


Fig 3.10

(Fig 3.7-3.10) Comparison of predicted vs experimental value

Results revealed that vitamin C degraded with increasing temperature. Vitamin C most affected by temperature and time of storage. Vitamin C is very unstable during heat treatment. Vitamin C content degraded during drying involves oxidation and hydrolysis[28]. Increase of temperature caused decrease in the concentration of this compound. From table 3.6 and fig 3.11 it was observed that all pretreated sample retained more vitamin C than untreated sample. At the initial stage of storage the degradation of vitamin C is maximum in 50^0C than 60^0C and 70^0C temperature. But after 3 months of storage 60^0C retained maximum amount of vitamin C. Similar results were repoted by Inga Klimczak et al[31]. among all pretreatments sample with 1% KMS showed maximum amount of vitamin C (1.21 mg/100 g)

at 60^0C after 3 months of storage which was followed by steam blanched and 1% sugar samples.

Table 3.6: Vitamin C content of bael powder during storage

Months	Vitamin C (mg/100 g)											
	50^0C				60^0C				70^0C			
	Untreated	Steam Blanched	1% sugar	1% KMS	Untreated	Steam Blanched	1% sugar	1% KMS	Untreated	Steam Blanched	1% sugar	1% KMS
0	1.23±0.25	1.525±0.03	1.43±0.3	2.45±0.13	0.834±0.09	1.23±0.2	1.03±0.03	2.11±0.13	0.62±0.11	0.95±0.07	0.81±0.04	1.95±0.3
1	0.713±0.007	0.95±0.42	0.88±0.3	2.23±0.08	0.63±0.03	0.972±0.07	0.813±0.09	1.93±0.19	0.452±0.04	0.76±0.05	0.525±0.008	1.63±0.07
2	0.36±0.02	0.568±0.016	0.49±0.04	1.86±0.19	0.378±0.08	0.65±0.03	0.45±0.03	1.65±0.07	0.213±0.03	0.471±0.04	0.29±0.11	1.3±0.19
3	0.175±0.50	0.22±0.18	0.2±0.03	1.11±0.21	0.192±0.01	0.296±0.05	0.22±0.06	1.21±0.2	0.142±0.01	0.193±0.01	0.18±0.3	1±0.02

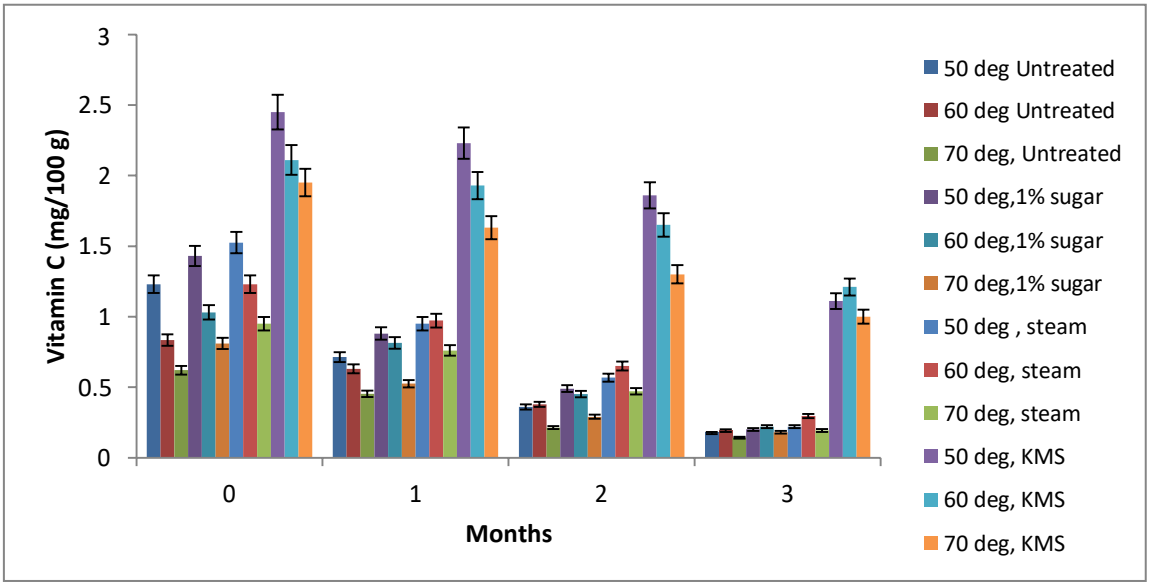


Fig: 3.11 Storage study of vitamin C

Degradation of phenolic content increased with time and temperature[27]. Thermal breakdown of polyphenols can happened during drying that can affect the cell structure[32]. Phenolic compounds degraded due to the effect of polyphenol oxidase (PPO) enzymatic activity[33]. Result showed that total phenol content degraded during storage[34]. This degradation of total phenol content was described that polyphenols were utilized as substrates for the PPO protein[35]. It was obtained that at the initial stage of drying at 50°C the amount of total phenol content was maximum for all samples as the temperature was low but after storage of 3 months minimum retained of total phenol content showed by 50°C because phenol degrading enzymes were activated at low temperature whereas shorter exposure period inactivate the enzyme at high temperature. It was obtained from table 3.7 and fig 3.12 that maximum retention of total phenol observed in sample with 1% KMS at 60°C (24.33 mg GAE/g) and steam blanched 24.05 mg GAE/g and sample with 1% sugar 19.69 mg GAE/g after 3 months of storage.

Table 3.7: Total phenol content of bael powder during storage

Months	Total phenol content (mg GAE/g)											
	50⁰C				60⁰C				70⁰C			
	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS
0	27.5±0.12	27.74±0.6	28±0.19	28.5±0.15	25.1±0.04	26.05±0.2	27.34±0.4	27±0.01	20.6±0.3	21.43±0.3	23.5±0.11	27.5±0.2
1	23.37±0.02	24.78±0.03	26.17±0.2	28.02±0.03	23.04±0.2	24.75±0.4	27.11±0.02	26.56±0.4	17.96±0.02	20.01±0.05	22±0.2	26.2±0.04
2	18.22±0.07	21.05±0.04	24.92±0.2	27.14±0.3	20±0.13	22.05±0.05	26.3±0.1	25.18±0.03	15.1±0.1	18.3±0.1	21.04±0.07	25.43±0.2
3	13.75±0.19	16.5±0.2	21.3±0.14	23.19±0.11	17.26±0.07	19.69±0.05	24.05±0.07	24.33±0.12	13±1	14±0.5	19±0.9	23.11±0.14

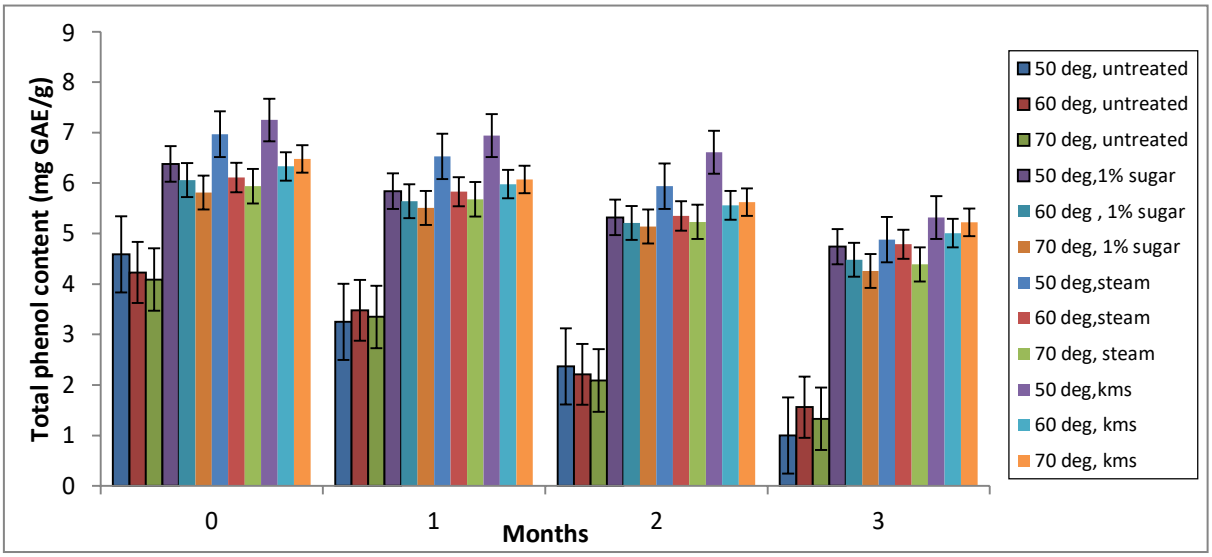


Fig: 3.12 ***Storage study of Total phenol content***

Result showed that maximum retention of carotenoid in sample with KMS at 50^0C (6.61µg/g) which was followed by steam blanched (5.94 µg/g) and sample with 1% sugar (5.32 µg/g). As carotenoid was heat sensitive and sensitive to oxidative degradation[36] for this carotenoid degraded at higher temperature.

Table 3.8: Total Carotenoid content of bael powder during storage

Months	Carotenoid content (µg/g)											
	50^0C				60^0C				70^0C			
	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS
0	4.59±0.25	6.38±0.05	6.97±0.2	7.25±0.05	4.23±0.11	6.06±0.3	6.11±0.5	6.48±0.03	4.09±0.1	5.81±0.26	5.94±0.3	6.33±0.02
1	3.25±0.03	5.84±0.3	6.53±0.03	6.94±0.08	3.48±0.8	5.64±0.2	5.83±0.03	6.07±0.03	3.35±0.4	5.51±0.08	5.68±0.06	5.98±0.06
2	2.37±0.1	5.32±0.1	5.94±0.12	6.61±0.02	2.21±0.07	5.21±0.01	5.35±0.2	5.62±0.5	2.09±0.06	5.14±0.29	5.23±0.13	5.56±0.7
3	1±0.15	4.74±0.05	4.88±0.25	5.32±0.007	1.56±0.15	4.48±0.04	4.79±0.016	5.22±0.1	1.33±0.12	4.26±0.11	4.39±0.2	5.01±0.2

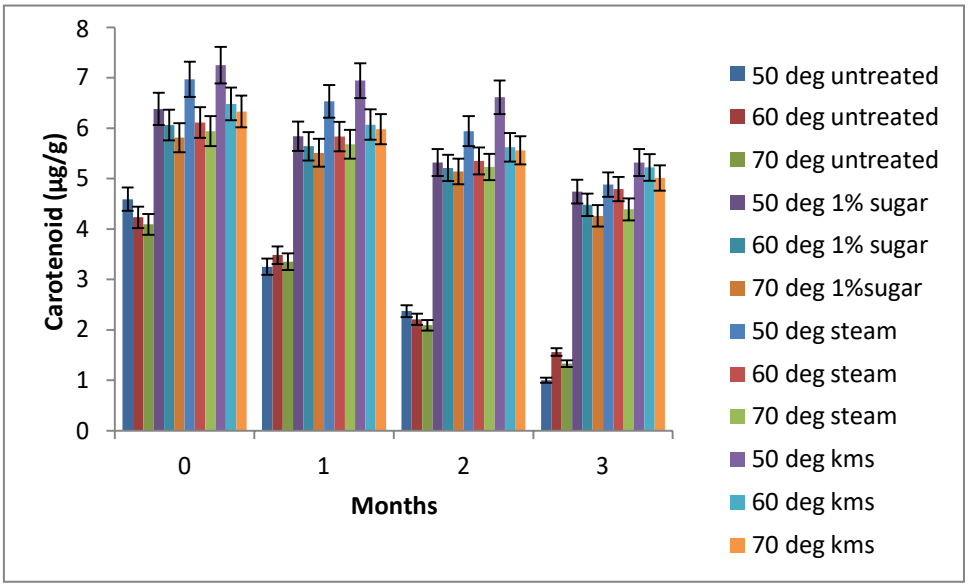


Fig: 3.13 ***Storage study of carotenoid content***

Table 3.9 and fig 3.14 represents the changes in the antioxidant activity of samples measured. Result showed that antioxidant declined during storage in all temperature for all samples. Total antioxidant of bael powder degraded significantly with increase in storage period. This might be due to loss of ascorbic acid and total phenolics during storage[31] which might be mainly responsible HAP contribution in the powder. The loss of total antioxidant was slightly lower in the pretreated samples during storage. This might be due to pre treatment effect as well as effect of other factors like temperature and storage period on the powder which might have caused this change. Maximum retention of antioxidant showed in sample with KMS 18.89 mM $FeSO_4$/g.

Table 3.9: Antioxidant content (FRAP) of bael powder during storage

Months	Antioxidant content (mM $FeSO_4$/g)											
	50^{0}C				60^{0}C				70^{0}C			
	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS
0	28±0.02	21.5±0.5	26±0.13	25±0.1	22.38±0.03	22.35±0.01	22.97±0.22	22.25±0.02	21.5±0.03	21.63±0.01	22.4±0.04	22.15±0.2
1	23±0.3	20.3±0.04	23.15±0.32	22.95±0.03	20.3±0.2	21.04±0.04	21.56±0.07	20.98±0.3	19.7±0.03	20.55±0.32	21.27±0.01	21.25±0.11
2	17.05±0.11	17.12±0.12	18.92±0.2	18.94±0.5	19.1±0.3	19.66±0.1	20.6±0.12	20.53±0.05	18.23±0.2	19.24±0.5	20.08±0.02	19.96±0.3
3	12.78±0.1	12.91±0.3	13.17±0.02	14.24±0.3	17.71±0.2	18.04±0.11	18.83±0.05	18.89±0.2	17.12±0.23	17.22±0.4	18.59±0.2	18.75±0.06

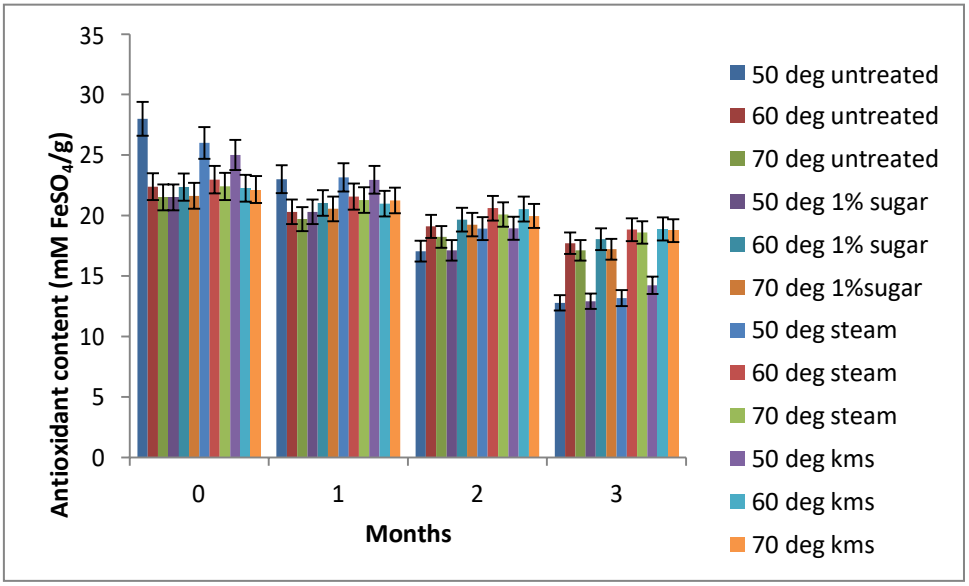


Fig: 3.14 ***Storage study of Antioxidant content***

From table 3.10 and fig 3.15 it was observed that sensory score decreased gradually with increase in storage period at room temperature. The score was significantly decreased during storage. Similar findings were reported by Satkar et al. (2013)[37]. Temperature plays an important role in biochemical changes that leads to development of off flavour as well as

discolouration in the beverages. The best sample with high sensory score was sample with 1% KMS.

Table 3.10: Sensory analysis of dehydrated bael pulp

Quality charecteristics	50⁰C				60⁰C				70⁰C			
	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS	Untreated	1%Sugar	Steam Blanched	1% KMS
Colour	4.8	4.5	5.7	6	5.16	6.33	7.5	8.13	6.67	6.25	7.16	8.23
Taste	3.9	7.16	5.16	5.6	4.3	7	6.5	7.67	6.12	7.1	6.3	6.68
Aroma	7.2	3	6.5	5.6	8.33	4.3	7.16	5.16	7.8	4.28	6.54	6
O.A	5.3	6.8	7	7.7	7.23	7.8	8.3	9.3	7.04	7.92	8.22	8.34

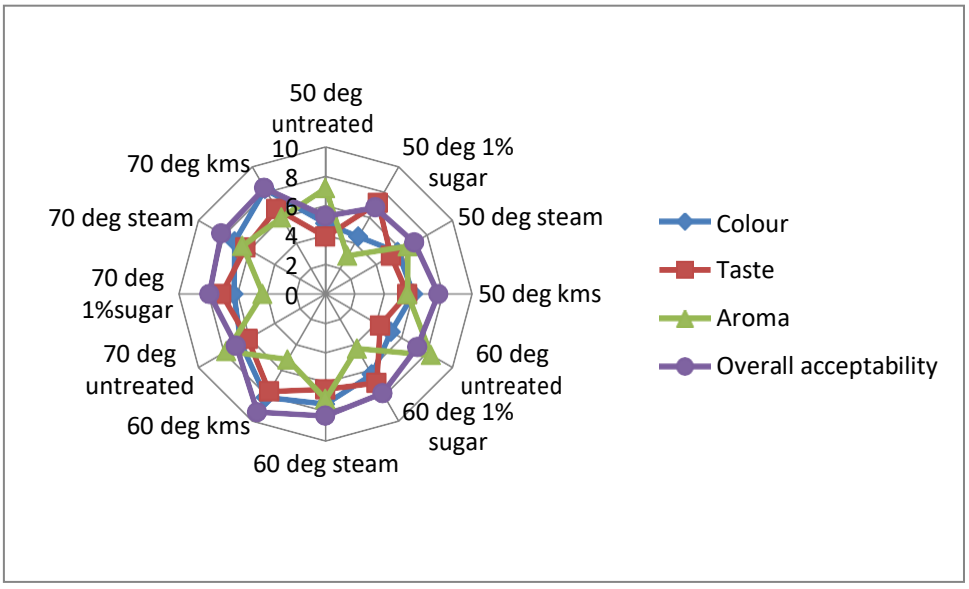


Fig 3.15: ***Descriptive analysis on sensory score of bael powder***

3.3.2 EFFECT OF THERMAL TREATMENT ON PHENOLIC AND ANTIOXIDANT CONTENT OF BAEL JUICE

As shown in fig 3.16. the total phenolic content decreased with increasing time and temperature of thermal treatment. The present results are similar with the previous result

where total phenolic content of some vegetables was declined with the increase in time and temperature of thermal processing[38]. The decrease in the content of total phenolic compounds during thermal treatment were explained with previous studies that polyphenolics were heat labile and that prolonged heat treatment could cause irreversible chemical changes to phenolic compounds[39] .

As shown in fig 3.17, the antioxidant capacity of bael juice decreased with increasing temperature and time of treatments. Normally, high temperature could enhance degradation of bioactive compounds and decrease the antioxidant capacity of sample[40]. Garau et al.[41] also observed that the antioxidant capacity in orange peel and pulp both decreased by air drying. A similar trend was observed by Zhang and Hamauza[42] that the antioxidant content in broccoli decreased during thermal processing.

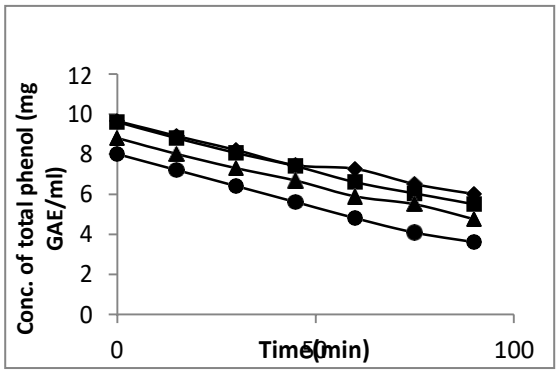


Fig-3.6.

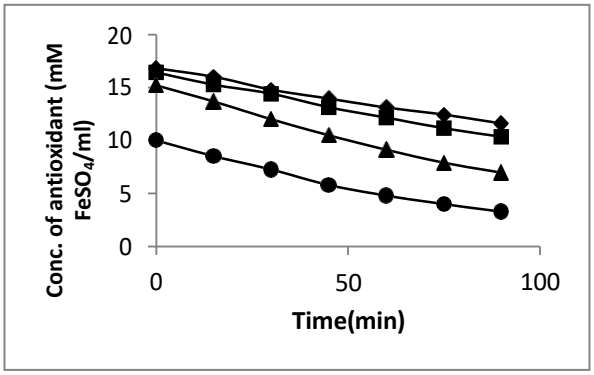


Fig-3.7.

Degradation of total phenolic content of bael juice (Fig 3.16) and total antioxidant activity of bael juice (Fig 3.17) with increasing time and temperature(♦-55°C ■-65°C ▲-75°C ●- 85°C)

The order of the thermal degradation of Total phenol content was estimated by examining the coefficient of determination (R^2) from plots of Total phenol versus treatment time over the temperature range of 55^0-85^0C(Table 3.11). On the basis of the mean R^2 (0.99) the thermal

degradation of total phenol tended to follow first order kinetics. Earlier studies also reported that total phenolic content degradation follows first order kinetic model[43, 44].

The order of reaction for antioxidant activity was determined by comparing R^2 from plots of Antioxidant versus treatment time over the temperature range of 55^0-85^0C(Table 3.11). Degradation of antioxidant content showed a high degree of fit for first order kinetic model being most suitable with highest R^2 value, ranging from 0.995-0.998. similar finding were observed by Jaiswal et al[44].On the basis of R^2 values, the degradation of total phenol and antioxidant fits better with first order model with R^2 (0.99). From table 3.11 it can be concluded that degradation of total phenol and antioxidant content could commonly be fitted by first order reaction model.

Table 3.11- Reaction order determination of total phenol and antioxidant degradation based on R^2 from zero, first and second order model

	Temp	Zero order		First order		Second order	
		T.P	FRAP	T.P	FRAP	T.P	FRAP
R^2	55^0C	0.986	0.986	0.991	0.998	0.964	0.977
	65^0C	0.979	0.989	0.997	0.997	0.988	0.975
	75^0C	0.987	0.982	0.997	0.995	0.966	0.957
	85^0C	0.986	0.987	0.998	0.997	0.956	0.962

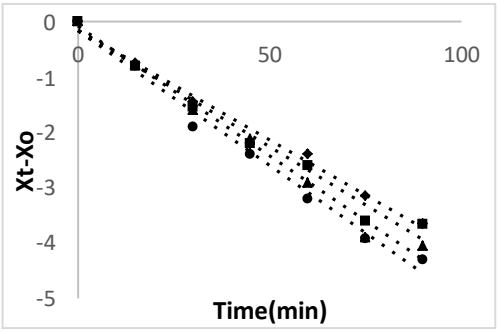


Fig-3.18. Zero-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

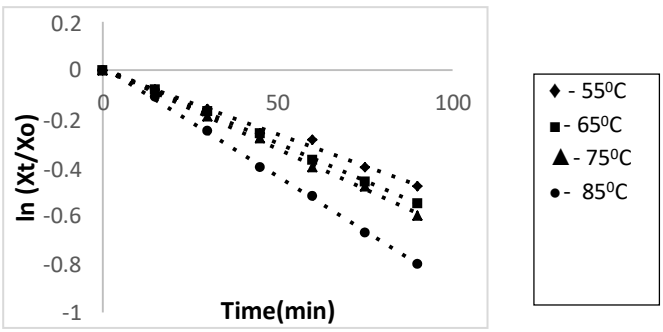


Fig-3.19. First-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

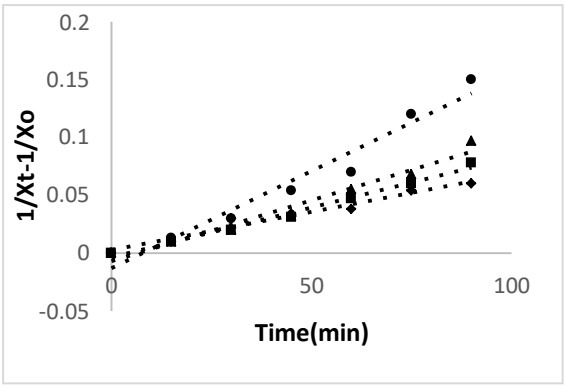


Fig3.20. Second-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

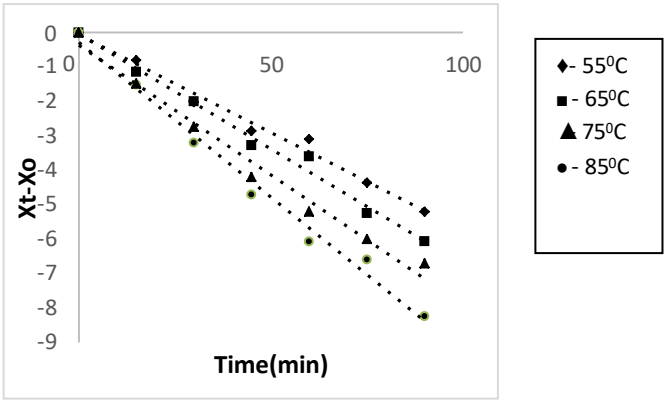


Fig-3.21. Zero-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

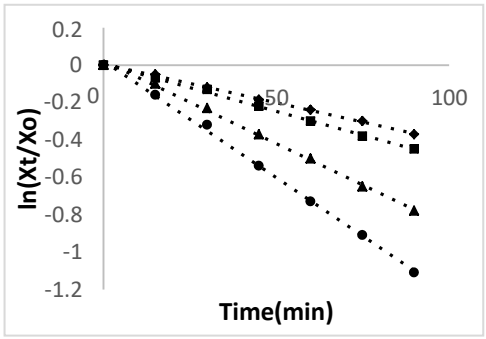


Fig3.22. First-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

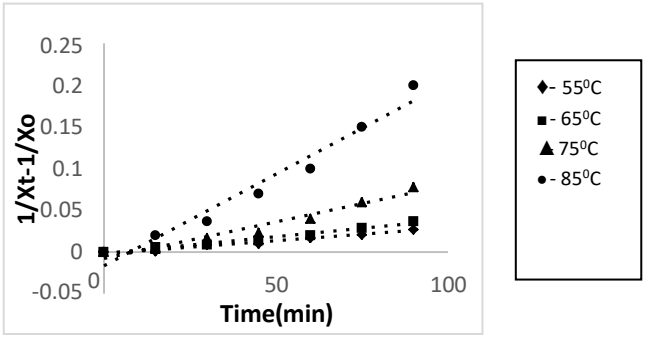
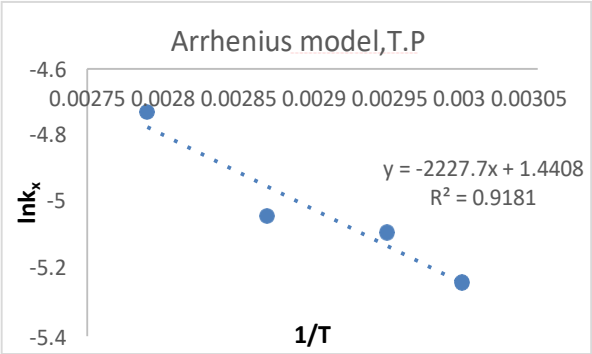


Fig-3.23. Second-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

The kinetics parameters K_x, $t_{1/2}$ and R^2 of first order model through a least square fitting procedure of total phenol and antioxidant degradation are given in table 3.12. A good fit was obtained R^2 0.991 -0.998 from this first order model. The degradation rate constant (K_x) increased systematically with temperature (Table 3.12). The half-life ($t_{1/2}$) for phenolic compound decreased from 130.75-78.75min and for antioxidant 173.25-57.27 min as the temperature increased from 55-85^0C. The half –life ($t_{1/2}$)), the time required for phenolic compound and antioxidant to degrade to 50% of its original value.



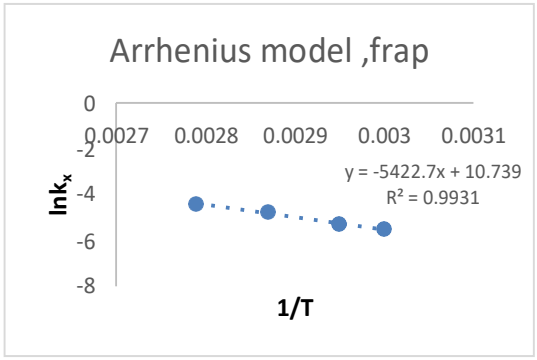
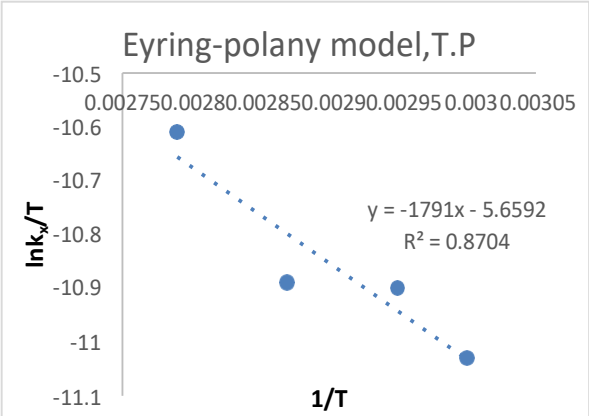


Fig-3.24. Plot of ln(k_X) versus (1/T) for degradation of flavonoid content from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min.

Fig-3.25. Plot of ln(k_X) versus (1/T) for degradation of antioxidant from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min



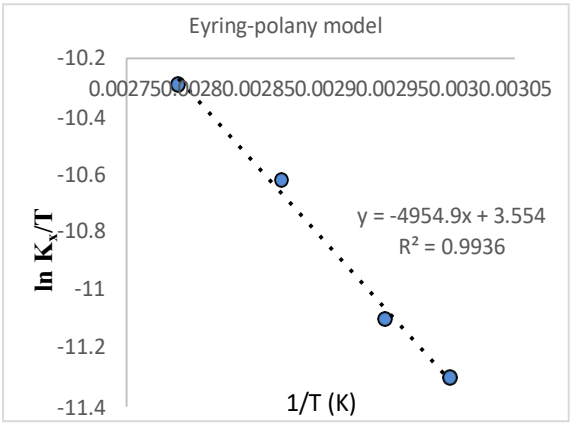


Fig-3.26. Plot of ln(k_X/T) versus (1/T) for degradation of flavonoid content from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min

Fig-3.27. Plot of ln(k_X/T) versus (1/T) for degradation of antioxidant content from bael juice during heating over the temperature range of 55^0-85^0C for 0-90 min

Table 3.12-Kinetics parameters for degradation of total phenol, antioxidant of bael juice due to thermal processing

	1st order model				Arrhenius model			Eyring-Polany model		
TPC	T (^{0}C)	K_x (min^{-1})	$t_{1/2}$ (min)	R^2	E_a (KJ mol^{-1})	K_x (min^{-1})	R^2	ΔH (KJ mol^{-1})	ΔS (J mol^{-1} k^{-1})	R^2
	55^0	0.0053	130.75	0.991						
	65^0	0.0061	113.63	0.997	18.52	2227.7	0.918	14.89	-244.60	0.87
	75^0	0.0065	106.62	0.997						
	85^0	0.0088	78.75	0.998						
Antioxidant activity	55^0	0.004	173.25	0.998						
	65^0	0.005	138.6	0.997	45.08	5422.7	0.99	41.19	-168.025	0.99
	75^0	0.0085	81.53	0.995						
	85^0	0.0121	57.27	0.997						

As shown in table 3.12 the increase of kinetic constant K_x of total phenol content and antioxidant compounds with increasing temperature confirmed that with increasing temperature degradation become faster, which is similar with the finding of Henriquez et al.(2014)[45]. Kinetic parameters of total phenol and antioxidant degradation from Arrhenius model are showed in table 3.12. The K_x value is 2227.7 for total phenol and 5422.7 for antioxidant. In case of total phenol R^2 (0.918) and for antioxidant R^2 (0.99). Activation energy (E_a) were 18.52 KJ mol^{-1} for total phenol and 45.08 KJ mol^{-1} for antioxidant. From Erying-Polany model (Table 3.8) we get R^2 (0.87) for total phenol and 0.99 for antioxidant. The activation enthalpy (ΔH) and entropy (ΔS) for total phenol was 14.89 KJ mol^{-1} and -

244.60 $JK^{-1}mol^{-1}$, and for antioxidant activation enthalpy (ΔH) and entropy (ΔS) were 41.195 KJ mol^{-1} and -168.025 $JK^{-1}mol^{-1}$.

3.4 Conclusion:

3.4.1

From the present study it can be concluded that temperature and storage affect the nutritional quality of bael powder. Pretreatment have positive effect on bael powder. Best retention of nutritional quality was observed with samples pretreated with 1% KMS followed by dehydration at 60°C in tray dryer.

3.4.2

This present study evaluated the effect of heat treatment on the kinetic behavior of phenolic compounds degradation and antioxidant loss from bael juice. These were best explained by first-order kinetic model. The temperature dependence of the degradation rate constant was well described by Arrhenius and Eyring-Polany model.

REFERENCES

1. Rahman S and Pravin R (2014) Therapeutic potential of *Aegle mammelos*(L)- An overview. *Asian Pac. J. Trop.* Dis. **4**(1):71-77

2. Patel P K, Jyoti S, Lokesh S, Narendra K P and Dubey B K (2012) Aegle marmelos: A review on its medicinal properties. *Int. J. Pharm. Phytopharmacal.* Res **1(5):** 332-341.

3. Vikram V B, Ramesh M N and Prapulla S G (2005) Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional method, *J Food Eng.* **69**:31-40.

4. Mazur S.P., Nes A., Wold A-B., Remberg S.F., Martinsen B.K., Aaby K. (2014) Effects of ripeness and cultivar on chemical composition of strawberry (Fragaria x ananassa Duch.) fruits and their suitability for jam production as a stable product at different storage temperatures. Food Chem. **146:** 412–422.

5. Remini H and et al. (2015) Degradation kinetic modelling of ascorbic acid and colour intensity in pasteurised blood orange juice during storage. *Food Chemistry* **173**: 665-673.

6. Loannou I, Hafsa I, Hamdi S, Charbonnel C and Ghoul M (2012) Review of the effects of food processing and formulation on flavonol and anthocyaninbehaviour. *Journal of Food Engineering.* **111 (2)** 208-217.

7. Singh A, Sharma H K, Kumar, Upadhyay S A and Mishra K P (2013) Comparative effect of crude and commercial enzyme on the juice recovery from bael fruit (*Aegle marmelos Correa)* using principle component analysis. *International Journal of Food Science* doi:10 1155/239839

8. Singh A K and Nath N (2004) Development and evaluation of whey protein enriched bael*(Aegle marmelos)* fruit beverage. *J Food Sci. Techol.* **41**(4):432-436.

9. Verma S and Gehlot R(2006) Development and evaluation of bael beverages. *Haryana J. Hortic. Sci*. 35(3/4): 245-248.

10. Nidhi, Gehlot R, Singh R and Rana M K (2008) Changes in chemical composition of ready-to-serve bael-guava blended beverage during storage. *J Food Sci. Technol*. **45**(4):378-380.

11. Kenghe R N, Zambre A V (2009) Effect of preservation on biochemical qualities of blended bael RTS. Bev. *Food World* **36** (4):51-52.

12. Hocine R,Christian M,Amine B,Nawel A,Manuel D and Khodir M (2015) Degradation kinetic modelling of ascorbic acid and colour intensity in pasturised blood orange juice during storage. *Food Chemistry* **173** :665-673.
13. Lanny S and Lie H (2014) Study on the kinetics of vitamin C degradation in fresh strawberry juices. *Procedia Chemistry.* **9 :**62-68.

14. Rangana S (1986) Handbook of analysis and quality control for fruit and vegetable products; 2nd edn (Tata McGraw Hill Publishing Company Ltd, New Delhi).

15. Singleton V L and Rossi J A (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am J Enol Viticult*. **16** 144-153.

16. Rangana S (1986) Handbook of analysis and quality control for fruit and vegetable products. 105-106.

17. Moyer R A, Hummer K E, Finn, C.E., Frei, B. and Wrolstad, R.E. (2002) Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: Vaccinium, Rubus, and Ribes. J. Agr. Food Chem. **50**:519–525.

18. Talcott S T and Howard L R (1999) Phenolic autoxidation is responsible for color degradation in processed carrot puree. *Journal of Agricultural and Food Chemistry*. **47 (5):** 2109–2115.

19. Suresh K P & Sagar V R (2014) Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions. *J Food Sci Technol* **51(8)** 1540-1546.

20. Tunde-Akintunde T Y & Ogunlakin G O (2013) Mathematical modeling of drying of pretreated and untreated pumpkin, *J Food Sci Technol* **50(4)** 705-713.

21. Mujumdar AS (1995) *Handbook of industrial drying* (second ed. New York): Marcel Dekker.

22. Singh S, Sharma R, BawaA S, Saxena D C (2008) Drying and rehydration characteristics of water chestnut (*Trapa natans*) as a function of drying air temperature. *J Food Eng,* **87:** 213-221.

23. Singh A, Sharma H K, Kumar N, Upadhyay A. and Mishra K. P. (2015) Thin layer hot air drying of bael *(Aegle marmelos)* fruit pulp *International Food Research Journal* **22(1):** 398-406.

24. Qing-An Zhang, Yun Song, Xi Wang, Wu-Qi Zhao and Xue-Hui Fan (2016) Mathematical modeling of debittered apricot (*Prunus armeniaca* L.) kernels during thin-layer drying. *CyTA - Journal of Food*. **14(4)** 509-517.

25. Akoy E O M (2014) Experimental characterization and modeling of thin-layer drying of mango slices. *International Food Research Journal.* **21(5)** 1911-1917.

26. Corradini M G and Pleg M (2006) Prediction of vitamins loss during non-isothermal heat processes and storage with non linear kinetic models. *Trends in Food Science &Technology.* **17:** 24-34

27. Paul R and Ghosh U (2012) Effect of thermal treatment on ascorbic acid content of pomrgranate juice. *Indian Journal of Biotechnology* pp 309-313.

28. Thankitsunthorn S, Thawornphiphatdit C, Laohaprasit N and Srzednicki G (2009) Effects of drying temperature on quality of dried Indian Gooseberry powder. *International Food Research Journal.* **16**: 355-361.

29. Kumar, N., Sarkar, B.C. and Sharma, H.K., 2011. Effect of air velocity on kinetics of thin layer carrot pomace drying. Food Science and Technology International 17(5): 459-469.

30. Rayaguru, K. and 2Routray, W. (2012) Mathematical modeling of thin layer drying kinetics of stone apple slices *International Food Research Journal* **19(4):** 1503-1510.

31. Klimczak I, Maria Ma"ecka, Miros"awa Szlachta, Anna Gliszczyn´ ska-S´ wig"o (2007) Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juicesJournal of Food Composition and Analysis. **20:** 313–322

32. Youssef KM, Mokhtar SM (2014) Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of Portulaca oleracea L. Leaves. *J Nutr Food Sci* 4:322. doi: 10.4172/2155-9600.1000322.

33. Sonawane S K and Arya S S (2015) Effect of drying and storage on bioactive components of jambhul and wood apple. *J Food Sci Technol.* **52(5)** 2833-2841.

34. Serea C, Barna O, Manley M and Kidd M (2014) Effect of storage temperature on the ascorbic acid content, total phenolic content and antioxidant activity in Lettuce (*Lactuca sativa* L.). *The Journal of Animal & Plant Sciences.* **24(4)** 1173-1177.

35. Janovitz-Klapp A H, Richard F C, Goupy P M and Nicolas J J (1990) Inhibition studies on apple polyphenol oxidase. *J. Agric. Food Chem*. **38(4)** 926-931.

36. Wijewardana R M N A, Nawarathne S B and Wickramasinghe I (2016) Effect of various dehydration methods on proximate composition and retention of antioxidants in different fruit powders. *International Food Research Journal* **23(5):** 2016-2020.

37. Satkar K P, Kulthe A A and Chalke P R (2013) Preparation of bitter gourd ready-to-serve beverage and effect of storage temperature on its keeping quality. *The Bioscan*. **8(1):** 115-117.

38. lin Y-C and Chou C C (2009) Effect of heat treatment on total phenolic and anthocyanin contents as well as antioxidant activity of the extract from Aspergillius awamori-fermented black soyabins, a healthy food ingredient. *Int J Food Sci Nutr.***60 (7)** 627-636.

39. Mrad N D, Boudhrious N, Kechaou N, Courtois F and Bonazzi C (2012) Influence of air drying temperature on kinetics,physico-chemical properties, total phenolic content and ascorbic acid of pears. *Food and Bioproducts processing* **90:** 433-441

40. Linyan Z, Zhenzhen C, Jinfeng B, Jianyong Y, Qinqin C, Xinye W and Mu Z (2016) Degradation kinetics of total phenolic compounds,capsaicinoids and antioxidant activity in red pepper during hot air and infrared drying process. *International Journal of Food Science and Technology.* **51:** 842-853.

41. Garau M C, Simal S, Roselló C and Femenia A (2007) Effect of air drying temperature on phphysico-chemical properties of dietary fibre and antioxidant capacity of orange (*Citrus aurantium v.Canoneta)* by-products. *Food Chemistry* **104:** 1014-1024.

42. Zhang D, Hamauza Y (2004) Phenolics,ascorbic acid,carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chemistry* **8(4)** 503-509.

43. Jaiswal A K, et al. (2011) Kinetic evaluation of colour, texture, polyphenols and antioxidant capacity of Irish York cabbage after blanching treatment. *Food Chemistry*. doi:**10**.1016/j.foodchem.2011.08.032.

44. Jaiswal A K and Abu-Ghannam N (2013) Degradation kinetic modeling of color, texture, polyphenols and antioxidant capacity of York cabbage after microwave processing. *Food Research International.* doi. 10.1016/j.foodres.2013.04.007

45. Henriquez C., Cordova A., Almonacid S. and Saavedra J.(2014). Kinetic modeling of phenolic coupound degradation during drum drying of apple peel by-products. Journal of Food Engineering,**143:**146-153.

CHAPTER 4

STUDIES ON DEVELOPMENT AND STORAGE STUDY OF BAEL-AMLA MIXED JUICE

4.1 Introduction

Bael fruit (*Aegle marmelos* L.) is a native fruits of India. It consists of many functional and bioactive compounds such as phenolics, flavonoids, carotenoids[1]. The ripe fruit have remedial, purificatory effect and good for heart, brain. But due to its hard shell and gluey texture are generally not accepted by consumers as raw. So several value added products are prepared from bael fruit such as candy, jam, powder and juice. Generally bael fruit are consumed as juice due to its excellent colour and flavour. On the other hand Amla (*Phyllanthus emblica* L.) is well known for its nutritional value. It is rich source of polyphenols, vitamin C and tannins[2]. Although the fruit is rich in antioxidants and different nutrients, it is not consumed as fresh due to excessive acidity, astringency, lower TSS and lack of flavour and colour. In previous studies researchers investigate the prospects of using amla fruit for making juice[3]. Consequently it's far necessary to convert amla juice into certain beverages before it could be consumed. There may be awesome possibility of acquiring notable exceptional beverages, if amla juice blended with bael juice. Juice mixing is one of the finest methods to enhance the nutritional quality of the juice. Though, processed fruits and vegetables have been taken into consideration to have a decrease in nutritional value than their own fresh commodities due to degradation of nutrients during processing[4]. Therefore the objective of this study is (i) to develop mixed juice by using the nutritional parameters of both bael and amla fruits.

(ii) Studied the effect of storage on nutritional parameters of mixed juice

4.2 Materials and methods:

Bael were collected from market then washed in running water. Then hard shell was breaking manually and after removing from hard shell seeds and fibre were removed from pulp. Then water was added (1:1 ratio) to the pulp and blend in a mixer grinder and centrifuged at 4000

rpm for 5 mins. The clear centrifugate juice was filtrated through muslin cloth and used as fresh bael juice.

After collecting amla from local market, amla were washed under running water. Then seed were removed with the help of a knife and amla were sliced. Then amla sliced were put in a mixer grinder and centrifuged at 4000 rpm for 5 mins. After that the clear centrifugate juice was filtrated through muslin cloth and used as fresh amla juice. Mixed both prepared by mixing bael and amla juice in 90:10 ratio.

Then amla, bael and bael with amla juices were filled in sterilized 200ml capacity glass bottles leaving 2-3 head space. The juices filled bottles were sealed with sterilized crown cork. After capping bottles were kept in boiling water for 15 min. After removal from boiling water bottles were cooled and store in room temperature. Juices were analysed for total phenol content and vitamin C during storage.

4.2.1 Thermal treatment:

Thermal degradation kinetics of total phenolic content and ascorbic acid was studied by heating at 60°C, 70°C, 80°C and 90°C. 10ml samples (bael: amla, 9:1) were taken in sealed glass tubes and heated by placing them in a thermostatic water bath (Scientific instrument & chemical company, India). At regular time interval of 15 min, the tubes were taken out and rapidly cooled by dipping them into ice water and analyzed for total phenolic content (TPC) and ascorbic acid.

4.2.2 Total soluble solid:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B.

4.2.3 Total phenolic content

Total phenolic content was determined by folin-ciocalteu method[5] at a wavelength of 765 nm using gallic acid standard as described in chapter 1 (1.2.1.2).

4.2.4 Ascorbic acid content

Ascorbic acid was determined by titrimetric method[6] and the value expressed as described in chapter 1 (1. 2.1.3).

4.2.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of drying on the sensory quality of bael powder. A 10-untrained member sensory panel[7] was used for evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, taste, aroma and overall acceptability (OA).

4.2.6 Titrable acidity (%)

10 ml sample taken in a beaker and add 2 drops of phenolphthalein in it. Then the sample titrated with 0.1 N NaOH until a faint pink colour appeared[8].

4.2.7 Thermal degradation

Total phenol degradation in foods during their thermal processing has been described in terms of zero, first and second order kinetics[9]. A general reaction rate expression for degradation kinetics can be written as follows[10].

$$d[c]/dt = -k_x[c]^n \quad \ldots (1)$$

Where 'c' is the quantitative value of the degraded product under consideration. 'k_x' is the reaction rate constant and 'n' is the reaction order, 't' is the reaction time (min).

The reaction order was determined through linear regression by graphical analysis, where exponent 'n' in eq. (1) was set to 0, 1, and 2 to compare the coefficients of determination (R^2).The integrated forms of zero, first and second order models are given in equation:-

Zero order: $X_t = X_0 - k_x t$ … (2)

First order: $\ln ([X]_t/[X]_0) = - k_x t$ … (3)

Second order: $1 / X_t – 1 / X_0 = k_x t$ … (4)

Using the experimental data, the coefficients of determination (R^2) were observed to be minimum for n = 1, predicting a first order reaction.

The relationship of reaction rate to temperature was evaluated by the Arrhenius equation[11]:

$K_x = A_0 \exp^{-(Ea/RT)}$

4.3 Results and Discussion

Thermal degradation kinetics of phenol content in amla juice, bael juice and bael with amla juice were examined at 60-90ºC. Table 4.1 showed the physical properties of amla and bael juice (fresh juice and treated juice at 60ºC after 60 min thermal treatment). Result revealed that all the parameters (TSS, total phenol, ascorbic acid and acidity) were decreased with thermal treatment. Results were resembles with previous research works[3, 4, 12, 13].

Table 4.1 : The physical characteristics of amla bael juices

Samples		Juice yield (%)	TSS (^{0}B)	Total Phenol (mg GAE/ml)	Ascorbic acid (mg/100 ml)	Acidity (%)
Amla juice	Fresh	41.69	9°B±0.01	12±0.02	350±7	2.25
	Treated		8.4°B±0.1	10.2±0.3	330.35±3	1.8
Bael juice	Fresh	20	14.2°B±0.3	8.38±0.11	30±0.97	1.58
	Treated		13.7°B±0.5	6.45±0.2	10.4±0.24	1.22

Table 4.2 and fig 4.1- 4.3 showed the effect of thermal treatment on concentration of total phenolic content of amla, bael and bael with amla juice. Results revealed that total phenolic content declined with increasing time and temperature during thermal treatment. Similar finding were observed by previous researchers[14]. Thermal breakdown of phenolic compound can occur during heat treatment which can affect the cell structure[15]. Degradation of phenolic compounds might be the activity of polyphenol oxidase (PPO) enzyme[16]. PPO protein perhaps used phenol compound as substrate[17]. The decline in the substance of total phenolic content during heat treatment were also clarified with past investigations that polyphenolics were heat labile and expanded heat treatment could make irreversible changes in phenolic compounds[18].

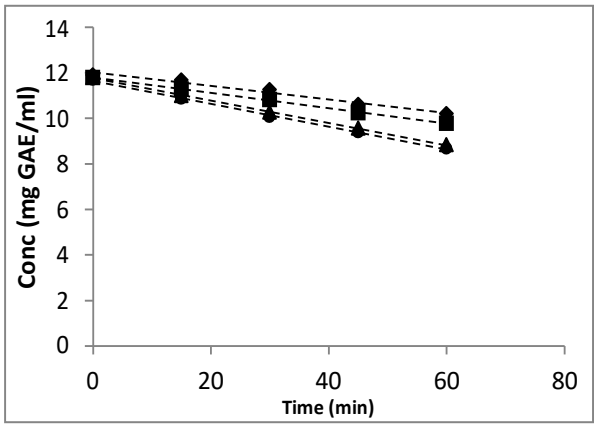


Fig. 4.1

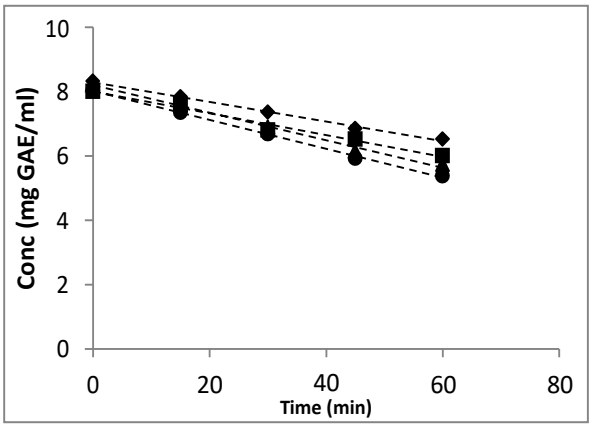


Fig. 4.2

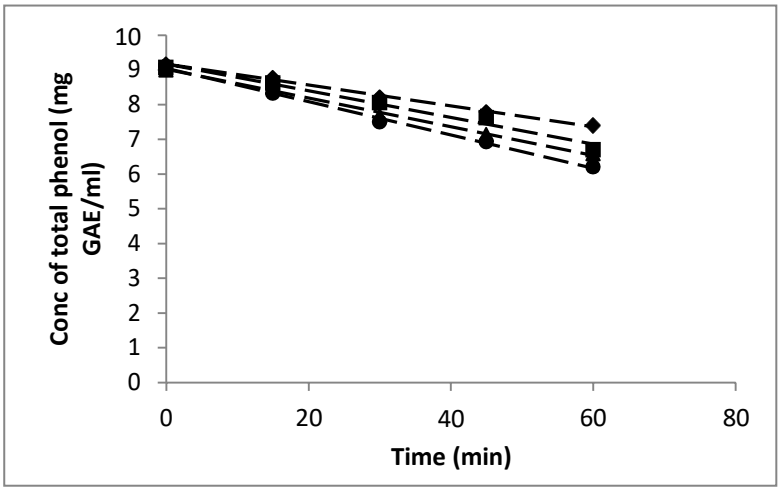


Fig 4.3

Thermal degradation of total phenol content concentration (Fig 4.1 Amla juice, 4.2 Bael juice, 4.3 Bael with amla juice) with increasing time and temperature (♦60ºC, ■ 70ºC,▲ 80ºC, ● 90ºC)

The reaction order of total phenol degradation was evaluated by comparing the R^2 (coefficient of determination) from graphs of Total phenol degradation against thermal treatment time over the temperature range of 60°-90°C in fig 4.4-4.12. By observing the R^2 from table 4.2 and fig 4.4-4.12 it can told that degradation of total phenol content during thermal treatment best fit first order kinetics model than zero order and second order model. Previous researchers also found that total phenol degradation follow first order kinetic model[19, 20, 21, 22].

Table 4.2 Reaction order determination of total phenol content of amla juice, bael juice and bael with amla juice based on R^2 from zero, first and second order model

Samples	Temperature	R^2 Value		
		Zero order	First order	Second orde
Amla juice	60ºC	0.984	0.993	0.981
	70ºC	0.959	0.960	0.943
	80ºC	0.999	0.999	0.995
	90ºC	0.998	0.999	0.992
Bael juice	60ºC	0.995	0.997	0.987
	70ºC	0.981	0.986	0.981
	80ºC	0.992	0.996	0.982
	90ºC	0.997	0.998	0.991
Bael with amla juice	60ºC	0.996	0.997	0.995
	70ºC	0.998	0.999	0.944
	80ºC	0.994	0.996	0.991
	90ºC	0.996	0.998	0.991

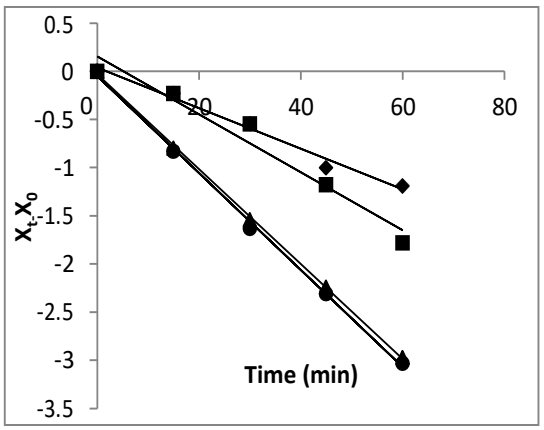


Fig 4.4

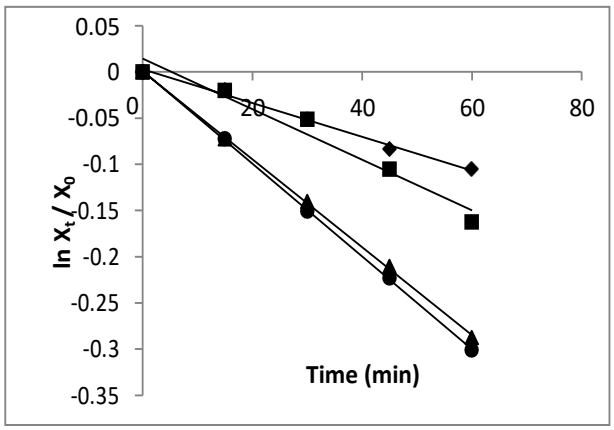


Fig 4.5

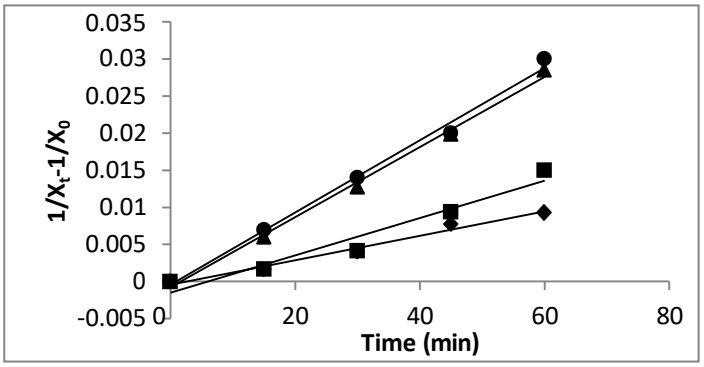


Fig 4.6

Degradation kinetics models of total phenol content of amla juice at 60ºC to 90ºC for 60 min. (4.4) Zero-order, (4.5) First order, (4.6) Second order model. (♦60ºC, ■ 70ºC,▲ 80ºC, ● 90ºC)

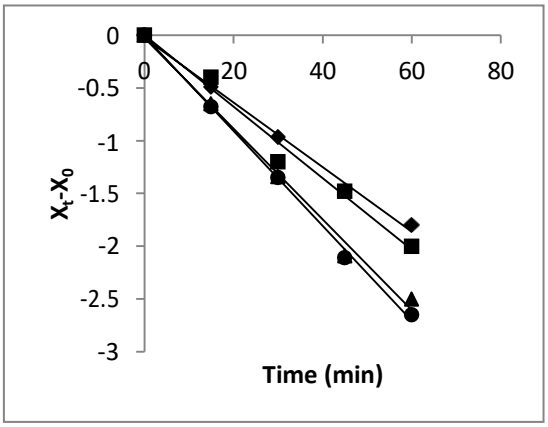


Fig 4.7

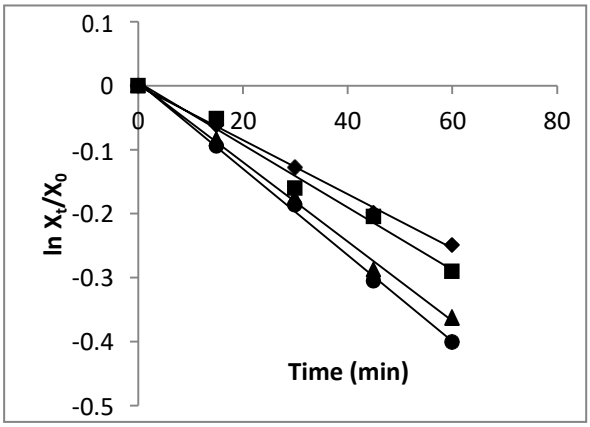


Fig 4.8

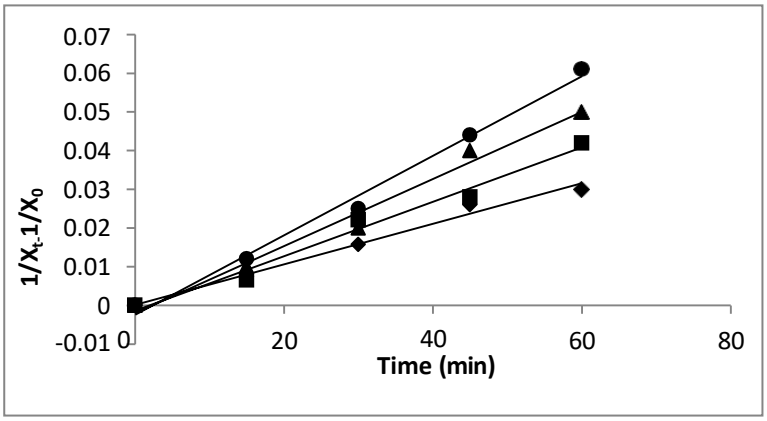


Fig 4.9

Degradation kinetics models of total phenol content of bael juice at 60ºC to 90ºC for 60 min. (4.7) Zero-order, (4.8) First order, (4.9) Second order model. (♦60ºC, ■ 70ºC,▲ 80ºC, ● 90ºC)

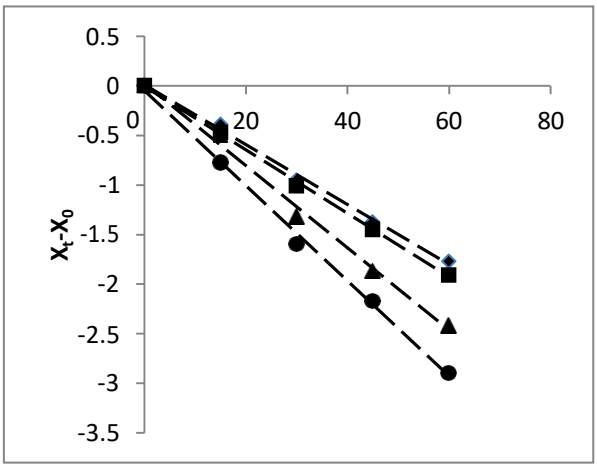


Fig 4.10

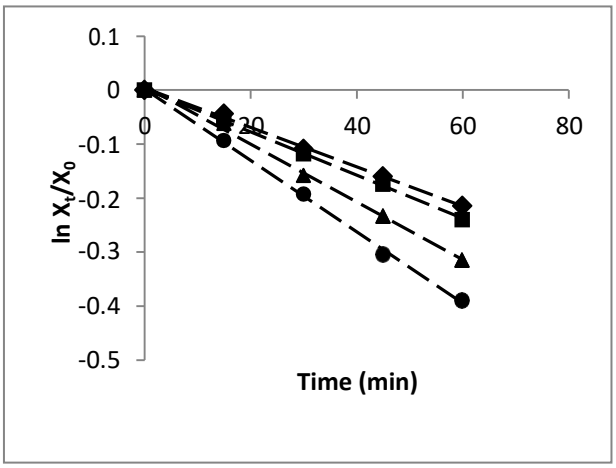


Fig 4.11

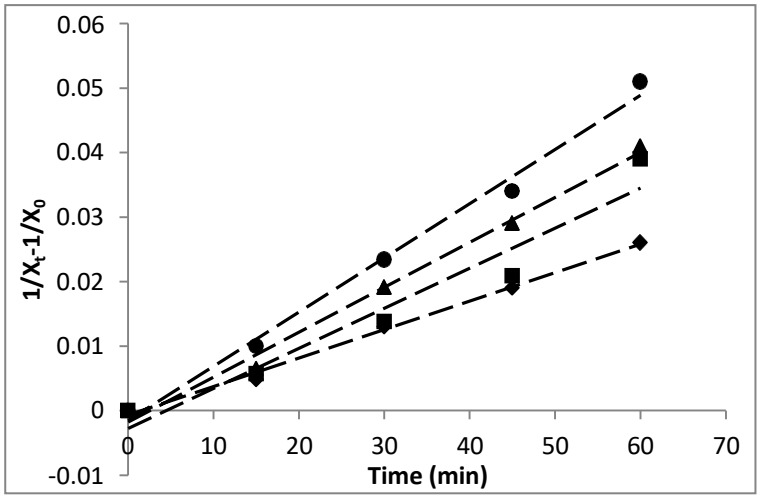


Fig 4.12

Degradation kinetics models of total phenol content of bael with amla juice at 60ºC to 90ºC for 60 min.
(4.10) Zero-order, (4.11) First order, (4.12) Second order model.
(♦60ºC, ■ 70ºC,▲ 80ºC, ● 90ºC)

Table 4.3 represented the reaction rate constant (k), the half life of phenol content ($t_{1/2}$) and other kinetics parameters of first order kinetic model for all samples. It was shown by comparing the k values for all three samples were present in the following manner k 60ºC< k 70ºC< k 80ºC < k 90ºC. That means the degradation rate constant (K) increased regularly with temperature[23] (Table 4.3). It could be seen clearly that the temperature greatly affected phenolic degradation. The time needed for 50% degradation ($t_{1/2}$) of phenol content of amla

juice and bael with amla juice were longer than that of bael juice at all (60-90ºC) temperatures.

Table 4.3 Kinetics parameters for degradation of total phenol content of amla, bael and bael with amla juice due to thermal processing

Samples	Temperature	K(min^{-1})	$T_{1/2}$ (min)	Ea (KJ mol^{-1})
Amla juice	60ºC	0.0013	533	
	70ºC	0.002	346.5	47.71
	80ºC	0.004	173.3	
	90ºC	0.005	138.6	
Bael juice	60ºC	0.004	173.25	
	70ºC	0.0042	165	17.28
	80ºC	0.006	115.5	
	90ºC	0.0063	110	
Bael with Amla Juice	60ºC	0.003	231	
	70ºC	0.004	173.25	20.85
	80ºC	0.005	138.6	
	90ºC	0.006	115.5	

Arrhenius equation for phenol degradation in three types of juices had been plotted ln k against 1/T in fig 4.13-4.15. The activation energy (Ea) was evaluated from the gas constant (R) and the slope obtained from the graphs (fig 4.13- fig 4.15).

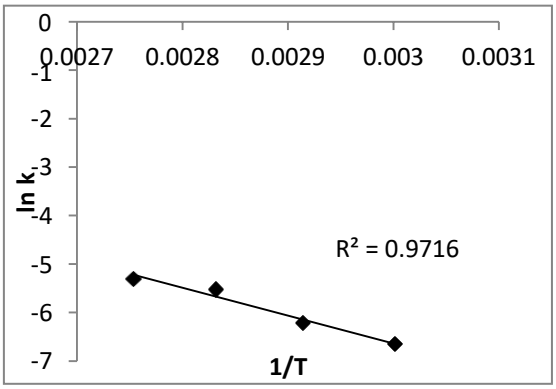


Fig 4.13

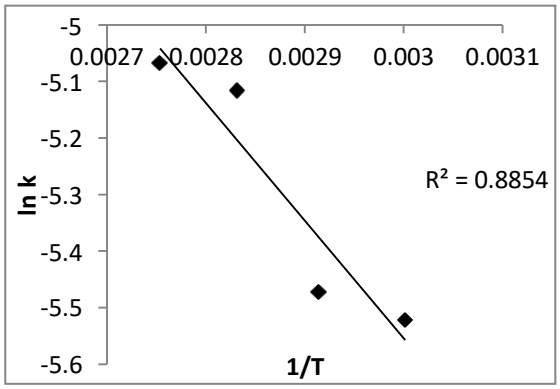


Fig 4.14

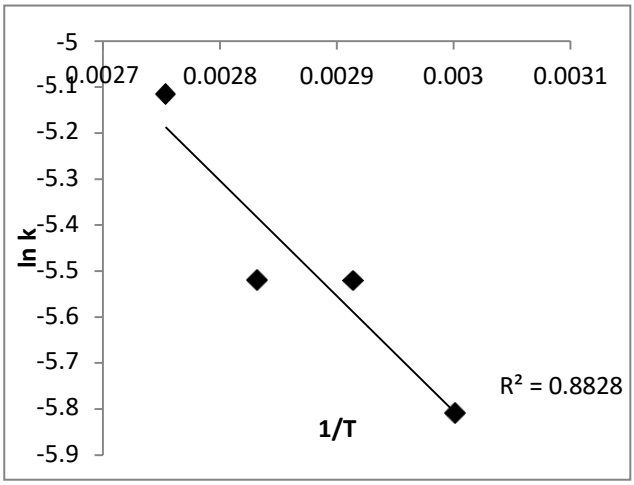


Fig 4.15

Fig-4.13-4.15. ***Plot of ln(k_X) versus (1/T) for degradation of total phenol content from amla juice, bael juice and bael with amla juice during heating over the temperature range of 60-90°C for 60 min.***

In table 4.3 the activation energy of amla juice, bael juice and bael with amla juice were shown 47.71, 17.28, 20.85 respectively which are resembles with previous research works[21, 24]. Result showed that activation energy was highest in amla juice which was followed by bael with amla juice and lowest in bael juice. When activation energy is high, that means more bonding present within components and lots of heat needed to break those bonds. Higher activation energy illustrated a delaying rate[25] of phenolic content degradation. This might be the action of phytochemicals mainly ascorbic acid present in amla juice and their synergetic effect that slower the degradation of phenol content.

The effect of heat treatment (60-90°C) on the concentration of vitamin C in amla juice, bael juice and bael with amla juice for different time intervals has been studied. Table 4.4 and fig 4.16-4.18 showed that the concentration of vitamin C degradation increased with increasing temperature and time for all samples. This may be due to the fact that vitamin C is very sensitive to heat, oxygen and light for which vitamin C easily oxidized in presence of heat and oxygen by using both enzymatic and non-enzymatic catalyst[26].

Table 4.4 Thermal degradation of vitamin C content concentration of amla, bael and bael with amla juice

Concentration of vitamin C (mg/100 ml)												
Time (min)	60°C			70°C			80°C			90°C		
	Amla juice	Bael juice	Bael-amla juice	Amla juice	Bael juice	Bael-amla juice	Amla juice	Bael juice	Bael-amla juice	Amla juice	Bael juice	Bael-amla juice
0	348±3	28.2±0.4	74±0.1	347.74±4	27.8±0.3	74.1±0.25	346±3	28.3±0.03	73.66±0.07	345.7±3	28.5±0.1	73.5±0.8
15	343.59±5	23.7±0.99	69.57±0.23	342.89±2	22.9±0.2	68.5±0.57	339.6±2	21.5±0.05	66.99±0.5	335.98±5	20.9±0.06	66.43±0.04
30	338.86±7	18.88±0.56	64.77±0.34	337.76±2	17.7±2	63.33±0.3	334.41±0.7	16.24±0.2	61.78±0.56	329.83±5	15.6±0.9	61.32±0.2
45	334.35±4	15.77±0.04	61.75±0.7	332.46±2	14.3±0.2	59±1	328.36±3	13.01±0.02	57.24±0.3	323.79±2	12.86±0.3	55.21±0.6
60	331.35±5	10.4±0.2	56.33±0.92	328.19±5	8.23±0.06	54.55±0.83	324.88±3	7±0.4	52.45±0.7	315±2	5.32±0.04	48.5±0.78

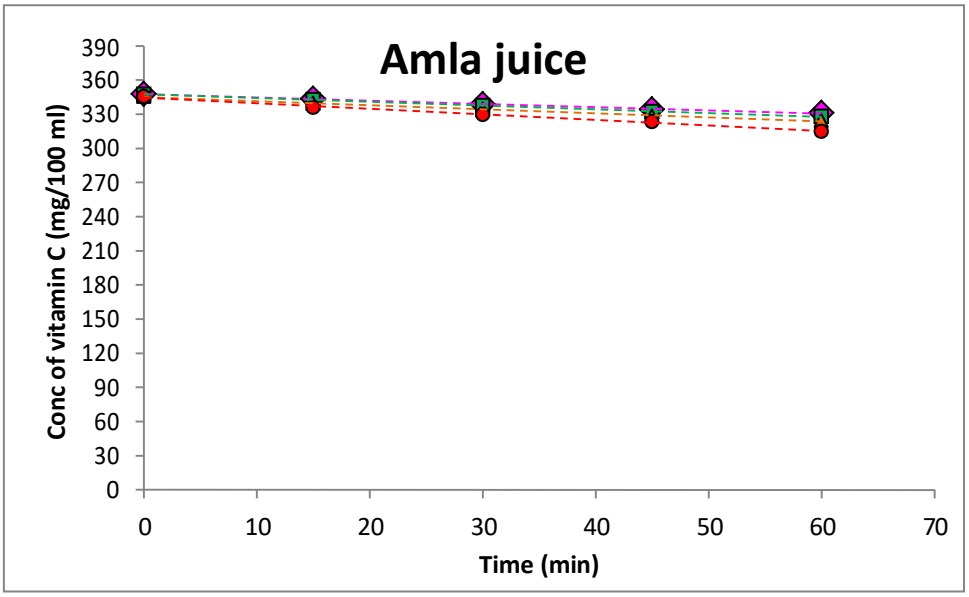


Fig 4.16

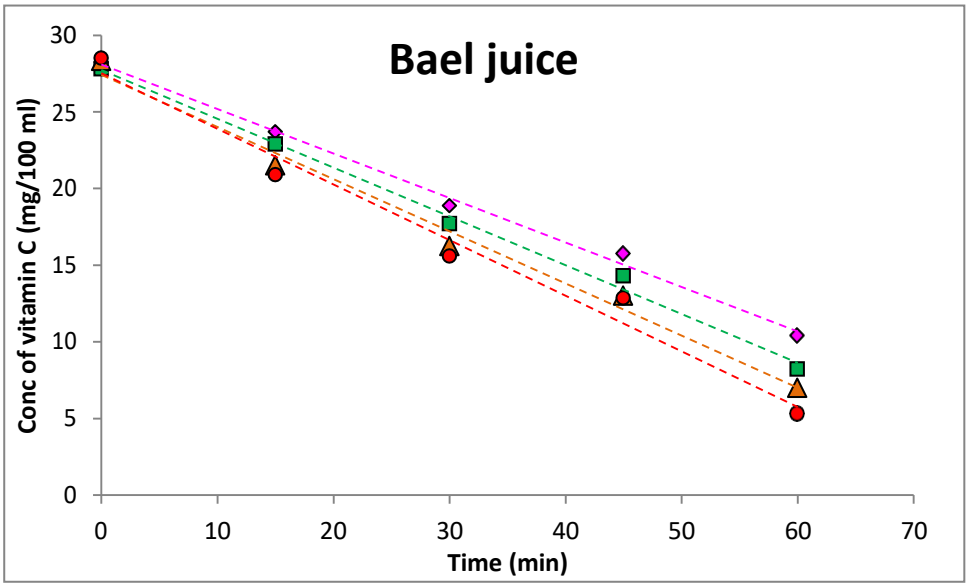


Fig 4.17

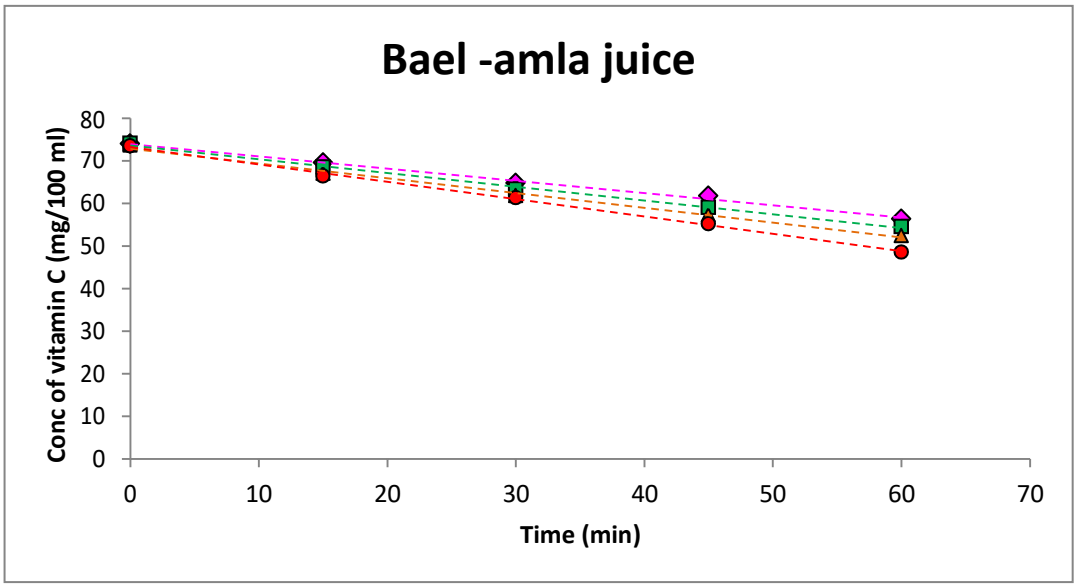


Fig 4.18

Thermal degradation of vitamin C content concentration (Fig 4.16 Amla juice, 4.17 Bael juice, 4.18 Bael with amla juice) with increasing time and temperature (♦60ºC, ■ 70ºC,▲ 80ºC, ● 90ºC)

The vitamin C also decreases during storage (Table 4.5). The degradation of vitamin C may be the result of increasing ambient temperature with the increase in storage period involving weather change from winter to summer season[27]. At the beginning the Vitamin C degrades more rapidly due to prompt reaction of an amount of vitamin C with the dissolved oxygen. After that the degradation rate became slower.

Table 4.5: Vitamin C content in juices during storage

Vitamin C (mg/100ml)			
Months	Amla juice	Bael juice	Bael-amla juice
Initial	342±3	28.6±0.6	73±1
1 month	331.02±5	14.6±0.77	60.8±0.89
2 months	323.1±2	5.8±0.8	52.4±2
3 months	320±3	2.83±0.3	48.42±0.6

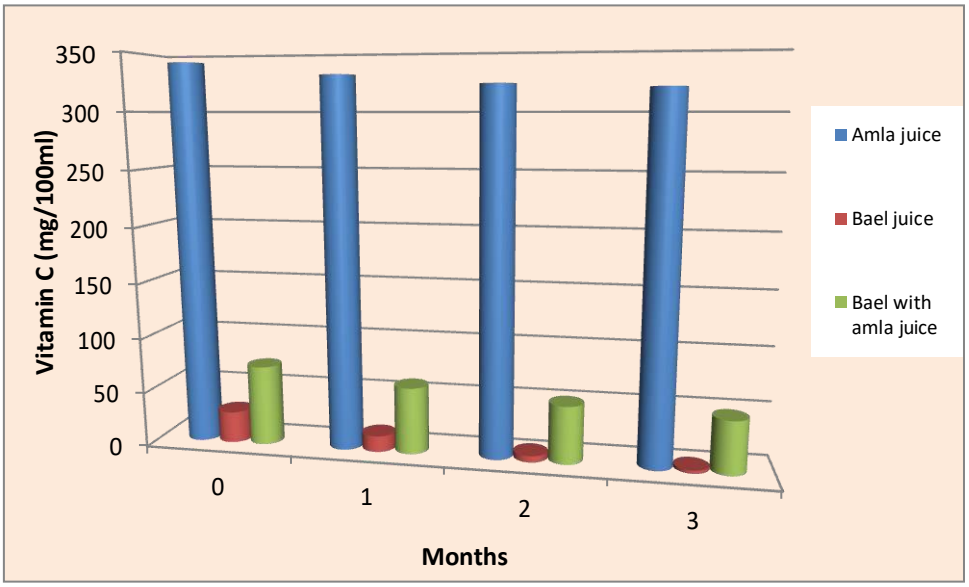


Fig 4.19 ***Vitamin C content in amla, bael and bael with amla juice during storage***

Table 4.6 and fig 4.20 shows that total phenol content decreased with increasing storage period for all samples. This decrease in total phenol content might have been due to the action of PPO (Polyphenoloxidase) enzyme as polyphenols were utilized as substrates for the PPO protein[28]. Result revealed that amla juice retained maximum amount of total phenol which was followed by bael-amla juice and loss of total phenol content maximum in bael juice.

Table 4.6 Total phenol content in juices during storage

Total phenol content (mg GAE/ml)			
Months	Amla juice	Bael juice	Bael-amla juice
Initial	11.85±0.2	8±0.07	9.11±0.04
1 month	11.77±0.03	7.91±0.25	9.04±0.1
2 months	11.71±0.6	7.84±0.5	8.98±0.06
3 months	11.65±0.3	7.77±0.68	8.92±0.9

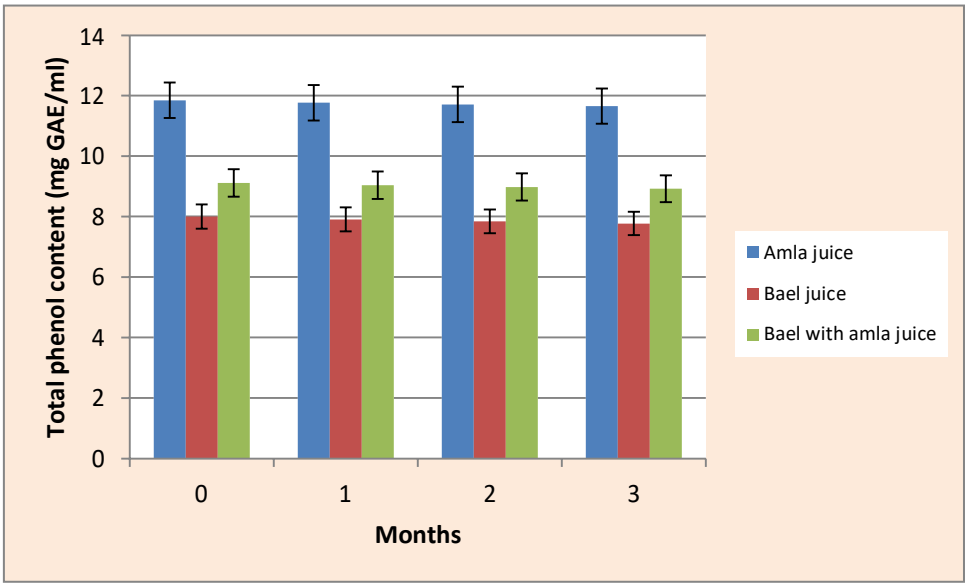


Fig 4.19 ***Total phenol content in amla, bael and bael with amla juice during storage***

Table 4.7 and fig 4.21 revealed that Sensory score decreased gradually with increase in storage period at room temperature. The score was significantly decreased during storage. Bael with amla mixed juice shows best result than bael and amla juice and it can be store upto 3 months.

Table 4.7 Sensory analysis of juices during storage

Quality charecteristics	Amla juice				Bael juice				Bael with amla juice			
	Initial	1 month	2 months	3 months	Initial	1 month	2 months	3 months	Initial	1 month	2 months	3 months
Colour	7	6.42	6.08	5.93	8	7.33	7	6.6	8.2	8	8	7.82
Aroma	5.3	5.11	5	5	7.1	6.57	6.3	5.9	9	9	8.76	8.7
Taste	5.7	5.46	5.12	5.03	7.5	7.2	7	6.8	9	8.92	8.78	8.4
O.A	6.4	6	6	5.8	8.14	8	7.45	7.2	8.6	8.73	8.55	8.34

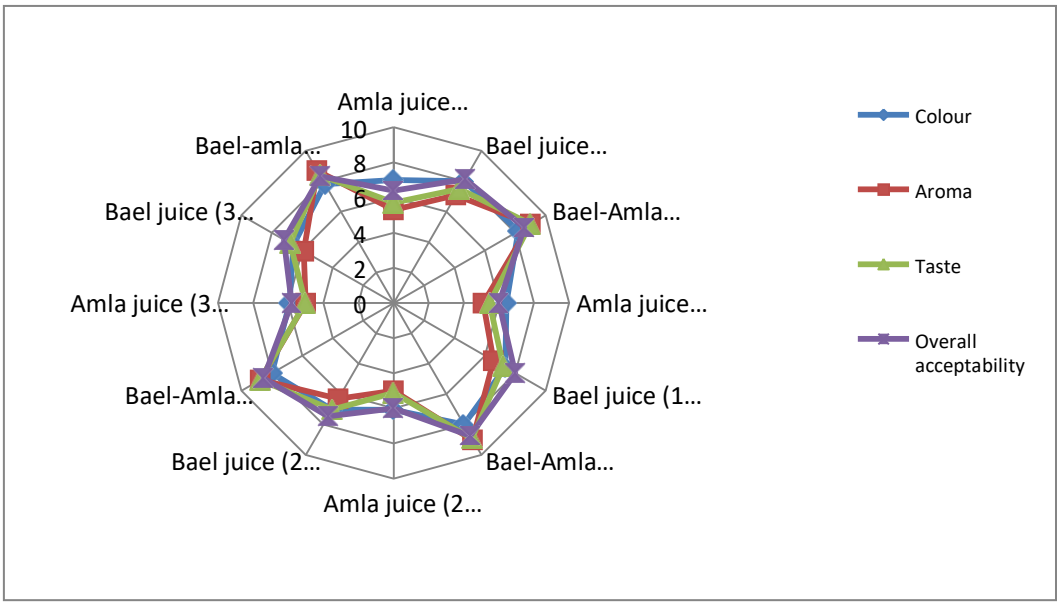


Fig: 4.21 ***Descriptive analysis on sensory score on amla, bael and bael with amla juices***

4.4 Conclusion

Total phenol content in all juices was declined with increasing temperature and time. Total phenol degradation follow first order kinetic model. Among three juices amla juice and bael with amla juice contained higher activation energy of total phenol degradation and bael juice contain lower activation energy. The half life of amla juice and bael with amla juice were longer than bael juice. Concentration of ascorbic acid also degraded during thermal treatment. Total phenol content and ascorbic acid both declined during storage. Bael with amla juice score best in sensory test. Thus it can be concluded that mixing of bael juice with amla juice was accepted as the best during the storage period because it was adjudged with the best organoleptic rating with high amount of nutrition.

REFERENCES

1. Subrata Kumar Bag & Prem P. Srivastav & Hari N. Mishra (2011) Optimization of Process Parameters for Foaming of Bael (Aegle marmelos L.) Fruit Pulp. *Food Bioprocess Technol* **4:**1450–1458

2. Jain SK, Akhurdiya DS. (2000) Anola: potential fruit for processing. Delhi Garden Mega. **38:**50–51.

3. JAIN S K & KHURDIYA D S. (2004) Vitamin C Enrichment of Fruit Juice Based Ready-to-Serve Beverages Through Blending of Indian Gooseberry (*Emblica officinalis* Gaertn.) Juice *Plant Foods for Human Nutrition* **59:** 63–66.

4. B. Karpagavalli1, S. Amutha, T. Padmini, R. Palanisamy and K. Chandrakumar (2014) Effect of Processing on Retention of Antioxidant Components in Value Added Amla Products
   Indian Journal of Science and Technology, **7(5)** 672–677.

5. Singleton V L & Rossi J A (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am J Enol Viticult*.16 144-153.

6. Rangana S, (1986) Handbook of analysis and quality control for fruit and vegetable products. 105-106.

7. Suresh K P & Sagar V R (2014) Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions. *J Food Sci Technol* **51(8)** 1540-1546.

8. Rangana, S.(2003). Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw Hills Publishing Co.Ltd., NEW DELHI(INDIA).

9. Corradini M G & Pleg M (2006) Prediction of vitamins loss during non-isothermal heat processes and storage with non linear kinetic models. Trends in Food Science & Technology, **17:** 24-34.

10. H. Remini et al., (2015) Degradation kinetic modelling of ascorbic acid and colour intensity in pasteurised blood orange juice during storage. *Food Chemistry*. **173:** 665-673

11. Thankitsunthorn S, Thawornphiphatdit C, Laohaprasit N and Srzednicki G (2009) Effects of drying temperature on quality of dried Indian Gooseberry powder. *International Food Research Journal.* **16**: 355-361.

12. Sharmaa H P, Patel H, Sharma S and Vaishali (2014) Study of Physico-Chemical Changes During Wood Apple (*Feronia Limonia*) Maturation. *JOURNAL OF FOOD RESEARCH AND TECHNOLOGY*. **2(4):** 148-152.

13. Awadhesh Kumar A and Deen B (2017) Studies on Bio-Chemical Changes in Wood Apple (*Limonia acidissima* L.) Fruits during Growth and Development*Int.J.Curr.Microbiol.App.Sci* **6(8):** 2552-2560

14. Lin, Y.C. and Chou, C.C. (2009).Effect of heat treatment on total phenolic and anthocyanin contents as well as antioxidant activity of the extract from Aspergillius awamori-fermented black soyabins, a healthy food ingredient. *Int J Food Sci Nutr*., **60(7):** 627-636.

15. Youssef, K.M., Mokhtar, S.M., (2014). Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of *Portulaca oleracea* L. Leaves. *J Nutr & Food Sci.,* **4(6).** DOI: 10.4172/2155-9600.1000322.

16. Sonawane, S.K., and Arya, S.S., (2015). Effect of drying and storage on bioactive components of jambhul and wood apple. *J Food Sci Technol,* **52(5):**2833-2841.

17. Janovitz-Klapp, A.H., Richard, F.C., Goupy, P.M. and Nicolas, J.J. (1990). Inhibition studies on apple polyphenol oxidase. *J. Agric. Food Chem*, **38 (4):** 926-931.

18. Mrad,N.D., Boudhrious,N., Kechaou,N., Courtois,F. and Bonazzi,C.(2012). Influence of air drying temperature on kinetics,physico-chemical properties, total phenolic content and ascorbic acid of pears. *Food and Bioproducts processing*.,**90**: 433-441.

19. Jaiswal,A.K. and Abu-Ghannam,N.(2013).Degradation kinetic modeling of color,texture,polyphenols and antioxidant capacity of York cabbage after microwave processing. *Food Research International*., **53 (1):** 125-133.

20. ELSA M. GONC-ALVES, JOAQUINA PINHEIRO, CARLA ALEGRIA, MARTA ABREU, TERESA R. S. BRANDA O, AND CRISTINA L. M. SILVA, (2009) Degradation Kinetics of Peroxidase Enzyme, Phenolic Content,and Physical and Sensorial Characteristics in Broccoli (Brassica oleracea L. ssp. Italica) during Blanching *J. Agric. Food Chem*. **57:**5370–5375.

21. Jaiswal, A. K., Gupta S,Abu-Ghannam N. (2012). Kinetic evaluation of colour, texture, polyphenols and antioxidant capacity of Irish York cabbage after blanching treatment. *Food Chemistry.* **131(1)** 63-72.

22. Zhou L , Cao Z , Bi J , Yi J , Chen Q , Wu X, Zhou M O. (2016) Degradation kinetics of total phenolic compounds, capsaicinoids and antioxidant activity in red pepper during hot air and infrared drying process. *International journal of Food Science + Technology.* **51(4)** 842-853.

23. CAO Shao-qian, LIU Liang and PAN Si-yi. (2011) Thermal Degradation Kinetics of Anthocyanins and Visual Color of Blood Orange Juice Agricultural Sciences in China.**10(12):** 1992-1997

24. Zori Z, Dragovi Uzelac V, Pedisi S, Kurtanjek and Garofuli I E (2014) Kinetics of the Degradation of Anthocyanins, Phenolic Acids and Flavonols During Heat Treatments of Freeze-Dried Sour Cherry Marasca Paste *Food Technol. Biotechnol.* ***52*** **(1)** 101–108.

25. Sapei L and Hwa L. (2014) Study on the kinetics of vitamin C degradation in fresh strawberry juices, Procedia Chemistry **9:** 62-68.

26. Rathod A S, Shakya B R, Ade K D. (2014) Studies on Effect of Thermal Processing on Preparation of Bael Fruit RTS Blended with Aonla; *IJREAT*, **2(3)** 1-6.

27. Anup Kumar Bhattacherjee & D. K. Tandon & A. Dikshit & S. Kumar (2011) Effect of pasteurization temperature on quality of aonla juice during storage J Food Sci Technol **48(3):**269–273

28. Janovitz-Klapp A H, Richard F C, Goupy P M and Nicolas J J (1990) Inhibition studies on apple polyphenol oxidase. *J. Agric. Food Chem*. **38(4)** 926-931.

CHAPTER 5

PROCESSING OF JACK FRUIT

5.1 Introduction

Jackfruit (*Artocarpus heterophyllus* L.) is a fruit belongs to the family Moraceae and is grown in the tropical part of India. The fleshy, fibrous bulb of this fruit is rich in sugar, carotenoids, carbohydrates, minerals, carboxylic acids, dietary fibre, and vitamins such as vitamin C[1]. Carotenoid is responsible for the attractive yellow colour of the ripe bulbs[2]. The phytochemicals such as vitamin C, polyphenol, flavonoids of jackfruit shows health promoting effects. They act as natural antioxidants which inhibit oxidation-induced degenerative changes in cell. The fruit deteriorates rapidly upon ripening. So it is desirable that pre cut bulbs are processed and stored by an appropriate method. Pre-cutting of jackfruit bulbs increases oxidative stress and they tend to lose keeping quality, significant reduction of phytochemicals, such as phenolics, flavonoids, vitamin C, and carotenoids[3]. Introduction of additives during minimal processing has been reported, to minimise these deteriorative changes in fresh-cut fruits and vegetables[4]. Additives such as citric acid, ascorbic acid and calcium chloride, sodium benzoate at minimum level during minimal processing of pre cut bulbs have been found beneficial in minimizing the stress-induced metabolism, reduction of nutrient loss, reducing the browning reaction, and improving the sensory quality along with shelf-life extension[5]. Several studies have been conducted for various minimally processed produces such as apricot, apple, pear etc but very limited works were reported on post-harvest technology of jackfruit bulbs by minimal processing.

However processing of jackfruit to products can also extend the shelf life of the fruit. Among them jackfruit jam is most important. Jam can reduce post harvest loss and increase utilization of the commodities. Jam is made from fruit pulp with addition of pectin which acts as gelling agent. Sugar and citric acid are also added[6]. Jam can store for several months. Lots of work has been done on other fruits but very little information is available about jackfruit jam.

Jackfruit can also store by dehydration. Dehydration of food products are often used as food products in industry. Drying process helps in extending the shelf life as well as reduces the volume of fruits and vegetables[7]. Hot air drying is most frequently used preservation technique but this process have negative effect on colour and nutritional quality of the foods for the longer duration of drying and high temperature used in drying[8]. Very little work has been done on the effect of temperature in pretreated dehydrated jackfruits.

Therefore the objectives of this work are

(i) To find out the effect of additives on nutritional quality of pre-cut jackfruit bulbs.

(ii) To produce jackfruit jam with good sensory attributes.

(iii) To find out the effect of pre-treatments on nutritional quality of dehydrated jackfruits during storage.

5.2 Materials and methods

5.2.1 Effect of pretreatments on nutritional quality of minimally processed jackfruit bulbs during storage

Ripe jackfruits were purchased from local market. After cutting the jackfruit yellowish bulbs were removed seeds were separated and used for further studies. Surface sanitized with 100 ppm chlorinated water[9]. Bulbs were cut in slices. Half of the fruits undergo a secondary phytosanitation wash in chilled chlorinated water (30 ppm) for 5 min. Then slice were separately dipped in solution containing $CaCl_2$ (0.05%, 1%, 2% w/v), sodium benzoate (0.01%, 0.02%, 0.05% w/v), Ascorbic acid (0.01%, 0.02%, 0.03% w/v) and Citric acid (0.5%, 1%, 1.5% w/v). Another part washed with water and used as untreated. Excess water drained of both pretreated and untreated samples. Then samples were packed in sealed polyethylene pouches and kept in low temperature for storage study.

5.2.1.1 Total phenol content:

Total phenolic content was determined by folin-ciocalteu method[10]at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit as described in chapter 1 (1.2.1.2).

5.2.1.2 Antioxidant content:

Antioxidant content was determined by FRAP method and the the value expressed as mM $FeSO_4$ /g fruit[11] as described in chapter 3 (3. 2.1.3).

5.2.1.3 Vitamin C content:

Ascorbic acid was determined by titrimetric method[12] and the value expressed as mg of ascorbic acid /100 g fruit as described in chapter 1 (1. 2.1.3).

5.2.1.4 Total carotenoid:

Carotenoid content was measured according to the process described by Saxena et al., 2009[9]. 0.5 g of pulp was mixed with a solvent containing 40 ml acetone and 60 ml hexane and extracted until the residue was colourless. Then the homogenate was filtered by a separating funnel. 50 ml hexane was added in the separating funnel, and acetone was separated from the extract by washings with distilled water. The upper hexane layer with extracted pigment was taken in a 100-mL volumetric flask, and the volume is made up with hexane. The absorbance was measured at 450nm. The value expressed as mg/100g[9].

$$\text{Total carotenoid (mg/100g)} = \frac{A(450) * \text{VOLUME MADE up (ML)} * 1000}{2500 * \text{sample w}g\ (g)}$$

5.2.1.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the effect of storage on the sensory quality of minimal processed bulbs. A 10-untrained member of sensory panel[13] was used for

evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, taste and aroma.

5.2.2 Development and storage study of jackfruit jam

5.2.2.1 Production of jackfruit jam

The jackfruits were purchased from local market. Then Jackfruit was cut with sharp knife and bulbs were removed. After that seeds were carefully removed from bulbs. Then bulbs were blended in a mixture grinder to get pulp. The pulp added with sugar, citric acid and pectin, and allowed to boil until gel was formed and final brix was maintained at 68^0B. At the end, the prepared jam was carefully poured in sterilized jam bottles and placed in room temperature for storage study.

Types of jam prepared:

(1) Sample 1: pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (1% of sugar)

(2) Sample 2: pulp and sugar ratio (50:50), pectin (2% of sugar) and citric acid (1% of sugar)

(3) Sample 3 pulp and sugar ratio (50:50), pectin (0.5% of sugar) and citric acid (1% of sugar)

(4) Sample 4 pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (0.5% of sugar)

(5) Sample 5 pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (2% of sugar)

(6) Sample 6 pulp and sugar ratio (55:45), pectin (1% of sugar) and citric acid (1% of sugar)

(7) Sample 7 pulp and sugar ratio (45:55), pectin (1% of sugar) and citric acid (1% of sugar)

5.2.2.2 Total soluble solid:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B.

5.2.2.3 Vitamin C content:

Ascorbic acid was determined by titrimetric method[12] and the value expressed as mg of ascorbic acid /100 g fruit as described in chapter 1 (1. 2.1.3).

5.2.2.4 Total carotenoid:

Carotenoid was measured by according to the process described by Saxena et al., 2009. Procedure briefly describe in chapter 5(5.2.1.3). The absorbance was measured at 450nm. The value expressed as mg/100g[9].

Total carotenoid (mg/100g)= $\frac{A(450)*\text{VOLUME MADE up (ML)}*1000}{2500*\text{sample w}g\ (g)}$

5.2.2.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the sensory quality of jam. A 10-untrained member sensory panel[13] was used for evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, spreadability, taste, aroma and overall acceptability.

5.2.3 Hot air dehydration of jackfruit bulb slices

Jackfruit was purchased from local market. At first bulbs were separated and after that seeds were removed. Bulbs were sliced with a sharp knife. Then jackfruit slices were blanched. Blanched bulbs were divided in 3 parts. First part kept as 1st pretreated sample. Second part (500g) dipped in 500 ml amlaki juice which contains 470 mg/100ml vitamin C for 5 minute, 10 minute and 15 minute duration. Third part of blanched samples dipped in same amount of ascorbic acid for 5 minute, 10 minute and 15 minute duration and untreated samples were kept as control. All pretreated and untreated samples were dried at 50^0 C temperature.

During the drying process the weight of the samples was measured periodically at intervals of 30 minutes. The experiment was continued until the equilibrium moisture content reached.

5.2.3.1 Determination of moisture %

The moisture content of different samples was measured on the basis of initial weight of the samples[14]. At first weight of previously dried aluminium cup was noted. After that 50 mg of sample was placed on it and the weight was noted accurately. Then it was placed in a hot air oven overnight at 105°C next day weight was taken.

The loss in weight was reported as moisture %.

$$\% \text{ moisture (d.b)} = \frac{\text{moisture content (w.b)}}{100-\text{w.b}} \times 100 \qquad (1)$$

Mathematical modelling:

$$MR = \frac{M_t - M_e}{M_i - M_e} \qquad (2)$$

MR= Moisture Ratio, M_i=Initial moisture content (% db) M_t= Moisture content in time t (% db), M_e=Equilibrium moisture content (% db)

To describe drying behaviour of pretreated sliced jackfruit bulbs two different established thin layer drying[15, 16] were used:

Newton model: MR= exp(-kt) **(3)**

Page model: MR= exp(-kt^n) **(4)**

SPSS software was used to evaluate these two models. The lower χ^2, RMSE, and higher R^2 were used as main criteria for selecting model[22]

Chi-square value (χ^2)[23]:

$$\chi^2 = \frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}{N-z} \qquad (2)$$

Root mean square error[19]**:**

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2} \qquad (3)$$

Where: MR_{exp} = Experimental moisture ratio, MR_{pred} = Predicted moisture ratio, N = Number of observations, z = Number of constants

5.2.3.2 Total phenol content:

Total phenolic content was determined by folin-ciocalteu method[10]at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit as described in chapter 1 (1.2.1.2).

5.2.3.3 Antioxidant content:

Antioxidant content was determined by FRAP method and the the value expressed as mM $FeSO_4$ /g fruit[11] as described in chapter 3 (3. 2.1.3).

5.2.3.4 Total carotenoid:

Carotenoid was measured by according to the process described by Saxena et al., 2009. Procedure briefly describe in chapter 5(5.2.1.3). The absorbance was measured at 450nm. The value expressed as mg/100g[9].

Total carotenoid (mg/100g)= $\frac{A(450)*\text{VOLUME MADE up (NS)}*1000}{2500*\text{sample w}g\ (g)}$

5.2.3.5 Sensory analysis:

Descriptive sensory analysis was carried out to determine the sensory quality of jam. A 10-untrained member sensory panel[13] was used for evaluation described in chapter 1 (1.2.1.4).The characteristics considered were colour, texture, flavour and overall acceptability.

5.3 Results and discussions

5.3.1 Effect of pretreatments on nutritional quality of minimally processed jackfruit bulbs during storage

In recent years the design of food product undergoes remarkable changes with the addition and understanding of functional components of the foods. Foods and vegetables contain large

amount of natural antioxidants and therefore the challenge is to retain maximum amount of these important components during processing. Generally jackfruit is available in market as separated bulb which is extremely susceptible to oxidative stress which results loss of important nutrients. Therefore some additives such as citric acid as anti respiratory agent, $Cacl_2$ as texturing substance, sodium benzoate as preservative and ascorbic acid as a supplement may be used to reduce the adverse excessive loss of nutrients due to pre-cutting process[20].

Table 5.1 Characteristics of jackfruit bulb

Analysis	Jackfruit
TSS (^{0}B)	22±0.36
Moisture (%)	72±0.60
Total Phenol(mg GAE/g)	0.75±0.06
Ascorbic acid (mg/100 g)	8.32±0.93
FRAP(mM $FeSO_4$/g)	0.5±0.035
Carotenoid (mg/100 g)	1.336±0.21

5.3.1.1 Total phenol content of jackfruit bulb during storage:

It was observed from table 5.2 and graph 5.1 that total phenol content decreases during storage in both pretreated and untreated samples. Pretreated samples showed lower loss of total phenol than untreated sample shows higher degree of degradation during storage. The pretreatments extended the shelf life and increased retention of total phenol by decreasing the oxidative stress[21]. Samples pretreated with ascorbic acid retained maximum amount of total phenol (0.557 mg GAE/g) after 21 days of storage. Similar finding were observed by Saxena et al[9]. This was followed by citric acid 0.492 mg GAE/g. The decrease in Total phenol during storage of fresh-cut jackfruit could be results of enzymatic degradation by peroxidase (POD)

and PPO activities. Generally POD is responsible for oxidation of polyphenols[22]. POD can cause membrane damage and oxidative stress[23].Ascorbic acid and citric acid can restricted the action of polyphenoloxidase enzyme[24], they act as anti respiratory agent.

Table 5.2: Total phenol content of fresh cut jackfruit during storage

Days	Total phenol content (mg GAE/g)													
	Untreated	Chlorinated (30 ppm)	$CaCl_2$ (0.5%)	$CaCl_2$ (1%)	$CaCl_2$ (2%)	Na-B (0.01%)	Na-B (0.02%)	Na-B (0.05%)	Ascorbic acid (0.01%)	Ascorbic acid (0.02%)	Ascorbic acid (0.03%)	C.A (0.5)	C.A (1%)	C.A (1.5%)
0	0.5	0.59	0.63	0.64	0.654	0.61	0.63	0.67	0.65	0.65	0.69	0.6	0.61	0.63
7	0.324	0.51	0.59	0.613	0.626	0.59	0.61	0.639	0.62	0.623	0.67	0.55	0.58	0.6
14	0.214	0.473	0.54	0.54	0.59	0.56	0.561	0.59	0.58	0.58	0.625	0.5	0.52	0.55
21	0.102	0.37	0.45	0.47	0.51	0.48	0.5	0.52	0.52	0.524	0.557	0.42	0.44	0.492

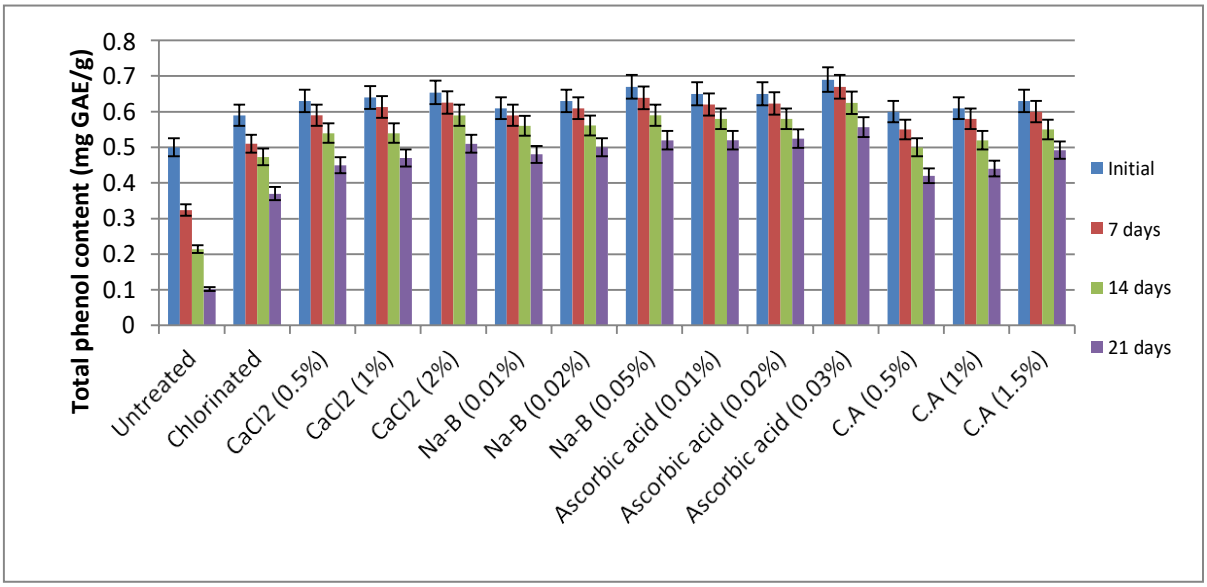


Fig 5.1 ***Total phenol content of fresh cut jackfruit during storage***

5.3.1.2 Antioxidant content of jackfruit bulb during storage:

Table 5.3 and fig 5.2 shows the degradation of antioxidant of pretreated and untreated samples. After 21 days of storage the untreated sample retained only 0.06 mM $FeSO_4$/g antioxidant. Whereas pretreated with ascorbic acid (conc 0.03%) contain 0.413 mM $FeSO_4$/g and citric acid 0.392 mM $FeSO_4$/g which were followed by sodium benzoate and $Cacl_2$. Cutting of jackfruit bulb cause physiological stress that cause loss of phytochemical components which are responsible for antioxidant activity[25].Addition of ascorbic acid during pretreatment can retained maximum amount of antioxidant.

Table 5.3: antioxidant content of fresh cut jackfruit during storage

Days	Antioxidant content (mM $FeSO_4$/g)													
	Untreated	Chlorinated (30 ppm)	$CaCl_2$ (0.5%)	$CaCl_2$ (1%)	$CaCl_2$ (2%)	Na-B (0.01%)	Na-B (0.02%)	Na-B (0.05%)	Ascorbic acid (0.01%)	Ascorbic acid (0.02%)	Ascorbic acid (0.03%)	C.A (0.5)	C.A (1%)	C.A (1.5%)
0	0.41	0.38	0.43	0.43	0.45	0.426	0.45	0.46	0.45	0.46	0.473	0.45	0.453	0.46
7	0.201	0.266	0.342	0.37	0.42	0.38	0.4	0.44	0.43	0.43	0.452	0.41	0.417	0.435
14	0.132	0.2	0.27	0.32	0.41	0.34	0.39	0.42	0.387	0.4	0.43	0.368	0.37	0.411
21	0.06	0.12	0.215	0.29	0.379	0.278	0.35	0.388	0.33	0.38	0.413	0.3	0.32	0.392

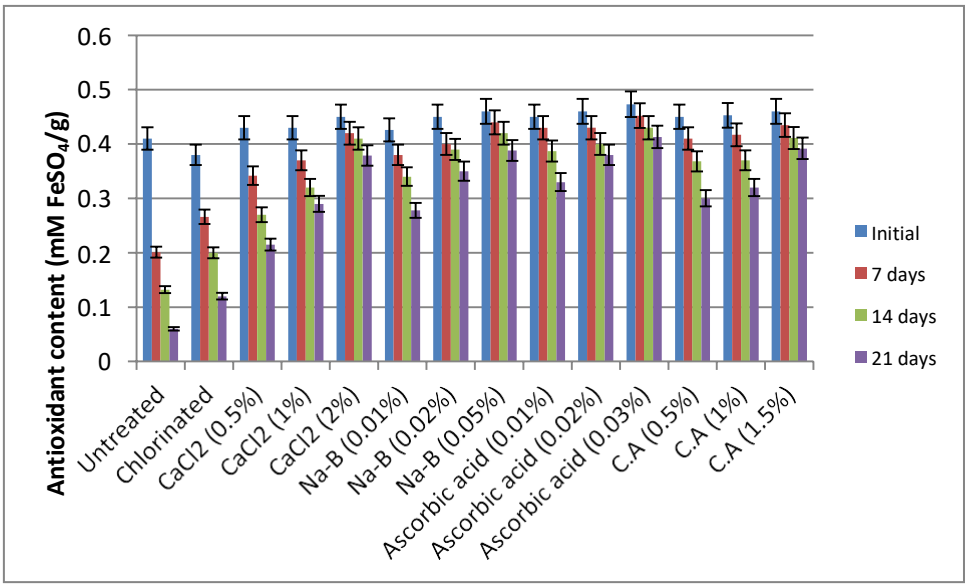


Fig 5.2: ***Antioxidant content of fresh cut jackfruit during storage***

5.3.1.3 Vitamin C content of jackfruit bulb during storage:

Vitamin C plays an important role as antioxidant. The oxidative stress introduce during fresh cut jackfruit cause degradation of vitamin C. Table 5.4 and fig 5.3 shows that the addition of ascorbic acid during pretreatment retained maximum amount of vitamin C . Degradation could be the result of vitamin C oxidation into dehydroascorbic acid. The untreated sample showed a rapid loss of vitamin C content during storage. Results were closely resembles with other research work[9, 24].

Table 5.4: Vitamin C content of fresh cut jackfruit during storage

Days	Vitamin C (mg/100 g)													
	Untreated	Chlorinated (30 ppm)	$CaCl_2$ (0.5%)	$CaCl_2$ (1%)	$CaCl_2$ (2%)	Na-B (0.01%)	Na-B (0.02%)	Na-B (0.05%)	Ascorbic acid (0.01%)	Ascorbic acid (0.02%)	Ascorbic acid (0.03%)	C.A (0.5)	C.A (1%)	C.A (1.5%)
0	4.8	4.6	4.9	5.1	5.5	5.9	6.1	6.2	6.4	6.4	6.5	6	6.1	6.4
7	3.6	3.8	4	4.2	4.7	4.8	5.2	5.6	5.7	5.8	5.82	5.2	5.5	5.74
14	2.17	2.5	2.8	3.1	3.58	3.62	4.08	4.53	4.76	4.93	5.16	4.33	4.7	4.85
21	0.15	0.5	0.85	1.1	1.6	1.6	2.09	2.59	2.92	3.13	3.46	2.31	2.72	2.92

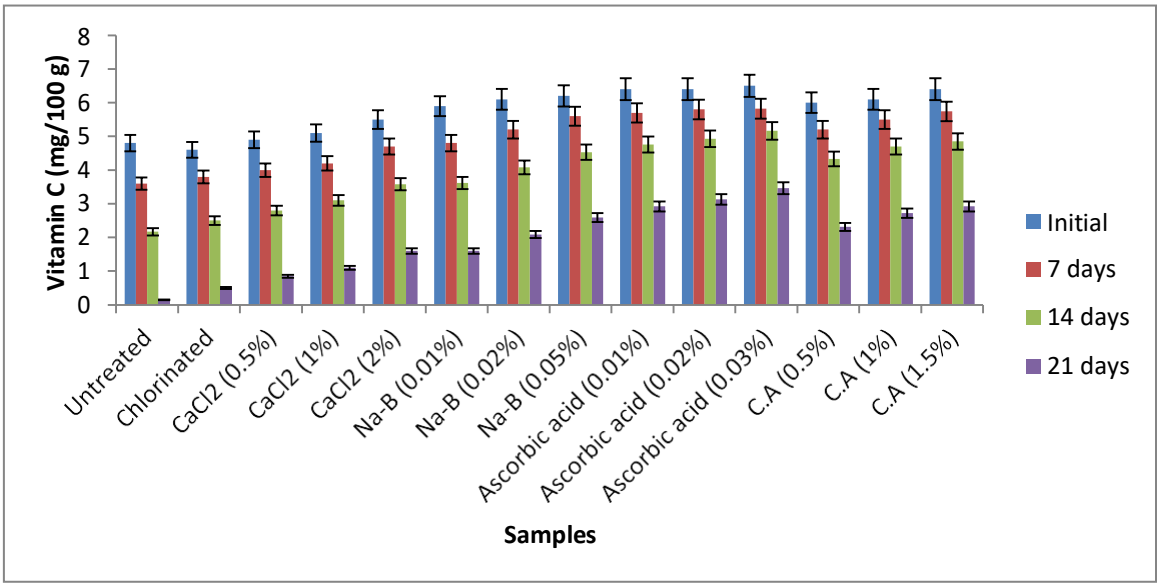


Fig 5.3: ***Vitamin C content of fresh cut jackfruit during storage***

5.3.1.4 Total carotenoid of jackfruit bulb during storage:

Carotenoids are potential antioxidant but they are very susceptible to oxidative degradation. Study revealed from table 5.5 and fig 5.4 that pretreated samples contain higher amount of carotenoid than untreated sample. Pretreatment with ascorbic acid could minimize the carotenoid loss by preventing carotenoid oxidation[26], which was followed by pretreated sample with calcium chloride ($CaCl_{2)}$. That might be due to their role as radical scavenger and reducing agent in prevention of browning[27].Pretreated with ascorbic acid contain 1.28 mg/100g carotenoid at the initial stage and 0.85 mg/100 g after 21 days of storage.

Table 5.5: Carotenoid content of fresh cut jackfruit during storage

Days	Carotenoid content (mg/100 g)													
	Untreated	Chlorinated (30 ppm)	$CaCl_2$ (0.5%)	$CaCl_2$ (1%)	$CaCl_2$ (2%)	Na-B (0.01%)	Na-B (0.02%)	Na-B (0.05%)	Ascorbic acid (0.01%)	Ascorbic acid (0.02%)	Ascorbic acid (0.03%)	C.A (0.5)	C.A (1%)	C.A (1.5%)
0	0.852	0.568	0.598	0.856	1.136	0.56	1.1	1.16	0.744	1.2	1.28	0.824	1.11	1.2
7	0.6	0.48	0.52	0.79	1	0.49	0.69	0.9	0.67	0.74	1.19	0.69	0.712	0.94
14	0.3	0.376	0.41	0.7	0.89	0.36	0.57	0.71	0.592	0.62	1	0.56	0.51	0.713
21	0.15	0.24	0.3	0.56	0.72	0.24	0.39	0.48	0.49	0.51	0.85	0.38	0.413	0.5

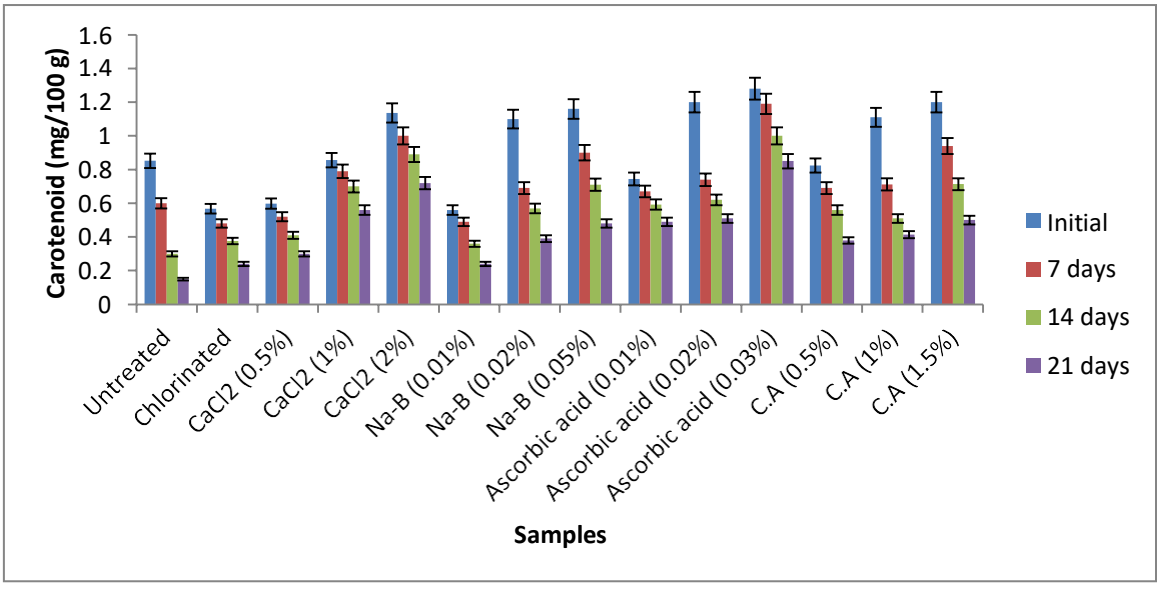


Fig 5.4: ***Carotenoid content of fresh cut jackfruit during storage***

5.3.1.5 Sensory test:

Sensory test of pre cut jackfruit bulbs showed better responses by the panellists for pretreated samples than untreated samples. The sensory parameters of control decrease significantly after 7 days of storage which was detected by browning, off flavour. Samples with ascorbic acid and $cacl_2$ retained better quality of colour, taste and aroma. Panellist decided most important attributes were colour, aroma, and taste for shelf life.

Table 5.6 Sensory analysis of Pre cut jackfruit bulb during storage

Months	Sensory	Untreated	Chlorinated	$CaCl_2$ (0.5%)	$CaCl_2$ (1%)	$CaCl_2$ (2%)	Na-B (0.01%)	Na-B (0.02%)	Na-B (0.05%)	Ascorbic acid (0.01%)	Ascorbic acid (0.02%)	Ascorbic acid (0.03%)	C.A (0.5)	C.A (1%)	C.A (1.5%)
0	Colour	8.7	7.82	7.3	7.64	8.5	8.02	8.2	8.32	8.24	8.47	8.63	8	8.01	8.43
	Taste	7.9	7.88	8.47	8.6	8.77	8.09	8.34	8.56	8.87	9.16	9.24	8.23	8.45	8.61
	Aroma	8.2	7.1	7.53	7.6	7.94	7.21	7.5	7.91	8.33	8.45	8.9	8.03	8.16	8.6
1	Colour	6.46	7.11	6.92	7.3	8	7.12	7.41	8	7.4	7.76	8.4	7	7.16	7.82
	Taste	4.8	6.33	7	7.14	7.78	6.14	6.32	7.23	7.13	7.2	8.2	6.4	7.05	7.54
	Aroma	4	5.77	6.21	6.83	7.5	6.11	6.3	7.2	6.55	7.4	7.8	6.18	6.7	7.32
2	Colour	3.71	5.46	5.97	6.85	7.73	6	6.3	7.06	6.34	6.72	7.8	5.87	6.5	6.88
	Taste	2.67	4.21	5.8	6.22	6.84	4.6	5.43	6.2	6	7.16	7.5	4.77	5.8	6.4
	Aroma	2.2	4.05	4.83	5.5	6.43	4.17	5.08	6.1	5.2	5.8	6.5	4.7	5.3	6.22
3	Colour	3	4.03	4.89	6.6	7.08	4.23	4.54	5.7	6	6.58	7.13	4.65	4.8	5.96
	Taste	1	3.4	5.5	5.98	6.67	3.7	3.8	4.5	5.8	6.46	6.95	4.6	4.9	4.98
	Aroma	1.4	2.9	3.47	3.89	6.04	3.16	3.67	5.5	4	4.5	6.21	3.4	4.3	5.9

5.3.2 Development and storage study of jackfruit jam

Jams of varying composition were prepared and stored. It was observed that nutritional component degraded during jam making but the degradation rate was low during storage.

5.3.2.1 Total soluble content

The results are shown in table 5.7 and fig 5.5. According to Bureau of Indian Standards (BIS) and Prevention of Food Adulteration (PFA, 2004)[28] specifications, jam should contain minimum 45% of pulp and 68.5% total soluble solids (TSS). Whereas, the Codex Alimentarius Commission, state that the finished jam should contain more than 65% TSS. Above 70^0 Brix the jam becomes crystallized.

Table 5.7: Total soluble solid content of jackfruit jam during storage

Time in Months	TSS^0B						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
0	68±0.11	68.1±0.14	68±0.34	68.2±0.21	68±0.13	68±0.53	68±0.5
2	68±0.2	68.75±0.3	68±0.2	68.2±0.3	68.2±0.32	68±0.45	68±0.23
4	68.25±0.34	69±0.16	68.2±0.3	68.4±0.4	68.5±0.3	68.4±0.6	69.2±0.9
6	68.5±0.1	69.5±0.1	68.25±0.12	68. 5±0.5	68.5±0.2	69±0.1	70.5±1.2

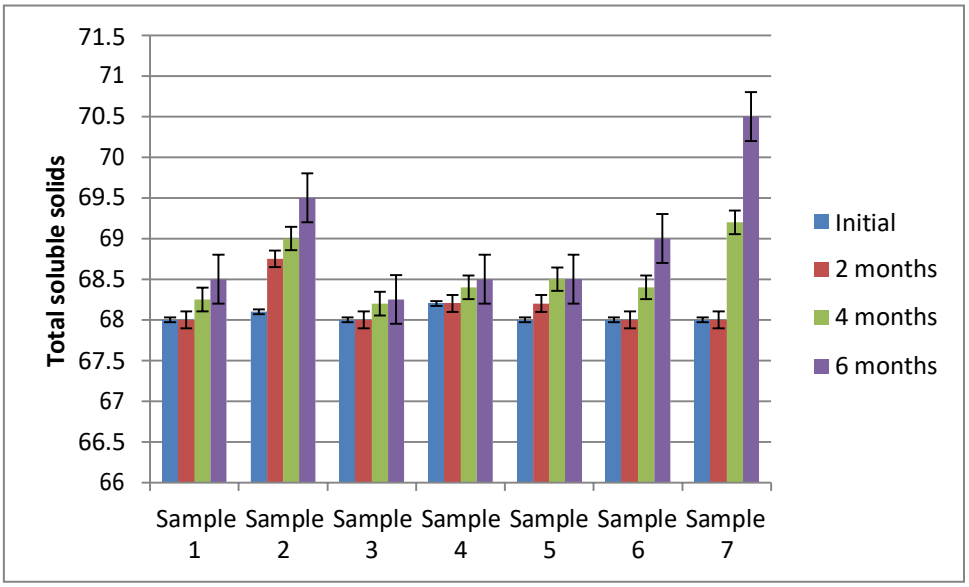


Fig 5.5: ***Total soluble solid content of jackfruit jams during storage***

5.3.2.2 Vitamin C content

Vitamin C is very unstable compound easily degraded at unfavourable condition[29]. At high temperature vitamin C oxidized. It was obtained from the results that the loss of vitamin C was higher at the initial stage may be the result of higher temperature employed for jam preparation but very minimum amount reduced during storage study. At the initial stage amount of vitamin C was maximum in sample 5 (0.06mg/g) which was followed by sample 4. After 6 months of storage maximum vitamin C retained by sample 4.

Table 5.8: Vitamin C content of jackfruit jams during storage

Time in Months	Vitamin C (mg/g)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
0	0.046±0.36	0.048±0.32	0.043±0.11	0.05±0.45	0.06±0.12	0.0594±0.23	0.0466±0.4
2	0.041±0.40	0.043±0.45	0.039±0.27	0.046±0.36	0.056±0.34	0.048±0.33	0.039±0.3
4	0.033±0.53	0.037±0.28	0.032±0.33	0.04±0.23	0.04±0.2	0.036±0.35	0.032±0.23
6	0.021±0.42	0.029±0.34	0.023±0.08	0.033±0.45	0.03±0.23	0.02±0.16	0.029±0.45

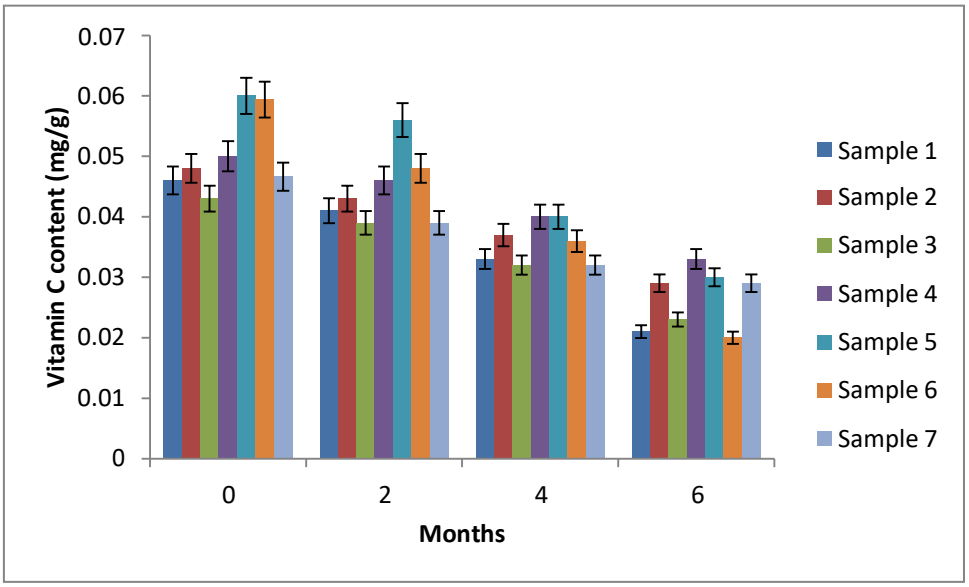


Fig 5.6 :*Vitamin C content of jackfruit jams during storage*

5.3.2.3 Total carotenoid

Carotenoid is highly susceptible to degradation at high temperature[30]. From table 5.9 and fig 5.7 it was observed that carotenoid decreased significantly for all samples. Among them sample 4 contain maximum amount of carotenoid at initial stage 0.264mg/100g and 0.126 mg/ 100 g after 6 months of storage.

Table 5.9 Carotenoid content of jackfruit jams during storage

Time in Months	Carotenoid (mg/100g)						
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
0	0.108±0.02	0.152±0.4	0.08±0.2	0.264±0.31	0.08±0.13	0.248±0.5	0.104±0.2
2	0.088±0.3	0.122±0.32	0.06±0.33	0.23±0.2	0.064±0.3	0.196±0.007	0.088±0.5
4	0.06±0.3	0.097±0.4	0.035±0.05	0.189±0.05	0.04±0.03	0.12±0.01	0.063±0.03
6	0.042±0.06	0.048±0.06	0.024±0.6	0.126±0.12	0.031±0.4	0.096±0.02	0.0483±0.16

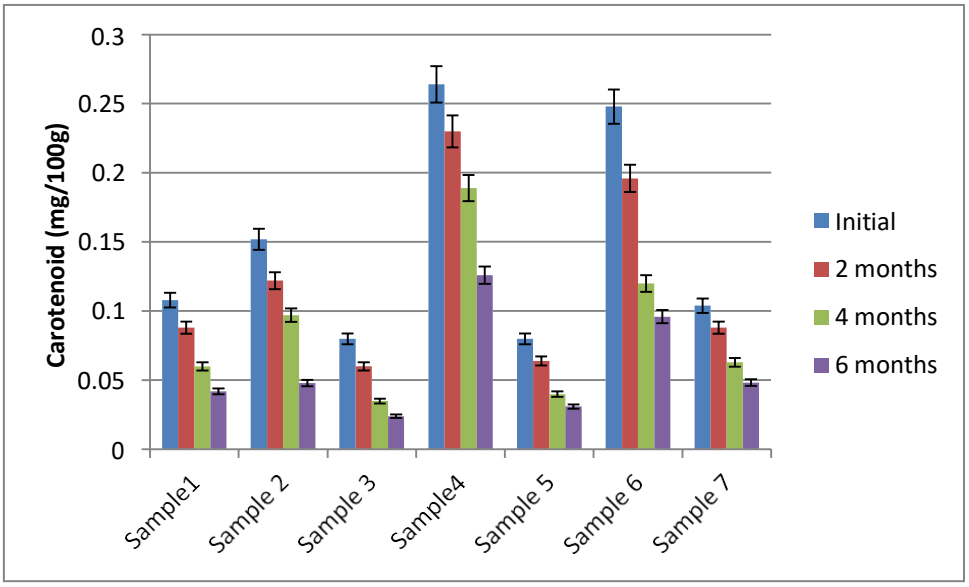


Fig 5.7 ***Carotenoid content of jackfruit jams during storage***

5.3.2.4 Sensory test

Table 5.10 showed the sensory score of all samples. The score were analysed in terms of colour, spreadability, taste, aroma and overall acceptability. Results showed that panellist score highest for sample 4 in all aspect.

Table 5.10 Sensory analysis of jackfruit jams during storage

Sensory test		Sample1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7
Initial	Colour	7.8	7.5	7.1	8.76	8.55	8.6	8.52
	Spreadability	7.5	4.7	8.2	9.6	7.5	8.16	8.1
	Taste	7.56	7.5	6.8	8.96	6.3	4.8	9.2
	Aroma	8.3	8.32	6.79	8.75	7	5.77	8.2
	Overall Acceptability	7.6	6.5	7.4	9.3	6.9	6.86	8.5
3 months	Colour	6.8	7.2	6.3	8.5	7.88	6.9	7.4
	Spreadability	7.2	4.1	3.8	9.47	8.12	4.5	4
	Taste	7.3	6.72	6.5	8.8	5.2	4.67	8.06
	Aroma	7.98	8.2	5.88	8.76	6.1	5.6	8.11
	Overall Acceptability	6.54	6.3	5.1	9.18	6.1	5.93	7.14
6 months	Colour	6.12	7.4	5.5	8.32	6.4	6.8	7.2
	Spreadability	7.1	4	3.45	9.2	7.6	7.3	3.2
	Taste	7.16	6.5	5.54	8.6	5.1	5	7.9
	Aroma	7.3	7.42	5.5	7.95	5.1	5.5	7
	Overall Acceptability	6.5	6	4.8	9.11	6	5.2	6.2

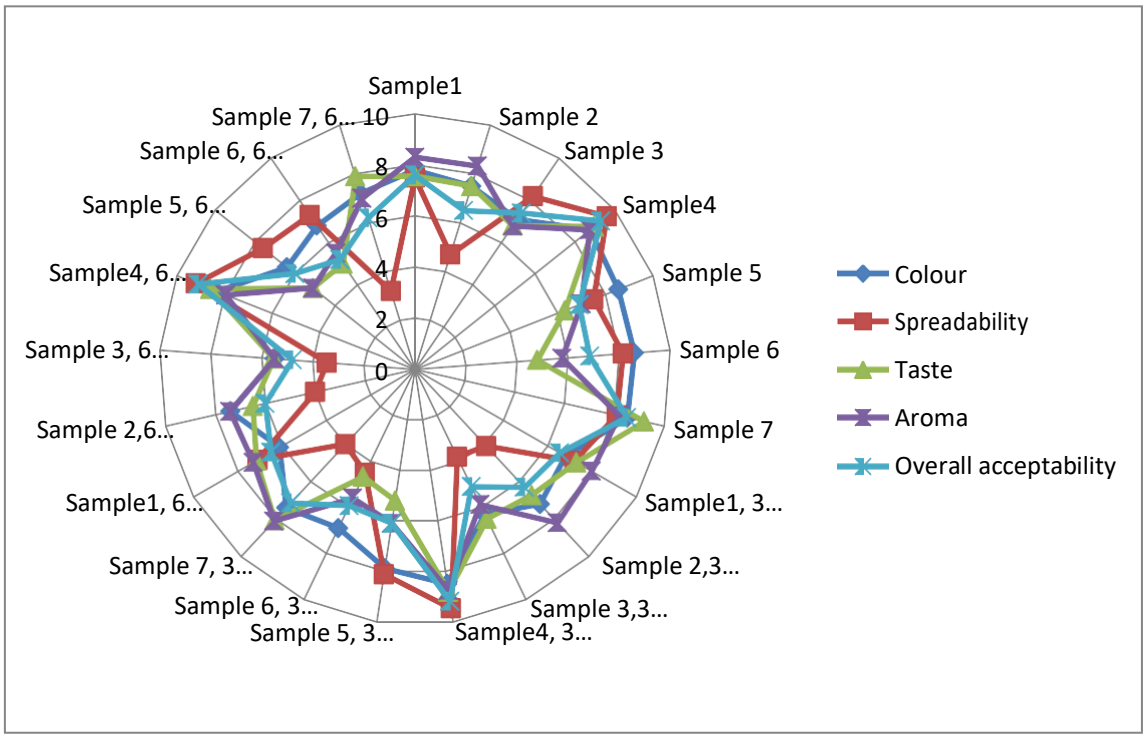


Fig 5.8 ***Sensory analysis of jackfruit jams during storage***

Good jam should have a soft uniformity without any individual part of pulp. Product quality is the most important for customer choice. The amount of additives affect the jam quality in terms both sensory and nutritional components. The colour, texture, aroma, spreadability and overall acceptability and retention of nutrient were higher in sample 4 comapred with other samples.

5.3.3 Dehydration of sliced jackfruit bulb

The effect of pretreatment on dehydrated jackfruit bulbs and its storage on moisture content, total phenol content, antioxidant and carotenoids were studied at 50^0 C temperature.

5.3.3.1 Moisture content of dehydrated sliced jackfruit bulbs:

Final moisture content of dehydrated jackfruit slices in different condition varies from 9.2 to 8% (dry basis). Table 5.11 represent the effect of pretreatment on time taken to reach the desired moisture content. Moisture content shows a non linear relationship with drying time[41].Amount of moisture content decreases with increasing drying time. The drying rate

decreased continuously with increasing drying period. The moisture ratio decreased exponentially with increasing drying time[31].

It is clear from table 5.11 and 5.9 that the constant rate period was absent and the drying process of jackfruit slices took place in falling rate period. It was observed from table 5.11 and figure 5.9 that pretreatments effect drying time. Among all samples pretreated samples took less time for drying than untreated samples[32]. It might be the action of pretreatment which increased the mass transfer[33].

Table 5.11: Moisture content of pre-treated and untreated jackfruit bulb slices

Time (min)	Moisture Content (% d.b)							
	Control	Blanched	Amla juice, 5min (1:1) (conc of Vitamin C 47%)	Amla juice, 10 min (1:1) (conc of Vitamin C 47%)	Amla juice, 15 min (1:1) (conc of Vitamin C 47%)	Ascorbic acid, 5 min (conc 47%)	Ascorbic acid, 10 min (conc 47%)	Ascorbic acid, 15 min (conc 47%)
0	264	265	265.4	265.7	266	265	265.5	266
30	242	227	227.2	226.7	227	227	225.5	225
60	195	164.6	164	163	162	162.8	160	156.6
90	160	111	111.4	110	108.7	110	106	102.4
120	115	77.2	77.7	75.8	73.8	76	71.5	67
150	95	58.7	59.4	56	54	57.2	52	47.7
180	78	36	36	34	34	42	33	27
210	62.6	33	31	28	25.5	31.9	24.8	20
240	52	30	28	25	22	29	22	17
270	47.5	27	25	21	19	25	18.2	14
300	44	24	23	19	15	23.5	16	11
330	41	22	19	15	12	20	12	10
360	35.5	20.3	16.5	13	10	17	10	9
390	30.2	15	12.3	10	8.3	13.9	9	8
420	25.4	10.3	10	8.7	-	9.4	8.5	-
450	21	8.93	8.8	-	-	8.76	-	-
480	15	-	-	-	-	-	-	-
510	12	-	-	-	-	-	-	-
540	10							
570	9.2	-	-	-	-	-	-	-

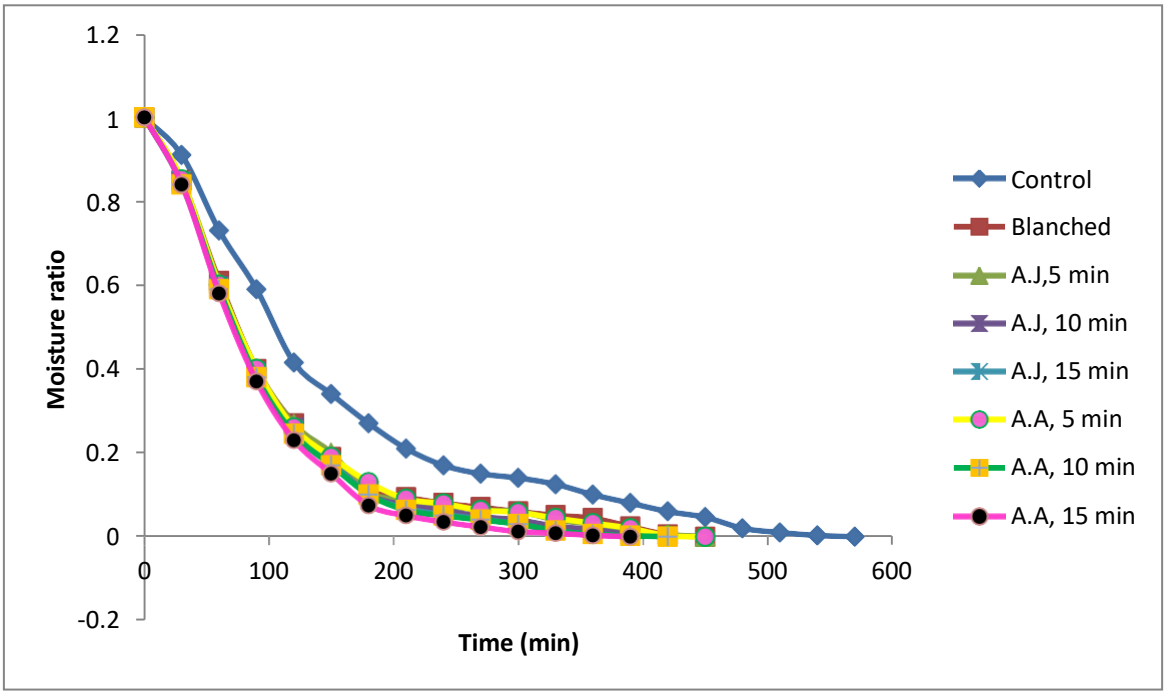


Fig 5.9: ***Moisture content of pre-treated and untreated samples dehydrated at 50° C***

Two mathematical models for thin layer drying were selected to investigate the drying characteristics of sliced jackfruit. Among two models it was observed from table 5.11 that Page model gave highest R^2 (0.999-0.992) and lowest chi-square (χ^2) value (0.000117-0.000756).

Table 5.12 Estimated values of parameters for two models at 50ºC

Temperature	Sample	Model					
		Newton			Page		
		R^2	Chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE
50ºC	Control	**0.988**	0.001118	0.032589	**0.992**	0.000756	0.026081
	Blanched	**0.985**	0.001506	0.037569	**0.993**	0.000749	0.025594
	Amla juice, 5min	**0.985**	0.001486	0.03733	**0.995**	0.00058	0.022524
	Amla juice, 10 min	**0.983**	0.001747	0.040382	**0.997**	0.000337	0.017083
	Amla juice, 15 min	**0.981**	0.00205	0.043629	**0.998**	0.000261	0.014955
	Ascorbic acid, 5 min	0.986	0.001383	0.036007	**0.994**	0.000615	0.02319
	Ascorbic acid, 10 min	**0.983**	0.001772	0.040663	**0.998**	0.000217	0.013723
	Ascorbic acid, 15 min	**0.978**	0.002401	0.047215	**0.999**	0.000117	0.009998

Hence to understand the accuracy of the Page model the predicted MR value plotted with experimental MR value in fig 5.10-5.17. The result showed that Page model can be used to predict the drying behaviour of dehydrated slice jackfruit as both MR were well fitted in the graphs.

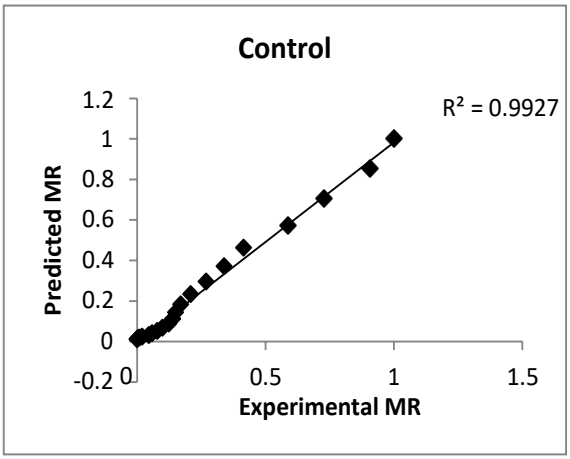


Fig.5.10

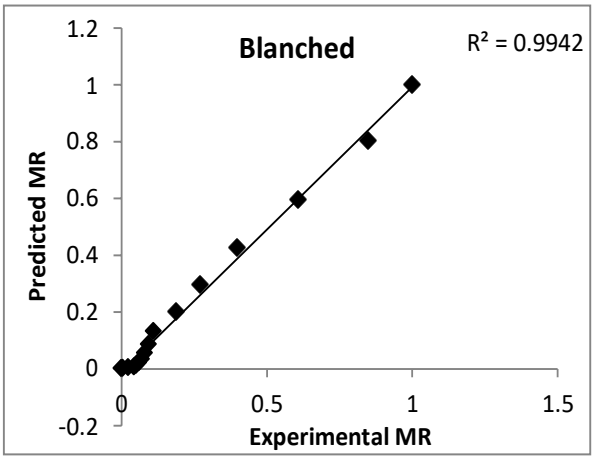


Fig. 5.11

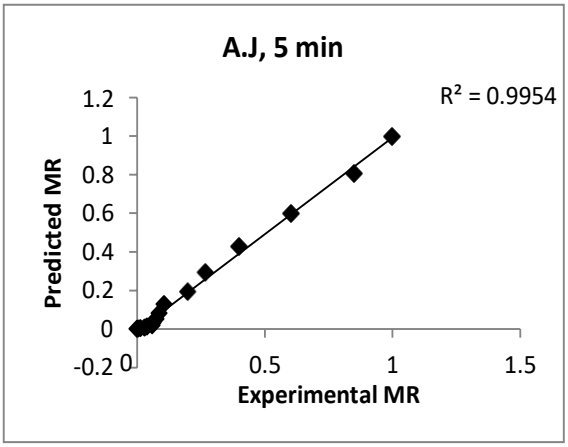


Fig. 5.12

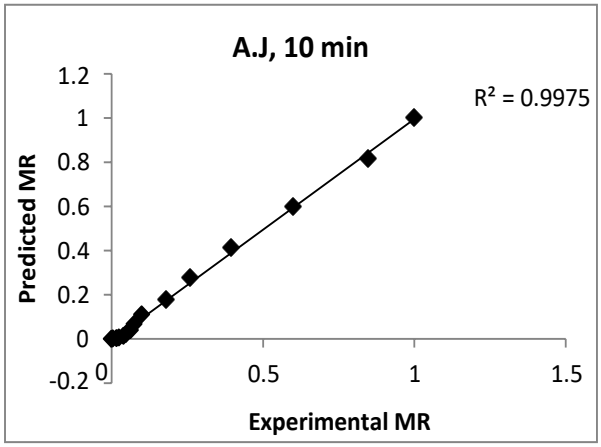


Fig. 5.13

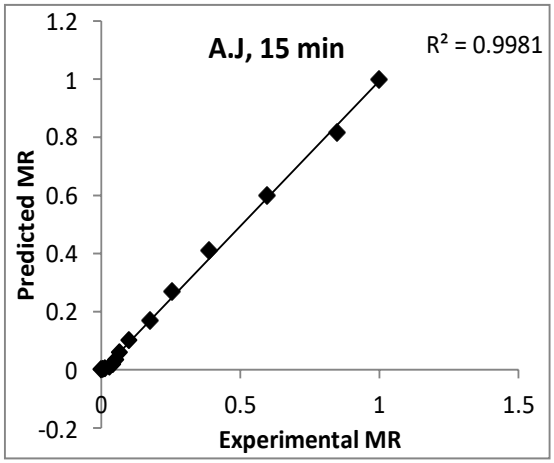


Fig. 5.14

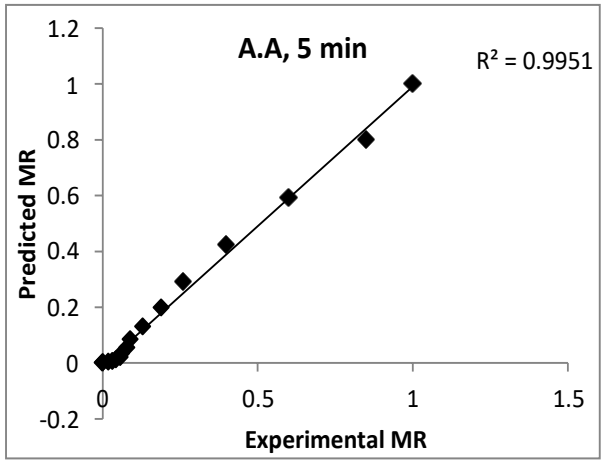


Fig. 5.15

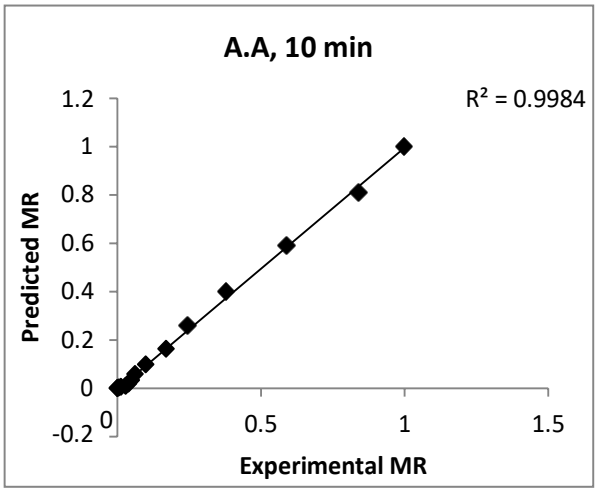


Fig. 5.16

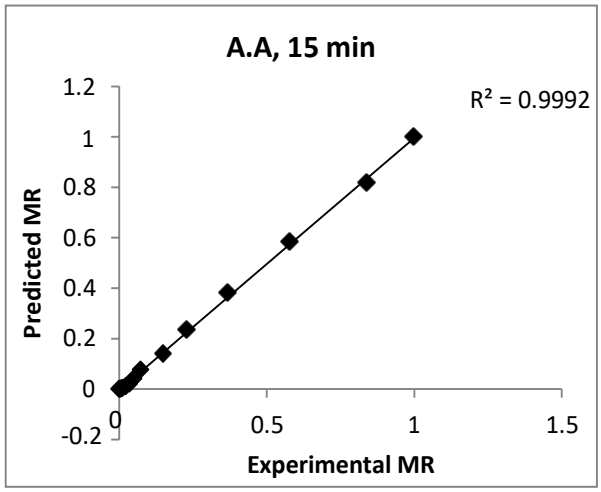


Fig. 5.17

Fig 5.10 – 5.17. ***Predicted MR versus Experimental MR by Page model at 50ºC***

5.3.3.2 Total phenol content of dehydrated bulbs:

Table 5.13 and figure 5.10 shows the effect of pretreatment and temperature on phenolic content. Total phenol content degraded during drying for untreated and pretreated samples. According to some previous work phenolic content degraded during drying[34]. The decrease in total phenol content in dried samples may be result of binding of polyphenols with other compounds[35] or the action of polyphenol oxidase enzyme. Untreated sample contain lower amount of phenolic compound where pretreatement shows positive effect on dried samples for retention of maximum amount of phenolic compound. Among all dried samples pretreated with amla juice for 15 minutes contained maximum amount of phenolic compound (0.47 mg GAE/g) after 4 months of storage which was followed by samples pretreated with ascorbic acid for 10 minutes 0.41 mg GAE/g.

Table 5.13 Total phenol content of pretreated and untreated samples dehydrated at 50^0 C

Time	Total phenol content (mg GAE/g)							
Months	Untreated	Blanched	Amla juice (5 min)	Amla juice (10 min)	Amla juice (15 min)	Ascorbic acid (5 min)	Ascorbic acid (10 min)	Ascorbic acid (15 min)
Initial	0.43±0.03	0.485±0.1	0.55±0.5	0.566±0.04	0.58±0.02	0.517±0.04	0.54±0.02	0.524±0.4
2 month	0.34±0.02	0.419±0.22	0.498±0.07	0.524±0.3	0.543±0.02	0.456±0.32	0.486±0.3	0.469±0.05
4 months	0.238±0.03	0.33±0.4	0.407±0.2	0.43±0.2	0.47±0.3	0.37±0.01	0.41±0.07	0.39±0.02

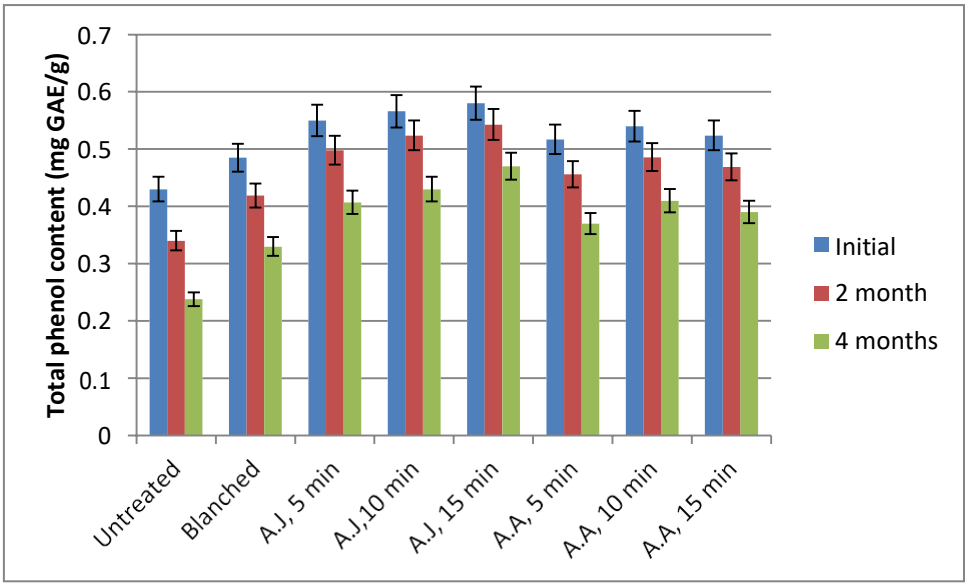


Fig: 5.10: ***Total phenol content of pretreated and untreated samples***

5.3.3.3 Antioxidant content of dehydrated bulbs

Antioxidant activity in fruits is due to the presence of polyphenol, carotenoid compounds, which interact with free radicals and terminate the chain reaction[36]. In this study the antioxidant content decreased during dehydration[37] for all samples. Heat treatment can affect the phytochemicals as well as antioxidant content by thermal breakdown that affect the uniformity of the cell structure which causes migration of components[38]. Samples pretreated

with amla juice for 15 minutes shows maximum amount of antioxidant (0.38 mM $FeSO_4$/g) at the initial stage and also after 4 months of storage 0.32 mM $FeSO_4$/g.

Table 5.14
Antioxidant content of pretreated and untreated samples dehydrated at 50^0 C

Time	Antioxidant content (mM $FeSO_4$/g)							
Months	Untreated	Blanched	Amla juice (5 min)	Amla juice (10 min)	Amla juice (15 min)	Ascorbic acid (5 min)	Ascorbic acid (10 min)	Ascorbic acid (15 min)
Initial	0.24±0.02	0.284±0.03	0.35±0.012	0.361±0.021	0.38±0.022	0.315±0.031	0.358±0.04	0.326±0.031
2 month	0.169±0.3	0.23±0.02	0.308±0.032	0.317±0.032	0.346±0.02	0.28±0.03	0.32±0.041	0.289±0.05
4 months	0.08±0.012	0.152±0.032	0.25±0.03	0.27±0.012	0.32±0.021	0.21±0.023	0.266±0.04	0.225±0.045

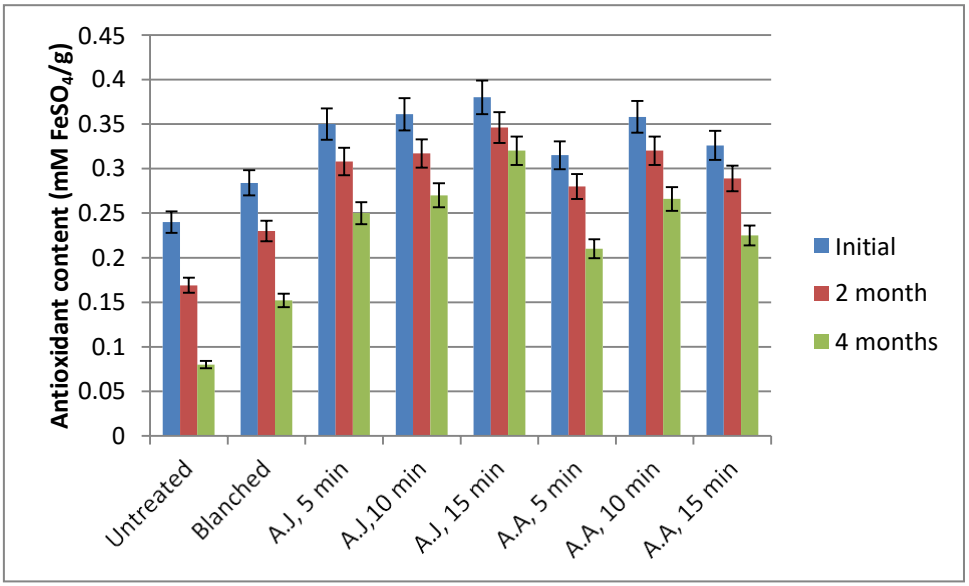


Fig 5.11 Antioxidant content of pretreated and untreated samples

5.3.3.4 Carotenoid content of dehydrated bulbs

Carotenoids are highly susceptible for oxidation reaction, which is accelerated at higher temperature[39]. These compounds are also sensitive to oxygen, and light[40]. During exposure to heat can cause carotenoid isomerisation[40]. As shown in table 5.15 and fig 5.12 carotenoid decreased with heat treatment and during storage. Similar findings were found in previous work[41]. The loss of colour minimised by using additives such as ascorbic acid[42] and blanching have a positive effect on bioactive such as carotenoid retention[43]. The best result was shown by samples pretreated with ascorbic acid for 5 minutes.

Table 5.15 Carotenoid content of pretreated and untreated samples dehydrated at 50^0 C

Time	Carotenoid content (mg/100 g)							
Months	Untreated	Blanched	Amla juice (5 min)	Amla juice (10 min)	Amla juice (15 min)	Ascorbic acid (5 min)	Ascorbic acid (10 min)	Ascorbic acid (15 min)
Initial	0.24±0.021	0.36±0.034	0.45±0.05	0.37±0.032	0.355±0.045	0.53±0.05	0.385±0.034	0.39±0.031
2 month	0.156±0.04	0.304±0.042	0.417±0.04	0.33±0.032	0.338±0.043	0.49±0.031	0.35±0.05	0.358±0.034
4 months	0.05±0.035	0.22±0.041	0.36±0.03	0.27±0.023	0.286±0.041	0.41±0.034	0.294±0.042	0.296±0.042

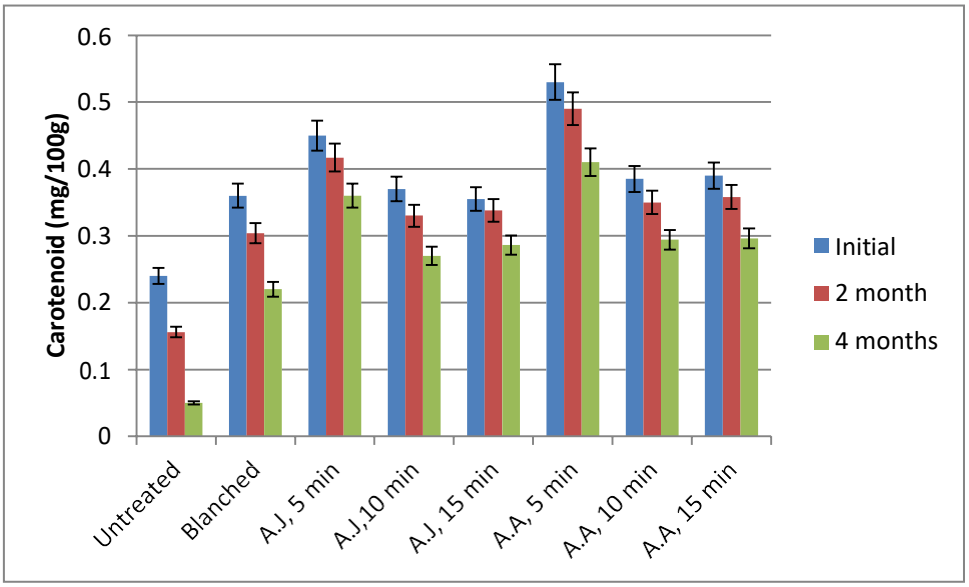


Fig 5.12 ***Carotenoid content of pretreated and untreated samples***

5.3.3.5 Sensory analysis of dehydrated bulbs

Sensory properties are very important factors for acceptability of dehydrated products by the consumer. In addition to colour, texture, flavour and overall acceptability are critical in determining their degree of acceptance. From table 5.16 and fig 5.13 it was observed that pretreated samples were better than untreated samples. Best colour and texture were obtained by pretreated sample with ascorbic acid. Samples pretreated with amla juice scores best in flavour.

Table 5.16 Sensory analysis of pretreated and untreated samples

	Sensory analysis							
	Untreated	Blanched	Amla juice (5 min)	Amla juice (10 min)	Amla juice (15 min)	Ascorbic acid (5 min)	Ascorbic acid (10 min)	Ascorbic acid (15 min)
Colour	5.76	7.4	6.7	6.55	6.3	7.85	7.9	8.76
Texture	5.64	6.88	7.38	7.4	7.8	7.63	8.04	8.1
Flavour	6.2	6.6	7.2	7.45	8	7.11	7.18	7.6
Overall acceptability	5.8	7.4	7.34	7.3	7.05	8.3	8.32	8.54

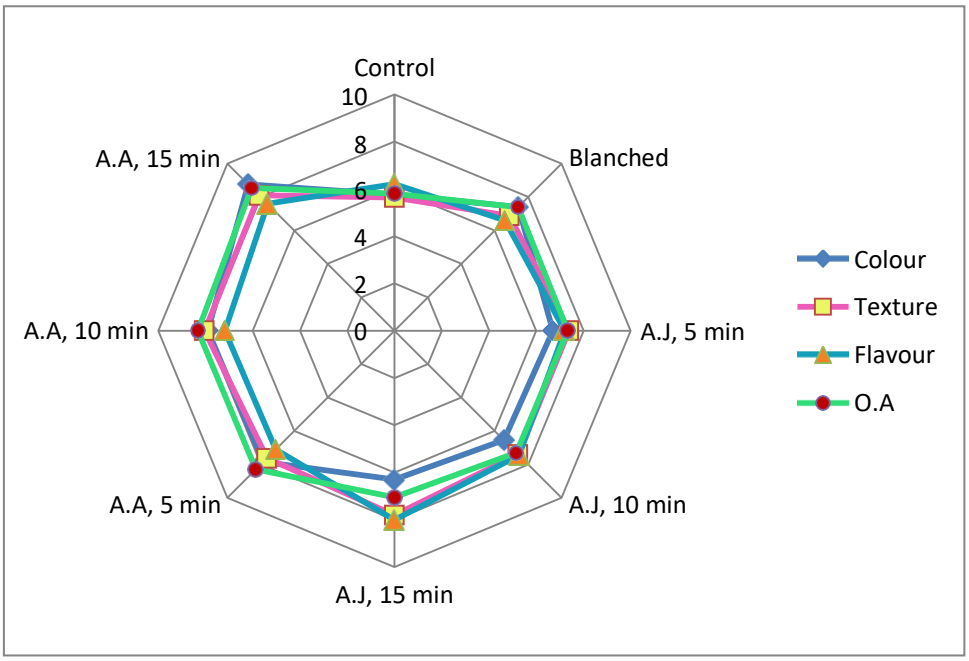


Fig 5.13 ***Sensory analysis of pretreated and untreated samples***

5.4 Conclusion

5.4.1 Minimal processing of bulbs

Pretreatment showed positive effect in pre cut fresh jackfruit during storage. Pretreatment can act as antirespiratory agents that minimize loss of nutrients such as vitamin C, polyphenols, and antioxidant, carotenoid. Among all pretreatments addition of ascorbic acid showed better results than others. Such assessment of polychemical status in processed foods, i.e., minimally-processed product, can help the modern health-conscious consumer.

5.4.2 For the processed product jam

It can be concluded from the results that jackfruit jam retained maximum amount of nutrients after storage. The developed jackfruit jam has shown to be accepted by panellist. Moreover, jackfruit jam showed high score of sensory attributes. It can be stored as value added product.

5.4.3 For the dehydrated bulbs

Dried jackfruit is commercially manufactured in many countries for production of different type of products such as ice cream, flavoured drink. It was observed that drying rate is much faster in pretreated samples than control sample. Falling rate period was noticed during drying. Among two model Page model was best fitted with experimental values.

The present study shows the effect of pretreatment on drying characteristics of jackfruit and nutritional quality during drying of jackfruit bulbs to obtain quality dehydrated jackfruit. Results revealed that pretreated samples retained maximum amount of nutritional properties. However the pretreated sample with amla juice shows better results but these samples were rejected by the panellists due to its undesirable colour. For this the second best ascorbic acid can be used for pretreatment of jackfruit bulbs.

REFERENCES

1. Rahman M A, Nahar N, Jabbar M A and Mosihuzzaman M (1999) Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions. *Food Chemistry*. **65:** 91–97.

2. Saxena A, Bawa A S, and Raju P S (2009) Optimization of a multitarget preservation technique for jackfruit (Artocarpus heterophyllus L.) bulbs. *Journal of Food Engineering.* **91(1)** 18–28.

3. Biacs P A, Czinkotai B, and Hoschke A (1992). Factors affecting stability of coloured substances in paprika powders. *Journal of Agriculture and Food Chemistry.* **40 :**363–367.

4. Raju P S, and Bawa A S (2006) Food additives in fruit processing. *In Y. H. Hui (Ed.), Handbook of fruits and fruit processing (pp. 145–170). Oxford: Blackwell Publishing.*

5. Soliva-Fortuny R C, Grigelmo M N, Hernando J, Lluch M A, and Martin-Belloso O (2002) Effect of minimal processing on the textural properties of fresh-cut pears. *Journal of Science of Food andAgriculture.* **82:** 1682–1688.

6. Patten M (2001) Basics In: Jams, Preserves and Chutneys. *Handbook (2004 reprint ed.) Grub street books*. (ISBN 1902304721).

7. Prakash S, Jha S K and Data N (2004) Performance evaluation of blanched carrots dried by three different driers. *Journal of Food Engineering*. **62:** 305–313.

8. Alibas I, Akbudak B, and Akbudak N (2005) Microwave drying characteristics of spinach. *Journal of Food Engineering.* **78 (2)** 577–583.

9. Saxena A, Bawa A S, Raju P S (2009) Phytochemical changes in fresh-cut jackfruit (Artocarpus heterophyllus L.) bulbs during modified atmosphere storageFood Chemistry **115**: 1443–1449.

10. Singleton V L & Rossi J A (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am J Enol Viticult*.**16:** 144-153.

11. Benzie I F, Strain J J (1996) The ferric reducing ability of plasma (FRAP) as a measure of antioxidant power: The FRAP assay. *Anal Biochem.* **239:**70-6.

12. Rangana S (1986) *Handbook of analysis and quality control for fruit and vegetable products.*105-106.

13. Suresh K P & Sagar V R (2014) Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions. *J Food Sci Technol* **51(8)** 1540-1546.

14. AOAC. (1990) Official Methods of Analysis. Trends Food Science Technology. Association of Official Analytical Chemists, Washington DC, USA.

15. Mujumdar A S (1995) *Handbook of industrial drying* (second ed. New York): Marcel Dekker.

16. Singh S, Sharma R, Bawa A S and Saxena D C (2008) Drying and rehydration characteristics of water chestnut (*Trapa natans*) as a function of drying air temperature. *J Food Eng.* **87**: 213-221.

17. Goyal R K, Kingsly A R P, Mannikantan M R and Ilyas S M (2007) Mathematical modeling of thin layer drying kinetics of plum in a tunnel dryer. *Journal of food Engineering*. **79**: 176-180.

18. Qing-An Zhang, Yun Song, Xi Wang, Wu-Qi Zhao and Xue-Hui Fan (2016) Mathematical modeling of debittered apricot (*Prunus armeniaca* L.) kernels during thin-layer drying. *CyTA - Journal of Food*. **14(4)** 509-517.

19. Akoy E O M (2014) Experimental characterization and modeling of thin-layer drying of mango slices. *International Food Research Journal.* **21(5)** 1911-1917.

20. Lopez-Malo A, Palou E, Welti J, Corte P and Argaiz A (1994) Shelfstable high moisture papaya minimally processed by combined methods. *Food Research International*. **27:** 543–553.

21. Saxena A, Bawa A S and Raju, P S (2008). Use of modified atmosphere packaging to extend shelf-life of minimally processed jackfruit (Arotocarpus heterophyllus L.) bulbs. *Journal of Food Engineering.* **87(4)** 455–466.

22. Robinson D S (1991) Peroxidases and catalases in foods. In D. S. Robinson, & N. A. M. Eskin (Eds.), Oxidative enzymes in foods (pp. 1–45). *London New York: Elsevier Applied Science.*

23. Oms-Oliu G, Odriozola-Serrano I, Soliva-Fortuny R and Martin-Belloso O (2008) The role of peroxidase on the antioxidant potential of fresh-cut 'Piel de Sapo' melon packaged under different modified atmospheres. *Food Chemistry.* **106:** 1085–1092.

24. Cocci E, Rocculi P, Romani S and Dalla Rosa M (2006) Changes in nutritional properties of minimally processed apples during storage. *Postharvest Biology and Technology.* **39:** 265–271.

25. Lana M M, and Tijskens L M M (2006) Effect of cutting and maturity on antioxidant activity of fresh-cut tomatoes. *Food Chemistry.* **97:** 203–211.

26. Mercadante A Z, and Rodriguez-Amaya D B (1998) Effects of ripening, cultivar differences, and processing on the carotenoid composition of mango. *Journal of Agriculture and Food Chemistry.* **46:** 128–130.

27. Varela P, Salvador A and Fiszman S M (2007) The use of calcium chloride in minimally processed apples: a sensory approach. *European Food Research and Technology*. **224:** 461–467.

28. PFA (2004). The Prevention of Food Adulteration Rules, 1955. A.16.07.287. [http:// www.mohfw.nic.in/pfa%20acts%20and%20rules.pdf].

29. Lee H S and Coate G A (1999) Vitamin C in frozen, fresh, squeezed, unpasteurized, polyethylene bottled orange juice: A storage study. *Food Chemistry.* **65**:165-168.

30. Penicaud C, Achir N, Dhuique-Mayer C, Dornier M and Bohuon P (2011) Degradation of b-carotene during fruit and vegetable processing or storage: reaction mechanisms and kinetic aspects: a review. *Fruits.* **66:** 417–440.

31. Wankhadea P K, Sapkala R S, Dr.V.S.Sapkal V S (2013) Drying Characteristics of Okra slices on drying in Hot Air Dryer. *Procedia Engineering.* **51:** 371 – 374

32. Kingsly R P, Goyal R K, Manikantan M R & Ilyas S M (2007) Effects of pretreatments and drying air temperature on drying behaviour of peach slice. *International Journal of Food Science and Technology*.**42:** 65–69.

33. Dandamrongrak, R., Mason, R. & Young, G. (2003). The effect of pretreatments on the drying rate and quality of dried bananas. *International Journal of Food Science and Technology*, **38:** 877–882.

34. Djendoubi Mrad N, Boudhrioua N, Kechaou N, Courtois F, Bonazzi C (2012) Influence of air drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. *Food Bioprod Process*. **90:**433–441.

35. Mrad ND, Boudhrioua N, Kechaou N, Courtois F, Bonazzi C (2012) Influence of air drying temperature on kinetics, physicochemical properties, total phenolic content and ascorbic acid of pears. *Food Bioprod Proc.* **90:** 433-441.

36. Wang, S., Melnyk, J.P., Tsao, R. & Marcone, M.F. (2011). How natural dietary antioxidants in fruits, vegetables and legumes promote vascular health. Food Research International, **44:**14–22.

37. Piga, A., Del Caro, A. & Corda, G. (2003). From plums to prunes:influence of drying parameters on polyphenols and antioxidant activity. *Journal of Agricultural and Food Chemistry.* **51:**3675–3681

38. Davey MW, Van-Montagu M, Inze D, Sanmartin M, Kanellis A, et al. (2002) Plant L-ascorbic acid: Chemistry, function, metabolism, bioavailability and effects of processing. *J Sci Food Agric* **80:** 825-860.

39. Saxena A & Maity T and Raju P S and Bawa A S, (2012) Degradation Kinetics of Colour and Total Carotenoids in Jackfruit (Artocarpus heterophyllus) Bulb Slices During Hot Air Drying . *Food Bioprocess Technol* **5:**672–679

40. A. Rawson, A. Patras, B.K. Tiwari, F. Noci, T. Koutchma, N. Brunton (2011) Effect of thermal and non thermal processing technologies on the bioactive content of exotic fruits and their products: Review of recent advances. *Food Research International* **44:** 1875–1887

41. Zepka, L. Q., & Mercadante, A. Z. (2009). Degradation compounds of carotenoids formed during heating of a simulated cashew apple juice. Food Chemistry. **117:**28−34.

42. Y.B. Che Man, J. Irwandi, S. Yusof, J. Selamat, H. Sugisawa. (1997). Effect of different dryers and drying conditions on acceptability and physicochemical characteristics of durian leather. *J Food Process Pres* **21(5):** 425–441.

43. Skrede, G., Wrolstad, R. E., & Durst, R. W. (2000). Changes in anthocyanins and polyphenolics during juice processing of highbush blueberries (*Vaccinium corymbosum* L.). *Journal of Food Science*. **65:** 357−364.

SUMMARY

The present entitled “Studies on Optimization of Processing and Storage Conditions of Some Underutilized Fruits for Better Retention of Nutritional Quality” was undertaken as research attempt to explore new value added products, improvement of known product and increase shelf life of some underutilized fruit such as amla, bael and jackfruit.

The effect of temperature and pre-treatments on thin layer drying of amla in hot air dryer was investigated. Increase in drying temperature from 50 to 70 °C decreased the drying time for all the samples considered. The moisture content decreased from 433% (dry basis) to 6.9% (dry basis).The pretreated samples dried faster than the untreated samples. Samples pretreated with steam blanching with 0.5% sodium benzoate had shorter drying times (hence higher drying rates) compared to steam blanched, water blanched and control samples The entire drying process occurred in falling rate period. The drying characteristics follow the page model. Best colour, taste and overall acceptability were obtained with steam blanched with 0.5% sodium benzoate. In steam blanched with 0.5% sodium benzoate after 6 months storage loss of vitamin C is 18.74% where untreated have 62.9 % loss.

The highest amount of vitamin C (2.5 mg/g), naringin (1.9 mg/g) and total phenol content (37.5 mg GAE/g) was present in osmodehydrated water blanching prior pricking sample at 60°B. Water blanching prior pricking showed best colour, pricking prior water blanching and water blanching prior pricking were best for aroma, taste and overall acceptability. After 6 months storage vitamin C retained 1mg/g, naringin 1.25mg/g and total phenol content 31.25mg GAE/g by water blanching prior pricking sample followed by pricking prior water blanching sample.

Response surface methodology was effective in optimizing process parameters for osmotic dehydration of aonla slices in osmotic solution of sugar having concentration in the range of

45 to 65^{0}B sugar, temperature 30 to 50^{0}C, solution to fruit ratio 5:1 to 15:1 and immersion time 2 to 6 hours. Optimum osmodrying condition obtained was 54.25^{0}B sugar solution concentration, 50^{0}C osmotic solution temperature, 15:1 fruit:solution ratio and 2 hour of immersion time to get maximum possible vitamin C (8.34 mg/g), overall acceptability (88.3%) and total phenol (35.67 mg GAE/g).

Physical characteristic of bael observed Juice yield 20%, TSS 32^{0}B, 66 % moisture, 35.08 mg GAE/g total phenol content, ascorbic acid 5.254 mg/100g and carotenoid 12.15 µg/g. moisture content decreases with increasing time and temperature. Moisture level decreases from 194.12 to 6.2 (dry basis). Decrease of moisture ratio was faster with increasing temperature Results showed that pretreatment having positive effect on moisture ratio. The drying characteristics follow the two term model. Pretreated with 1% KMS showed the best result. Pretreated with 1% KMS sample showed maximum amount of vitamin C (1.21 mg/100 g), total phenol content (24.33 mg GAE/g), antioxidant (18.89 mM $FeSO_4$/g) at 60°C and carotenoid at 50^{0}C (6.61µg/g) after 3 months of storage followed by steam blanched sample. Best sensory score also observed by sample pretreated with 1% KMS.

Concentration of total phenolic content and antioxidant content of bael juice decreased with increasing temperature and time. Degradation kinetics was best fitted by first order reaction kinetic model for both phenolic compound and antioxidants. The retention of phenolic compound and antioxidants of bael juice treated at 55°C for 90 min was more than 61 and 68%, respectively as that of fresh bael juice.

In this experiment, Bael and Amla mixed juice was prepared considering the nutritional and healthy character of both the fruits. Both juices were blended in 90:10 ratio (Bael: Amla). Total phenol content degraded with time and temperature. In 70°C after 60 min thermal treatment retention of total phenol content is highest in amla juice (8.66 mg GAE/ml) whereas bael juice retain minimum amount of total phenol (5.38mg GAE/ml) but bael- amla mixed juice showed positive result (6.2 mg GAE/ml) which was better than bael juice. Degradation of total phenol content follow first order model for all samples. The Ea value of

amla juice 47.71(KJ mol^{-1}), bael juice 17.28(KJ mol^{-1}) and bael-amla mixed juice had 20.85(KJ mol^{-1}). During storage the vitamin C degradation was high in bael juice. After 6 months storage contained only 5.15 mg/100ml whereas bael-amla juice contain (52.73mg/100 ml). Total phenol content also higher in beal – amla juice (6.98 mg GAE/ml) which was higher than bael juice (5.35 mg GAE/ml) after 6 months of storage. Bael –amla mixed juice score better in sensory test than other two juices in all aspect.

Physical characteristic of jackfruit bulb contained TSS 22^0B, 72 % moisture, 0.75 mg GAE/g total phenol content, ascorbic acid 8.32 mg/100g and carotenoid 1.336 mg/g. Pretreatment showed positive effect in pre cut fresh jackfruit during storage. Maximum amount of total phenol content (0.557mg GAE/g), antioxidant content (0.413 mM $FeSO_4$/g), vitamin C (3.46mg/100g) and carotenoid (0.85mg/100g) retained by sample pretreated with 0.03% ascorbic acid after 21days of storage. . Samples pretreated with ascorbic acid and $cacl_2$ retained better quality of colour, taste and aroma.

In our study initial TSS of all types of jackfruit jam was almost 68°B. After 6 months storage maximum TSS observed in sample 7 [pulp and sugar ratio (45:55), pectin (1% of sugar) and citric acid (1% of sugar)] 70.5°B. At the initial stage maximum amount of vitamin C (0.06mg/g) was present in sample 5 [pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (2% of sugar)] which was followed by Sample 4 [pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (0.5% of sugar)]. After 6 months of storage maximum vitamin C (0.033mg/g) retained by sample 4. Carotenoid degraded during storage 0.264mg/100g to 0.126 mg/100g in sample 4 which was the highest value among all type of samples. Sample 4 score highest in all aspect of sensory test

During drying removal of moisture was highest (8%, dry basis) in jackfruit sliced pretreated with 47% ascorbic acid for 15 min. The moisture ratio decreased exponentially with increasing drying time. Among two mathematical model page model best describe the drying behavior. Among all dried samples pretreated with amla juice for 15 minutes (conc of Vitamin C 47%) contained maximum amount of phenolic compound (0.47 mg GAE/g) antioxidant content (0.38 mM $FeSO_4$/g) after 4 months of storage which was followed by sample pretreated with ascorbic acid (0.47%). The best amount of carotenoid (0.41mg/100g)

was shown by samples pretreated with ascorbic acid (0.47%) for 5 minutes. Best colour and texture were obtained by pretreated sample with ascorbic acid. Samples pretreated with amla juice scores best in flavour.

CONCLUSION

Thin layer drying of amla slices happened in the falling rate period that indicates that moisture elimination from the product was governed by way of inner diffusion phenomenon. All the treatments significantly improve the retention of ascorbic acid and phenol content among them sample treated with sodium benzoate followed by steam blanching showed best result and can store up to 6 months.

From the effect of pretreatment on osmodried whole amla it may be concluded that amla can preserve by osmotic dehydration process. Sample pricking after water blanching retained maximum amount of nutrition and can store for 6 months.

Statistical optimization of osmodried amla slices showed better result under following condition 54.25°B sugar solution concentration, 50°C osmotic solution temperature, 15:1 solution: fruit ratio and 2 hour of immersion time.

During thin layer drying, bael pulp treated with 1% KMS showed best result among all pretreated samples and can store upto 3 months.

Study revealed that loss of antioxidant and total phenol content increase with time and temperature of thermal treatment. 55°C temperature retained maximum nutrients than higher temperature.

Amla can use as a valuable ingredient for the production of mixed juice with bael. The mixed juice retained high amount of vitamin C and phenol content after 3 months of storage.

Pretreatment showed synergistic effect in the minimal processing of jackfruit bulbs. Sample treated with ascorbic acid showed best result after 21days of storage.

Jam production from jackfruit pulp showed better result under following condition: - pulp and sugar ratio (50:50), pectin (1% of sugar) and citric acid (0.5% of sugar). This can store for 6 months with good acceptability.

Thin layer drying of jackfruit bulb treated with amla juice and ascorbic acid showed best results up to 4 months.

So it can be concluded that pretreatment have positive effect in processing and preservation of underutilized fruits. The products can store for long periods containing high amounts of nutrients.

Future prospects:

- The fruits used in the present investigation can also be utilized for making other products.

- The future possibilities in this line might lie in mixing fruit to increase nutritional components and to inspire the utilization of underutilized fruit crops.

- Waste products can be utilized such as colour can be extracted from fibres of bael pulp, from residue of jackfruit and flour can be produced from jackfruit seed.

Effect of pretreatment and concentration of sugar solution on retention of nutritional parameters of osmodried whole amla (Phyllanthus emblica L)

Ipsita Banerjee
Department of Food Technology and Biochemical Engineering
Jadavpur University
Kolkata-700032

Uma Ghosh
Department of Food Technology and Biochemical Engineering
Jadavpur University
Kolkata-700032

Abstract - Ascorbic acid and poly phenols of amla are important components of our nutrition because of their antioxidant and disease resistant capacities. However the loss of nutritional value depends on processing and storage of amla. Thus osmodehydration of amla using sucrose solution (30^0-60^0B) was studied with respect to vitamin C, naringin and total phenol content. The samples under study were untreated, water blanching and prickling, prickling and water blanching, steam blanching. The study revealed that maximum retention of Vitamin C (2.1±0.15mg/g fruit), naringin (1.9± 0.11 mg/g fruit) and total phenol (37.5± 1.11 mg/g fruit) was observed for amla with prickling after blanching in boiling water for 2-3 mins, compared to untreated amla of 0.5±0.02 mg/g fruit Vitamin C, 33.33±0.24 mg/g fruit total phenol and 1.5±0.06 mg/g fruit naringin content. The products were stored successfully for 6 months in glass container.

Keywords: Amla, Sucrose, Vitamin C, Naringin, Phenol

I. INTRODUCTION

Amla (*Phyllanthus emblica* L) also known as amlaki, aonla or Indian Gooseberry is one of the important fruits which has high nutritional value. It is rich in ascorbic acid content[1] and possesses antiscorbutic, diuretic, laxative and antibiotic properties[2]. It contains polyphenols like ellagitannins[3, 4] and gallic acid[5]. However amla fruits are very astringent in taste and highly perishable in nature. Therefore processing of amla is very much needed to improve its taste and extension of shelf life.

Osmotic dehydration is one of the most widely studied preservation techniques. The process involves immersion of fruits and vegetables in hypertonic aqueous solution of osmotic agents commonly used are salt and sugar. The semipermeable nature of cell membranes of fruits and vegetables results diffusional mass transfer like passage of water from fruits and vegetables to solution resulting loss of water from it, transfer of solute from solution to sample. In addition solute of fruits and vegetables leaches out from the sample to solution. Thus nutrient loss occurs during osmotic treatment[6]. But impregnation of commodities with osmotic agent improves texture[7, 8] sensory properties and dietary value[9]. However the nutritional value of osmodried product depends on dehydration process parameters and application of osmotic agent[10, 11].

Hence the objective of our study was to evaluate the effect of sucrose concentration on retention of Vitamin C, naringin and phenolic content of pretreated amla compared to control. The osmodried amla products were stored at 30^0c.

II. MATERIALS AND METHODS

Fresh amla fruits were purchased from local market. The amla were cleaned thoroughly with tap water to remove adhering dust, foreign matter and wiped with a muslin cloth. The treatments prior to osmodehydration consisted of

(a) Whole fruits without any blanching were considered as control

(b) Water Blanching prior Pricking

(c) Pricking prior water Blanching

(d) Steam Blanching

Whole amla fruits were dipped in boiling water for 2-3 mins followed by cooling with cold water. Then amla fruits were pricked with the help of a needle. A portion of sample was first pricked with needle and then dipped in boiling water for 2-3 mins and immediately cooled by cold water. Steam Blanching was done in autoclave at 15 p.s.i pressure for 10 mins. The samples were separately dipped in sugar solution of 30^0B. The concentration of sugar syrup increased upto 60^0B. After 60^0 B samples were dried at 50^0c temperature for 7 hours and packed in glass container for storage study. Samples were analysed for Vitamin C, naringin and total phenol content.

Analytical parameters:

TSS was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B. Total phenolic content was determined by folin-ciocalteu method[12] at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit. Ascorbic acid was determined by titrimetric method[13] and the value expressed as mg of ascorbic acid /g fruit. Naringin content was determined by Davis Value Test at a wavelength of 420nm using naringin standard and the value expressed as mg of naringin/g fruit[13].

III. RESULTS AND DISCUSSION

Initial vitamin C content of amla was 4.7±0.14 mg/g fruit. The pretreatments given to the amla fruit before osmotic drying effects the retention of vitamin C. From the table 1 it is clear that retention of vitamin C in the control sample was minimum retaining only 0.5±0.02 mg/g fruit. While maximum retaining of vitamin C shows in the prickling after water blanching sample (2.1±0.15 mg/g fruit) followed by prickling before water blanching (1.3±0.03 mg/g fruit).

Table 1: Effect of concentration of sucrose solution on vitamin C, naringin and total phenol of whole amla

Sample	Vitamin C(mg/g)				Naringin(mg/g)				Total Phenol(mg/g)			
	Sucrose solution (^{0}B)				Sucrose solution (^{0}B)				Sucrose solution (^{0}B)			
	30	40	50	60	30	40	50	60	30	40	50	60
Control	4± 0.25	2.85± 0.08	1.5± 0.03	0.5± 0.02	2.5± 0.12	2.3± 0.05	1.5± 0.03	1.5± 0.06	66.67± 0.42	45.83± 0.44	35.42± 0.34	33.33± 0.24
WB+P	2.85 ±0.12	2.8± 0.08	2.7± 0.07	2.1± 0.15	2.5± 0.07	2.16± 0.07	2.16± 0.03	1.9± 0.11	47.93± 0.72	43.75± 0.86	41.66± 0.74	37.5± 1.11
P+WB	1.7± 0.03	1.4± 0.02	1.35± 0.03	1.3± 0.03	2.3± 0.07	2±0.1	1.67± 0.04	1.5±0 .03	47.08± 0.39	35.42± 0.98	34.58± 0.66	33.33± 0.47

SB	1.45 ±0.15	0.85± 0.016	0.75± 0.007	0.7± 0.015	2.2± 0.02	1.8± 0.02	1.5± 0.01	1± 0.19	40± 0.33	22.5± 1.45	21.25± 0.47	20± 0.64
Fresh	4.7±0.14				3±0.32				75±0.07			

Ascorbic acid being an unstable compound decomposed easily under undesirable conditions[14]. Among treated sample steam blanching results higher loss in Vitamin C retaining (0.7±0.015mg/g fruit). Sagar et al reported thermal degradation of amla during osmotic process[15]. In case of naringin content little change were observed with pretreatments of amla and it was (1 to 1.9 mg/g fruit) for treated samples. Reduction in total phenol content was observed with increase in concentration of sucrose solution and at 60^0B total phenol content (37.5±1.11mg/g fruit) was maximum with blanching prior prickling sample. Retention of total phenol content was minimum in steam blanching (20±0.64 mg/g fruit) followed by prickling before blanching (33.33±0.47 mg/g fruit).

Table 2: Nutritional parameters of osmodried amla after 6 months of storage

Sample	Vitamin C(mg/g)	Total phenol(mg/g)	Naringin(mg/g)
WB+P	1±0.11	31.25±0.46	1.25±0.1
P+B	0.5±0.02	29.16±0.3	0.62±0.03
SB	0.5±0.01	12.5±0.24	0.42±0.03

Table 2 represents the nutritional parameters of osmodried amla after 6 months of storage. Ascorbic acid content of osmodried amla decreases further when stored for 6 months. The retention was highest in water blanching prior prickling (1±0.11 mg/g fruit). Loss of naringin is highest in steam blanching retained only (0.42±0.03 mg/g fruit). Maximum amount of naringin revealed in blanching prior prickling sample (1.25±0.1 mg/g fruit). Maximum total phenol retained in prickling after water blanching (31.25±0.46 mg/g fruit) and minimum in steam blanching (12.5±0.24 mg/g fruit). In all cases loss in Vitamin C, naringin and total phenol occurs but loss was minimum for water blanching prior prickling samples. Control (Unblanched) samples became unacceptable within 8-9 weeks of storage due to dark brown coloration of amla. This may be due to faster rate of browning reaction of control samples than other pretreated samples.

However retention of nutritional content was not so significant between pretreated samples but better than control sample and can be stored upto 6 months in glass container.

IV. CONCLUSION

Whole amla can be preserved by osmotic dehydration process. Retention of nutritional parameters was maximum for amla fruits pricked after blanching. Samples were successfully stored up to 6 months at room temperature. Further studies are needed to prepare better quality product.

V. ACKNOWLEDGEMENT

The financial assistance of University Grant Commission in carrying out this work is gratefully acknowledged.

VI. ABBREVIATION

WB+P- Water blanching prior prickling, P+B- Prickling prior water blanching, SB- Steam blanching

REFERENCES

[1] Habib-ur-Rehman, Yasin KA, Choudhary MA, et al. "Studies on the chemical constituents of Phyllanthusemblica". Nat. Prod. Res., 21 (9): 775–81, 2007

[2] R.K. Goyal, R.T. Patil,A.R.P. Kingsly, HimanshuWalia and Pradeep Kumar "Status of Post-harvest Technology of Aonla in India- A Review" Am.J.Food Technol.,3(1): 13-23, 2008.

[3] Pragati, S. Dahiya and S.S. Dhawan ".Effect of drying methods on nutritional composition of Dehydrated aonla fruit (Emblica officinalis Garten) during storage" Plant Foods for Human Nutrition., 58: 1–9, 2003

[4] P.Mishra, M.Verma, V.Mishra and G.K.Rai "Studies on Development of Ready to Eat Amla (Emblica officinalis) Chutney and its Preservation by using class one Preservatives" Am. J. Food Technol., 6(3): 244-252, 2011

[5] R.C.Verma, Ajay Gupta "Effect of pre-treatments on quality of solar-dried amla" Journal of Food Engneering., 65: 397-402, 2004

[6] Stojanovic.J and Silva J.L. "Influence of osmotic concentration continuous high frequency ultrasound and dehydration on antioxidants, color and chemical properties of rabbiteye blueberries. Food Chemistry,101:898-906,2007

[7] Chiralt A; Martinez- Navarrete NM; Martinez-Monzo J; Talens P;Moraga G et al. "Changes in mechanical properties throughout osmotic processes cryoprotectant effect". J Food Engg. 49: 129-135, 2001

[8] Talens P; Martinez –Navarrete .N; Fitop Chiralt A. "Changes in optical and mechanical properties during osmodehydrofreezing of kiwi fruit". Innovative Food science & Engineering Technology 3:191-199, 2002.

[9] Torrenggiani D and Bertolo G.2001. "Osmotic pretreatments in fruit processing:chemical,physical and structural effects". J of Food Engg. 49:247-253, 2001

[10] Mandala.I.G; Anagnostaras.E.F and Oikonomou.C.K. "Influence of osmotic dehydration conditions on apple air-drying kinetics and their quality charecteristics". J of Food Engg. 69:307-316, 2005

[11] Chiralt.A and Talens.P. "Physical and chemical changes induced by osmotic dehydration in Plant tissues". J of Food Engg. 67:167-177, 2005

[12] Singleton V L & Rossi J A. "Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents". Am J Enol Viticult.16:144-153, 1965

[13] Rangana S. Handbook of analysis and quality control for fruit and vegetable products, 2nd edn (Tata McGraw Hill Publishing Company Ltd. New Delhi,):105-106, 1986

[14] Lee H.S. & Coates.G.A. "Vitamin C in frozen, fresh, squeezed, unpasteurized, polyethylene bottled orange juice: A storage study" Food Chemistry., 65:165-168, 1999.

[15] V.R. Sagar and P Suresh Kumar. "Involvement of some process variables in mass transfer kinetics of osmotic dehydration of mango slices and storage stability". Journal of Scientific & Industrial Research.68:1043-1048, 2009

Effect of Pretreatments on Nutritional Quality of Minimally Processed Jackfruit Bulbs During Storage

Ipsita Banerjee[1], Uma ghosh[2]
[1, 2] Dept of Food Technology and Biochemical Engineering
[1, 2] Jadavpur University
Kolkata-700032

Abstract- *Jackfruit (Artocarpus heterophyllus L.) is an important fruit that is generally consumed as a fresh fruit. A minimal process was carried out to investigate the effect of pre-treatments of fresh-cut jackfruit bulbs using additives such as ascorbic acid, citric acid, $CaCl_2$ and sodium benzoate in combination with mild acidified conditions for storage at low temperature. Pre-treated samples showed a restricted loss of around 25%, 17%, 58%, and 36% for total phenolics, antioxidants, vitamin C and total carotenoid respectively at the end of 21 days of storage. Among all pre-treatments the best result showed by sample pre-treated with ascorbic acid.*

Keywords- Fresh- cut jackfruit, pre-treatment, total phenolics, antioxidants, vitamin C, Carotenoid

I. INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* L.) is a fruit belongs to the family Moraceae and is grown in the tropical part of India. The fleshy, fibrous bulb of this fruit is rich in sugar, carotenoids, carbohydrates, minerals, carboxylic acids, dietary fibre, and vitamins such as vitamin C[1]. Carotenoid is responsible for the attractive yellow colour of the ripe bulbs[2]. The phytochemicals such as vitamin C, polyphenol, flavonoids of jackfruit shows health promoting effects. They act as natural antioxidants which inhibit oxidation-induced degenerative changes in cell. The fruit deteriorates rapidly upon ripening. So it is desirable that pre cut bulbs are processed and stored by an appropriate method. Pre-cutting of jackfruit bulbs increases oxidative stress and they tend to lose keeping quality, significant reduction of phytochemicals, such as phenolics, flavonoids, vitamin C, and carotenoids[3]. Introduction of additives during minimal processing has been reported, to minimise these deteriorative changes in fresh-cut fruits and vegetables[4]. Additives such as citric acid, ascorbic acid and calcium chloride, sodium benzoate at minimum level during minimal processing of pre cut bulbs have been found beneficial in minimizing the stress-induced metabolism, reduction of nutrient loss, reducing the browning reaction along with shelf-life extension[5]. Several studies have been conducted for various minimally processed produces such as apricot, apple, pear etc but very limited works were reported on post-harvest technology of jackfruit bulbs by minimal processing.

Therefore the objective of this work is to find out the effect of additives on nutritional quality of pre-cut jackfruit bulbs.

II. MATERIALS AND METHODS

Ripe jackfruits were purchased from local market. After cutting the jackfruit yellowish bulbs were removed seeds were separated and used for further studies. Surface sanitized with 100 ppm chlorinated water[6]. Bulbs were cut in slices. Half of the fruits undergo a secondary phytosanitation wash in chilled chlorinated water (30 ppm) for 5 min. Then slice were separately dipped in solution containing $CaCl_2$ (0.05%, 1%, 2% w/v), sodium benzoate (0.01%, 0.02%, 0.05% w/v), Ascorbic acid (0.01%, 0.02%, 0.03% w/v) and Citric acid (0.5%, 1%, 1.5% w/v). Another part washed with water and used as untreated. Excess water drained of both pretreated and untreated samples. Then samples were packed in sealed polyethylene pouches and kept in low temperature for storage study.

Total phenol content:

Total phenolic content was determined by folin-ciocalteu method[7]at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit.

Antioxidant content:

Antioxidant content was determined by FRAP method and the value expressed as mg of ascorbic acid /g fruit[8].

Vitamin C content:

Ascorbic acid was determined by titrimetric method[9] and the value expressed as mg of ascorbic acid /100 g fruit.

Total carotenoid:

Carotenoid content was measured according to the process described by Saxena et al., 2009[6]. The absorbance was measured at 450nm. The value expressed as mg/100g.

$$\text{Total carotenoid (mg/100g)} = \frac{A(450) * \text{volume made up (ml)} * 1000}{2500 * \text{sample wg (g)}}$$

III. RESULTS AND DISCUSSION

Generally jackfruit is available in market as separated bulb which is extremely susceptible to oxidative stress which results loss of important nutrients. Therefore some additives such as citric acid as anti respiratory agent, $Cacl_2$ as texturing substance, sodium benzoate as preservative and ascorbic acid as a supplement may be used to reduce the adverse excessive loss of nutrients due to pre-cutting process[10].

Table 1 Characteristics of jackfruit bulb

Analysis	Jackfruit
TSS (^{0}B)	22±0.36
Moisture (%)	72±0.60
Total Phenol(mg/g)	0.75±0.06
Ascorbic acid (mg/100 g)	8.32±0.93
FRAP(mg/g)	0.5±0.035
Carotenoid (mg/100 g)	1.336±0.21

Total phenol content of jackfruit bulb during storage:

It was observed from fig.1 that total phenol content decreases during storage in both pretreated and untreated samples. Pretreated samples showed lower loss of total phenol than untreated sample shows higher degree of degradation during storage. The pretreatments extended the shelf life and increased retention of total phenol by decreasing the oxidative stress[11]. Samples pretreated with ascorbic acid retained maximum amount of total phenol (0.557 mg/g) after 21 days of storage. Similar finding were observed by Saxena et al[6]. This was followed by citric acid 0.492 mg/g. The decrease in Total phenol during storage of fresh-cut jackfruit could be results of enzymatic degradation by peroxidase (POD) and PPO activities. Generally POD is responsible for oxidation of polyphenols[12]. POD can cause membrane damage and oxidative stress[13].Ascorbic acid and citric acid can restricted the action of polyphenoloxidase enzyme[14], they act as anti respiratory agent.

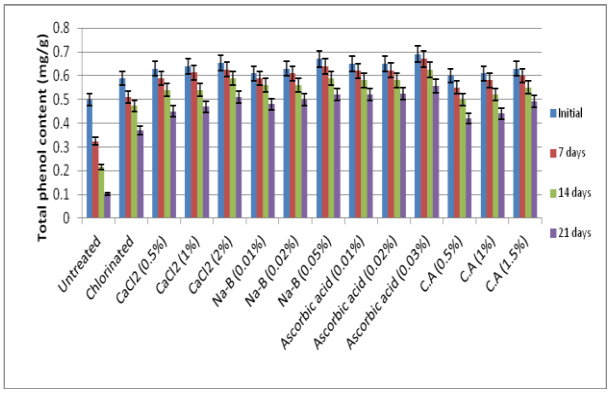


Fig .1 Total phenol content of fresh cut jackfruit during storage

Antioxidant content of jackfruit bulb during storage:

Fig.2 shows the degradation of antioxidant of pretreated and untreated samples. After 21 days of storage the untreated sample retained only 0.06 mg/g antioxidant. Whereas pretreated with ascorbic acid (conc 0.03%) contain 0.413 mg/g and citric acid 0.392 mg/ g which were followed by sodium benzoate and $Cacl_2$. Cutting of jackfruit bulb cause physiological stress that cause loss of phytochemical components which are responsible for antioxidant activity[15].Addition of ascorbic acid during pretreatment can retained maximum amount of antioxidant.

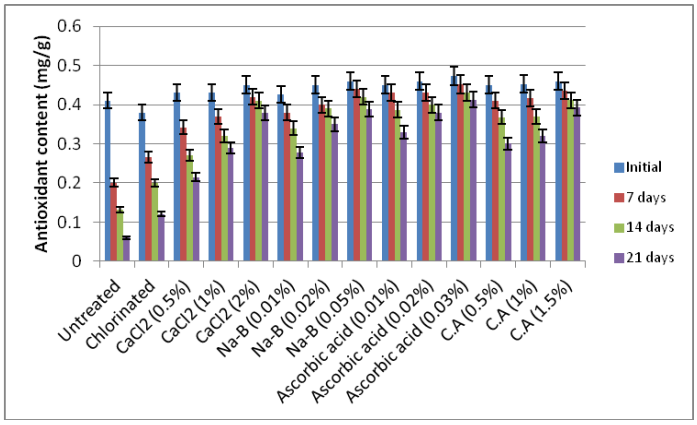


Fig .2: antioxidant content of fresh cut jackfruit during storage

Vitamin C content of jackfruit bulb during storage:

Vitamin C plays an important role as antioxidant. The oxidative stress introduce during fresh cut jackfruit cause degradation of vitamin C. Results shows that the addition of ascorbic acid during pretreatment retained maximum amount of vitamin C could be the result of vitamin C oxidation into dehydroascorbic acid. The untreated sample showed a rapid loss of vitamin C content during storage. Results were closely resembles with other research work[6, 14].

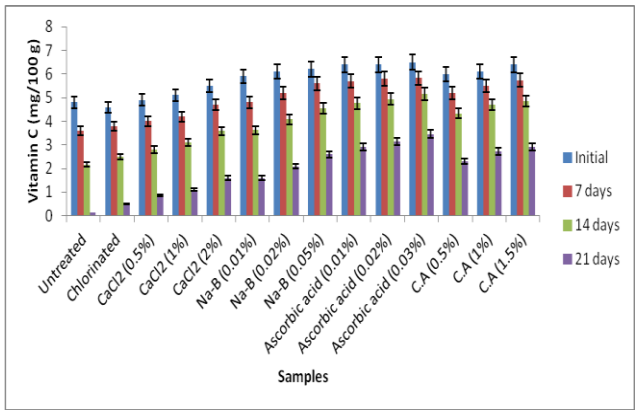


Fig.3: Vitamin C content of fresh cut jackfruit during storage

Total carotenoid of jackfruit bulb during storage:

Carotenoids are potential antioxidant but they are very susceptible to oxidative degradation. Study revealed from fig.4 that pretreated samples contain higher amount of carotenoid than untreated sample. Pretreatment with ascorbic acid could minimize the carotenoid loss by preventing carotenoid oxidation[16], which was followed by pretreated sample with calcium chloride ($CaCl_2$). That might be due to their role as radical scavenger and reducing agent in prevention of browning[17].Pretreated with ascorbic acid contain 1.28 mg/100g carotenoid at the initial stage and 0.85 mg/100 g after 21 days of storage.

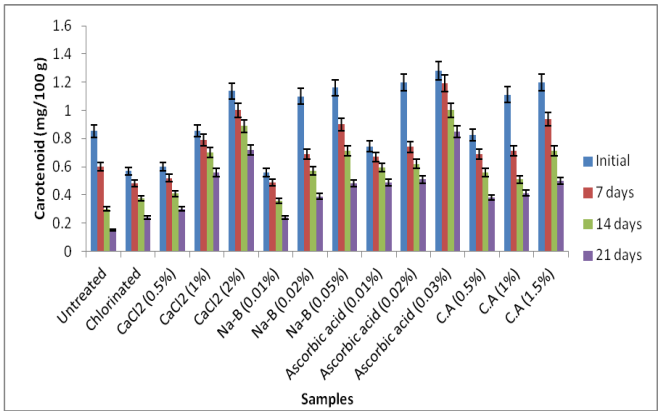


Fig .4: Carotenoid content of fresh cut jackfruit during storage

IV. CONCLUSION

Pretreatment showed positive effect in pre cut fresh jackfruit during storage. Pretreatment can act as antirespiratory agents that minimize loss of nutrients such as vitamin C, polyphenols, and antioxidant, carotenoid. Among all pretreatments addition of ascorbic acid showed better results than others. Such assessment of polychemical status in processed foods, i.e., minimally-processed product, can help the modern health-conscious consumer.

V. ACKNOWLEDGMENT

Authors greatly acknowledge University Grant Commission (UGC), New Delhi for their financial assistance.

REFERENCES

[1] M. A. Rahman, N. Nahar, M. A. Jabbar, and M. Mosihuzzaman, "Variation of carbohydrate composition of two forms of fruit from jack tree (*Artocarpus heterophyllus* L.) with maturity and climatic conditions," in Food Chemistry, vol. 65,pp. 91–97, 1999.

[2] A. Saxena, A. S. Bawa, and P. S. Raju, "Optimization of a multitarget preservation technique for jackfruit (Artocarpus heterophyllus L.) bulbs", in Journal of Food Engineering, vol. 91, no 1, pp. 18–28 , 2009.

[3] P. A. Biacs, B. Czinkotai, and A. Hoschke, "Factors affecting stability of coloured substances in paprika powders", in Journal of Agriculture and Food Chemistry, vol. 40, pp. 363–367, 1992.

[4] P. S. Raju, and A. S. Bawa, "Food additives in fruit processing", in Y. H. Hui (Ed.), Handbook of fruits and fruit processing, Oxford: Blackwell Publishing, pp. 145–170, 2006.

[5] R.C. Soliva-Fortuny, M.N. Grigelmo, J. Hernando, M.A. Lluch, O. Martin-Belloso, "Effect of minimal processing on the textural properties of fresh-cut pears", in Journal of Science of Food and Agriculture, vol. 82, pp. 1682–1688, 2002.

[6] Alok Saxena, A.S. Bawa, P.S. Raju, "Phytochemical changes in fresh-cut jackfruit (*Artocarpus heterophyllus* L.) bulbs during modified atmosphere storage", in Food Chemistry, vol. 115, 1443–1449, 2009.

[7] V. L. Singleton and J. A. Rossi, "Colorimetry of total phenolics with phosphomolybdic -phosphotungestic acid reagents", in Am J Enol Viticult.vol. 16, pp. 144-153, 1965 .

[8] I.F. Benzie, J.J. Strain, "The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay", in Anal Biochem, vol. 239, no. 1, pp.70-76, 1996.

[9] S. Rangana, "Handbook of analysis and quality control for fruit and vegetable products", 2nd ed, pp. 105-106, 1986.

[10] A. Lopez-Malo, E. Palou, J. Welti, P.Corte, A. Argaiz, "Shelf stable high moisture papaya minimally processed by combined methods" in Food Research International, vol.27, pp.543–553, 1994.

[11] A. Saxena, A. S. Bawa, and P. S. Raju, “Use of modified atmosphere packaging to extend shelf-life of minimally processed jackfruit (Arotocarpus heterophyllus L.) bulbs", in Journal of Food Engineering", vol.87, no.4, pp.455–466, 2008.

[12] D. S. Robinson, “Peroxidases and catalases in foods", in D. S. Robinson, & N. A. M. Eskin (Eds.), Oxidative enzymes in foods, London New York: Elsevier Applied Science, pp. 1–45, 1991.

[13] G.Oms-Oliu, I. Odriozola-Serrano, R. Soliva-Fortuny, and O. Martin-Belloso, “The role of peroxidase on the antioxidant potential of fresh-cut ‘Piel de Sapo’ melon packaged under different modified atmospheres", in Food Chemistry, vol. 106, pp. 1085–1092, 2008.

[14] E. Cocci, P. Rocculi, S.Romani and M. Dalla Rosa, “Changes in nutritional properties of minimally processed apples during storage", in Postharvest Biology and Technology, vol.39, pp.265–271, 2006.

[15] M. M. Lana, and L. M. M. Tijskens, “Effect of cutting and maturity on antioxidant activity of fresh-cut tomatoes", in Food Chemistry, vol.97, pp.203–211, 2006.

[16] A. Z. Mercadante, and D. B. Rodriguez-Amaya, “Effects of ripening, cultivar differences, and processing on the carotenoid composition of mango" in Journal of Agriculture and Food Chemistry, vol.46, pp.128–130, 1998.

[17] P.Varela, A. Salvador, S.M. Fiszman, “The use of calcium chloride in minimally processed apples: a sensory approach", in European Food Research and Technology, vol. 224, pp. 461–467, 2007.

RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 11 | Issue 2 | October, 2018 | 282-288
ISSN–0974–2662 ■ Visit us : *www.researchjournal.co.in* ■ **DOI: 10.15740/HAS/IJAE/11.2/282-288**

Effect of thermal treatment on phenolic and antioxidant content of fresh bael juice

■ **Ipsita Banerjee and Uma Ghosh**

Received : 24.04.2018; **Revised :** 03.08.2018; **Accepted :** 20.08.2018

See end of the Paper for authors' affiliation

Correspondence to :

Uma Ghosh
Department of Food Technology and Biochemical Engineering, Jadavpur University, **Kolkata (W.B.) India**
Email :
ughoshftbe@yahoo.co.in

■ **ABSTRACT :** Bael (*Aegla marmelos*) is one of the important fruit in India and bael juice is most important source of antioxidants. The loss of phenolic compound and antioxidant content over the temperature range of 55-85^0 C was studied. Degradation kinetics was best fitted by first order reaction kinetic model for both phenolic compound and antioxidants. Arhenius and Erying – polany models had been used to determine the temperature dependent degradation. Following the Arhenius model, the activation energy for the phenolic compound and antioxidants were 18.52 and 45.08 KJ mol^{-1}, respectively. The retention of phenolic compound and antioxidants of bael juice treated at 55^0 C for 90 min was more than 61 and 68 per cent, respectively as that of fresh bael juice.

■ **KEY WORDS :** Phenolic compound, Antioxidant, Degradation kinetic, Arhenius, Erying-Polany, Activation energy

■ **HOW TO CITE THIS PAPER :** Banerjee, Ipsita and Ghosh, Uma (2018). Effect of thermal treatment on phenolic and antioxidant content of fresh bael juice. *Internat. J. Agric. Engg.*, **11**(2) : 282-288, **DOI: 10.15740/HAS/IJAE/11.2/282-288.**

The bael (*Aegla marmelos*) is a wellknown fruit found widely throughout India (Rahman and Pravin, 2014). Every part of the tree, root, bark, leaf, fruit, seed, latex are useful for their medicinal properties (Patel *et al*., 2012). The bael pulp consist of vital bioactive compounds such as carotenoids, phenolics, alkaloids, pectins, tannins, coumarins, flavonoids and terpenoids (Maity *et al*., 2009; Suvimol and Pranee, 2008). Bael is one of the nature's rich source of antioxidants and is beneficial for health beyond nutrition. It also has excellent aroma. This fruit has a lot of potential to be processed to value added products (Singh *et al*., 2014) such as squash, nectars, toffy, jam, powder, preserves, juice and refreshing beverages (Singh *et al*., 2013). Due to increaseing demand of health drinks based on indigenous fruits bael fruit can be processed for making juice and RTS bevarages. Singh *et al.* (2013) reported that commercial and crude pectinase enzyme were used for optimization of bael juice extraction (Singh *et al*., 2013 and Singh and Nath, 2004). Bael juice was used for preparation of RTS drink, nectar, squash (Verma and Gehlot, 2006) and blended beverages (Nidhi *et al*., 2008; Kenghe and Zambre, 2009).

However, thermal treatments cause degradation and may be the reason of destruction of natural antioxidants in food (Vikram *et al*., 2005; Mazur *et al*., 2014 and Remini *et al*., 2015). Two important variables to be controlled are temperature of treatment and its duration (Loannou *et al*., 2012). Therefore, degradation kinetic modelling is important to control changes of physico-chemical parameter during processing (Remini *et al*., 2015). In addition to that kinetic model can be utilized for economic evaluation of food quality. The effect of several experimental variables on nutritional values

(Lanny and Lie, 2014) can also be predicted by kinetic model. Hence, the purpose of this experiment is to determine the kinetic parameters of both total phenolic and antioxidant content during thermal treatment at different temperature by using Arrhenius and Eyring-polany model. This approach will give an idea about suitable time and temperature of processing for developing a bael juice having better nutritional quality.

METHODOLOGY

Preparation of bael juice:

Fresh baels procured from local market were washed under running water and shells were broken to collect pulp. Then water (1:10 w/v) was added to the pulp followed by blending in a juicer and centrifuged at 4000 rpm for 5 mins. The clear centrifugate collected and used as fresh bael juice.

Thermal treatment:

Thermal degradation kinetics of total phenolic content and antioxidant activity were studied by isothermal heating at 55^0, 65^0, 75^0 and 85^0, respectively. 10 ml samples had been taken in each sealed glass tubes and then heated by placing them in thermostatic water bath (Scientific instrument and chemical company, India). At every 15 min interval the tubes had been taken out and immediately cooled by dipping them into ice water and analyzed for total phenolic content (TPC) and total antioxidant activity.

Analytical parameters:

Total soluble solid (TSS) was measured by Hand Refractometer (Erma Inc., Tokyo, Japan) and expressed in terms of ^{0}B.

Total phenolic content was determined by folin-ciocalteu method (Singleton and Rossi, 1965) at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit.

Determination of Ascorbic acid done by titrimetric method (Rangana, 1986) and the value expressed as mg of ascorbic acid /g fruit.

Antioxidant activity was measured by FRAP method (Benzie and Strain, 1996) at a wave length of 593nm.

Thermal degradation of nutrients:

Nutrients degradation in foods during their thermal processing has been described in terms of zero, first or second order kinetics (Corradini and Pleg, 2006). A general reaction rate expression for degradation kinetics can be written as follows (Paul and Ghosh, 2012).

$$\frac{d[c]}{dt} = k_x [c]^n \quad \ldots (1)$$

where, c= quantitative value of the degraded product under consideration. k_x = the reaction rate constant and 'm' is the reaction order, 't' is the reaction time (min).

The reaction order was determined by linear regression through graphical analysis, where exponent 'n' in eq. (1) was set to 0, 1, and 2 to compare the co-efficients of determination (R^2). The integrated forms of zero, first and second order models are given in eq.:

Zero order: $X_t = X_0 - k_x t$ … (2)

First order: $\ln\left(\frac{[X]_t}{[X]_0}\right) = -k_x t$ … (3)

Second order: $1 / X_t - 1 / X_0 = k_x t$ … (4)

Using the experimental data, the co-efficients of determination (R^2) were observed to be minimum for n = 1, predicting a first order reaction.

The relationship of reaction rate to temperature was evaluated by the Arrhenius equation (Paul and Ghosh, 2012):

$$K_x = A_0 \exp^{-(Ea/RT)} \quad \ldots (5)$$

where 'k_x' is the rate constant (min^{-1}), 'E_a' is the activation energy (kJ mol^{-1}) of the reaction, 'R' is the universal gas constant (8.314 J mol^{-1} k^{-1}), 'T' is the absolute temperature and 'A_0' is a pre exponential constant.

In Eyring-polany model enthalpy of activation (ΔH^*) and entropy of activation (ΔS^*) are the model's parameters (Eq. 6)

Entropy (ΔS^*_{xi}) and enthalpy (ΔH^*_{xi}) were obtained from the Eyring-polany model:

$$\frac{\ln K_x}{T} = \frac{\Delta H^* xi}{R} \cdot \frac{1}{T} + \frac{\ln K_B}{h} + \frac{\Delta S^* xi}{R} \quad \ldots (6)$$

where K_B = the Boltzmann constant (1.381 x 10^{-23} J K^{-1}), T = absolute temperature, h=the planck constant (6.626 x 10^{-34} J s).

Statistical analysis:

Data were analysed using student t-test (origin 6.1). Significance of differences was defined at $P \leq 0.05$.

RESULTS AND DISCUSSION

It was observed in Fig. 1 that the total phenolic content decreased with increasing time and temperature

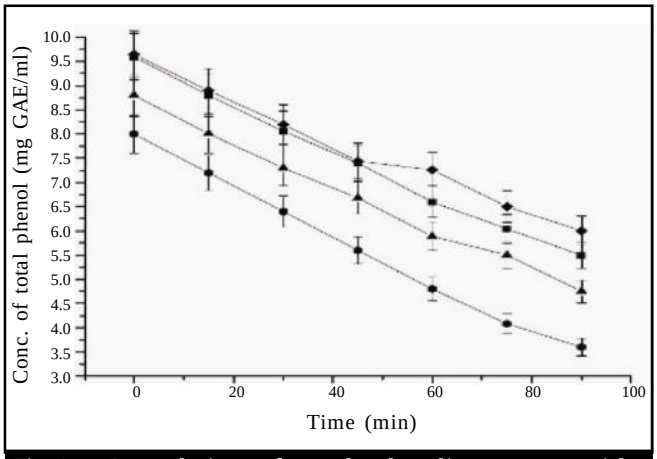


Fig. 1 : Degradation of total phenolic content with increasing time and temperature

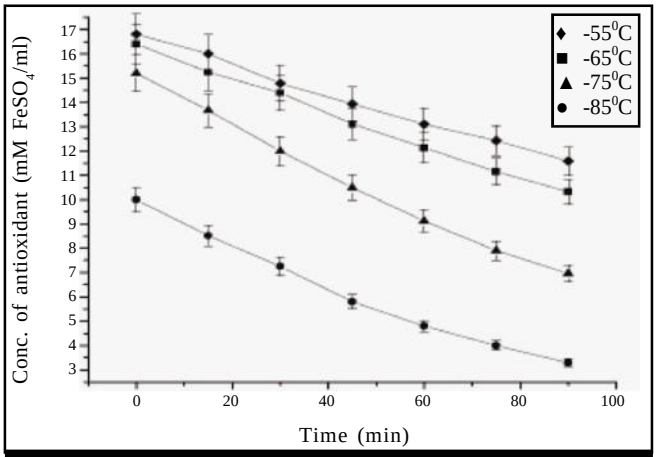


Fig. 2 : Total antioxidant activity with increasing time and temperature

Table 1 : Main characteristic of fresh bael

Analysis	Fresh bael
Juice yield (%)	20±0.26
TSS (^{0}B)	32±0.12
Moisture (%)	66±0.15
Total phenol (mg GAE/ml)	9.7±0.4
Ascorbic acid (mg/ml)	0.22±0.01
FRAP (mM $FeSO_4$/ml)	17±0.2
Carotenoid (µg/ml)	14.65±0.33

of thermal treatment. Results were similar with the previous findings where total phenolic content of some vegetables decreased with the increasing time and temperature of thermal processing (Lin and Chou, 2009). Thermal breakdown of polyphenols can happen during heat treatment that can affect the cell structure (Youssef and Mokhtar, 2014). Phenolic compounds degraded due to the effect of polyphenol oxidase (PPO) enzymatic activity (Sonawane and Arya, 2015). Polyphenols were utilized as substrates for the PPO protein (Janovitz-Klapp *et al*., 1990). The decrease in the content of total phenolic compounds during thermal treatment were also explained with previous studies that polyphenolics were heat labile and extended heat treatment could cause irreversible chemical modification to phenolic compounds (Mrad *et al*., 2012) .

As shown in Fig. 2, the antioxidant capacity of bael juice decreased with increasing thermal temperature and time. Normally, high temperature could enhance degradation of bioactive compounds and decrease the antioxidant capacity of sample (Zhou *et al*., 2016). Garau *et al*. (2007) also observed that the antioxidant capacity in orange peel and pulp both decreased by air drying. A similar trend was observed by Zhang and Hamauza (2004) that the antioxidant content in broccoli decreased with duration of thermal processing. Oxidation and isomerisation are the most important causes of antioxidants degradation during thermal processing (Shi and Le Maguer, 2000).

The order of the thermal degradation of total phenol content was estimated by examining the co-efficient of determination (R^2) from plots of total phenol versus treatment time over the temperature range of 55^0-85^0 C (Table 2). On the basis of the mean R^2 (0.99) it can be said that the thermal degradation of total phenol follow first order kinetics. Earlier studies also reported that total phenolic content degradation follows first order kinetic model (Jaiswal *et al*., 2012 and Jaiswal and Abu-Ghannam, 2013).

The order of reaction for antioxidant activity was determined by comparing R^2 obtained from plots of antioxidant versus treatment time over the temperature range of 55^0-85^0 C (Table 2). Antioxidant degradation showed a high degree of fit for first order kinetic model being most suitable with highest R^2 value, ranging from 0.995-0.998. Similar finding were seen by Jaiswal and Abu-Ghannam (2013). On the basis of R^2 values, the degradation of total phenol and antioxidant fits better with first order model with R^2 (0.99). From Table 2 and Fig. 3-8, it can be concluded that degradation of total phenol and antioxidant content could commonly be fitted by first order reaction model.

The kinetics parameters K_x, $t_{1/2}$ and R^2 of first order

Table 2 : Reaction order determination of total phenol and antioxidant degradation based on R^2 from zero, first and second order modal

	Temp	Zero order		First order		Second order	
		T.P.	FRAP	T.P.	FRAP	T.P.	FRAP
R^2	55^0C	0.986	0.986	0.991	0.998	0.964	0.977
	65^0C	0.979	0.989	0.997	0.997	0.988	0.975
	75^0C	0.987	0.982	0.997	0.995	0.966	0.957
	85^0C	0.986	0.987	0.998	0.997	0.956	0.962

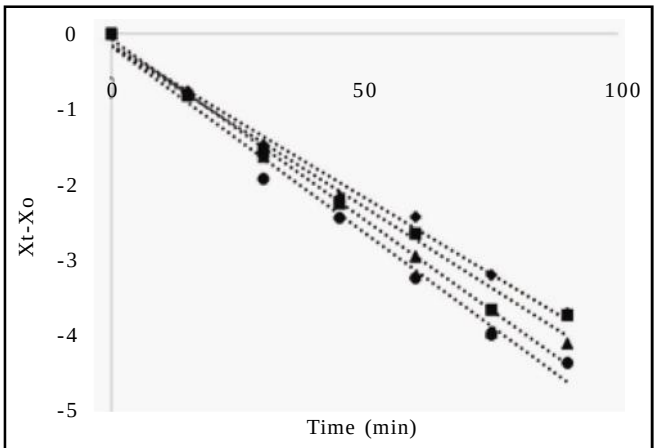


Fig. 3 : Zero-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

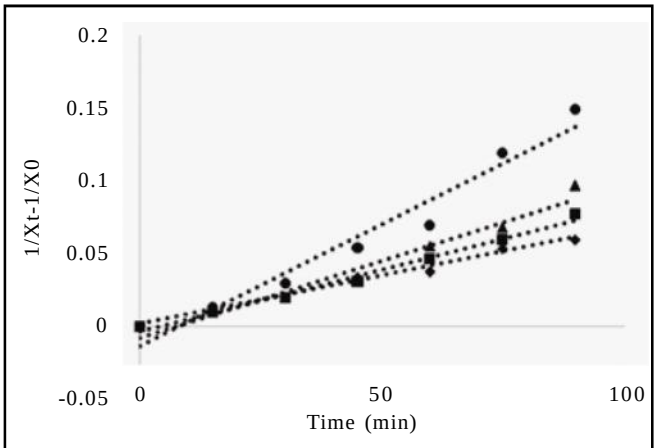


Fig. 5 : Second-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

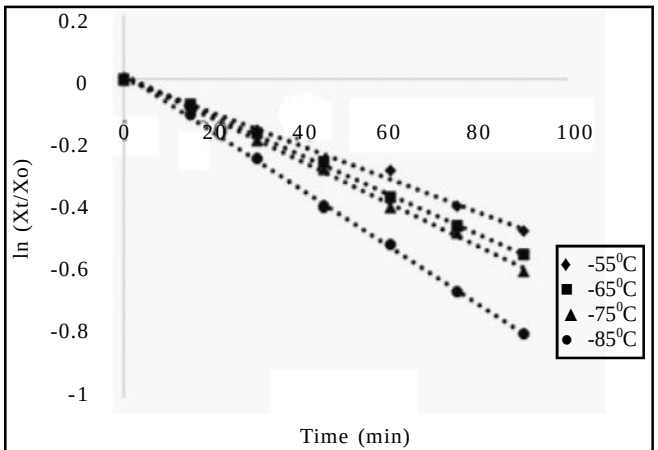


Fig. 4 : First-order plot for the degradation of phenolic compound from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

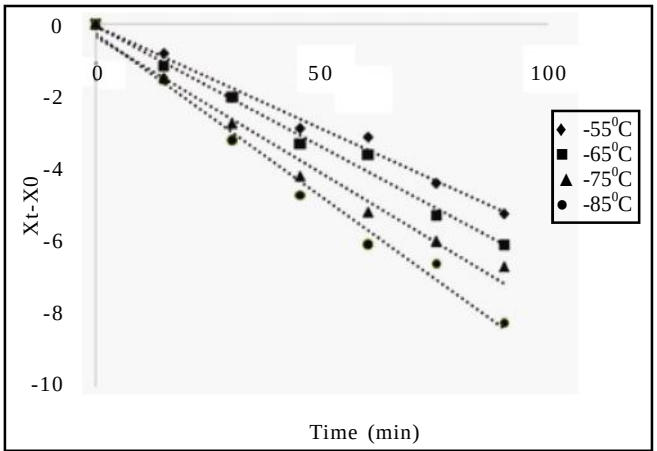


Fig. 6 : Zero-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

model through a least square fitting procedure of total phenol and antioxidant degradation are given in Table 3. A good fit was obtained R^2 0.991 -0.998 from this first order model. The degradation rate constant (K_x) increased systematically with temperature (Table 3). The half-life ($t_{1/2}$) for phenolic compound decreased from 130.75- 78.75min and for antioxidant 173.25-57.27 min as the temperature increased from 55-85°C.The half – life ($t_{1/2}$) is the time required for phenolic compound and antioxidant to degrade to 50 per cent of its original value.

As shown in Table 3 that kinetic constant K_x of total phenol content and antioxidant compounds increase with increasing temperature which confirmed that with increasing temperature degradation become faster.

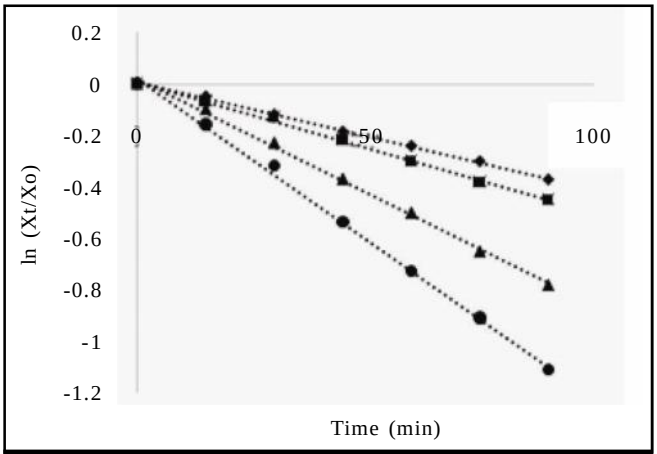


Fig. 7 : First-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

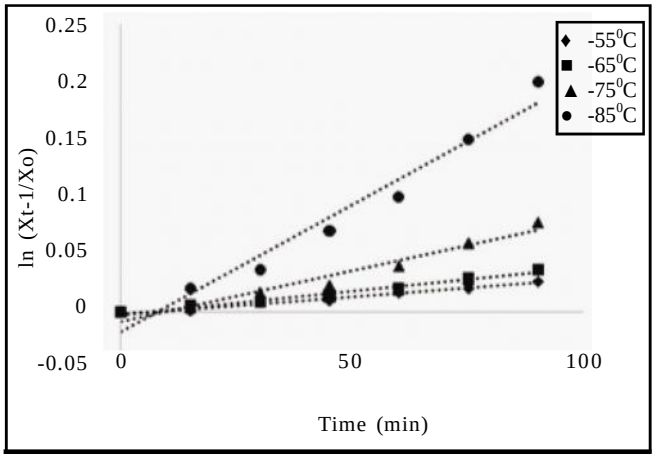


Fig. 8 : Second-order plot for the degradation of antioxidant from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

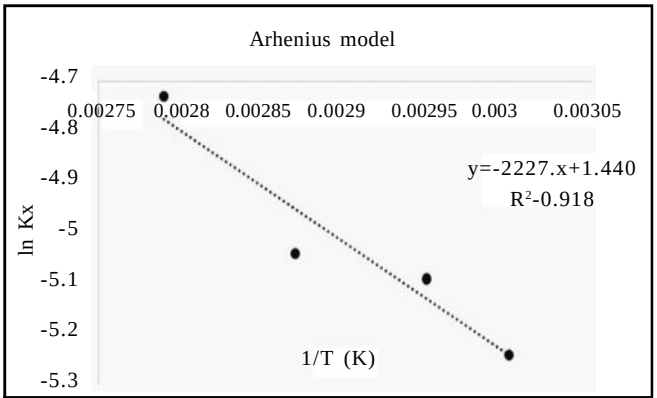


Fig. 9 : Plot of ln(k_x) versus (1/T) for degradation of flavonoid content from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

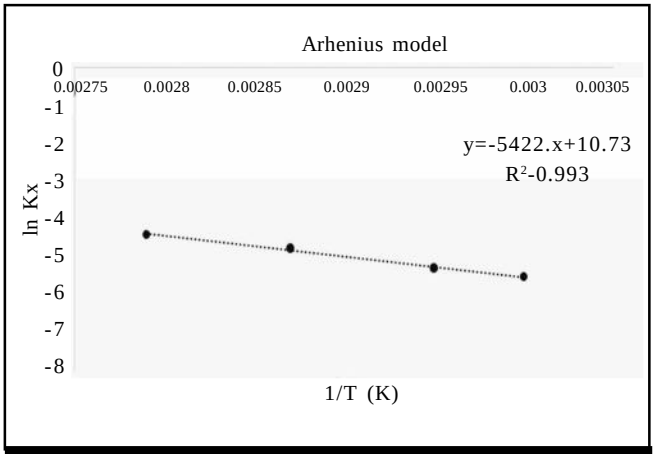


Fig. 10 : Plot of ln(k_x) versus (1/T) for degradation of antioxidant from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

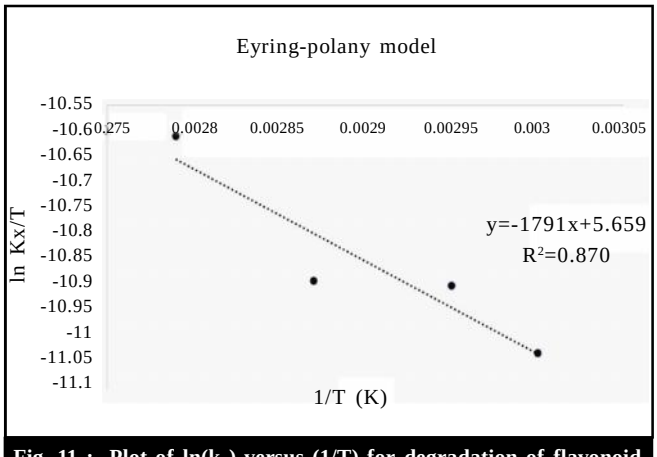


Fig. 11 : Plot of ln(k_x) versus (1/T) for degradation of flavonoid content from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

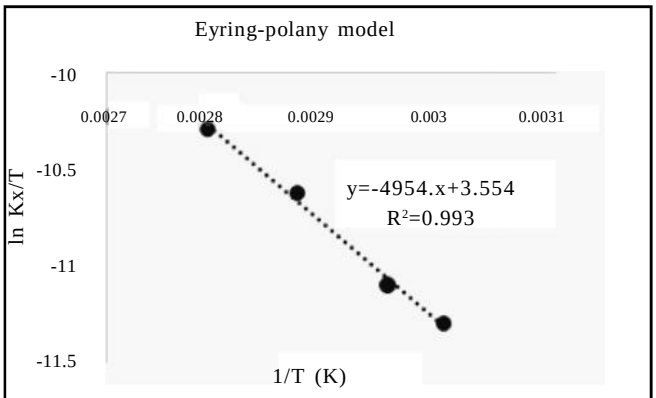


Fig. 12 : Plot of ln(k_x/T) versus (1/T) for degradation of antioxidant content from bael juice during heating over the temperature range of 55°-85°C for 0-90 min

Table 3 : Kinetics parameters for degradation of total phenol, antioxidant of bael juice due to thermal processing

	1st order model				Arrhenius model			Eyring-polany model		
	T(°C)	K_x(min^{-1})	$t_{1/2}$ (min)	R^2	E_a (KJ mol^{-1})	K_x (min^{-1})	R^2	ΔH(KJ mol^{-1})	ΔS (J mol^{-1} k^{-1})	R^2
TPC	55°	0.0053	130.75	0.991						
	65°	0.0061	113.63	0.997	18.52	2227.7	0.918	14.89	-244.60	0.87
	75°	0.0065	106.62	0.997						
	85°	0.0088	78.75	0.998						
Antioxidant	55°	0.004	173.25	0.998						
	65°	0.005	138.6	0.997	45.08	5422.7	0.99	41.19	-168.025	0.99
	75°	0.0085	81.53	0.995						
	85°	0.0121	57.27	0.997						

Which is similar with the finding of Henriquez *et al*. (2014). Kinetic parameters of total phenol and antioxidant degradation from Arrhenius model are shown in Table 3. The K_x value is 2227.7 for total phenol and 5422.7 for antioxidant. In case of total phenol R^2 (0.918) and for antioxidant R^2 (0.99). Activation energy (E_a) were 18.52 KJ mol^{-1} for total phenol and 45.08 KJ mol^{-1} for antioxidant. From Erying-Polany model (Table 3) we get R^2 (0.87) for total phenol and 0.99 for antioxidant. The activation enthalpy (ΔH) and entropy (ΔS) for total phenol was 14.89 KJ mol^{-1} and -244.60 JK^{-1}mol^{-1}, and for antioxidant activation enthalpy (ΔH) and entropy (ΔS) were 41.195 KJ mol^{-1} and -168.025 JK^{-1}mol^{-1}.

Conclusion:

This present study evaluated the effect of heat treatment on the kinetic behaviour of phenolic compounds degradation and antioxidant loss from bael juice which had been best defined through first-order kinetic model. Arrhenius and Eyring-Polany model well represented the temperature dependence of the degradation rate constant.

Acknowledgement:

The authors would like to acknowledge the UGC (University Grant Commission), New Delhi, for providing the financial assistance for the research work.

Authors' affiliations:

Ipsita Banerjee, Department of Food Technology and Biochemical Engineering, Jadavpur University, **Kolkata (W.B.) India**
(Email : ipsita.banerjee4@gmail.com)

REFERENCES

Benzie, I.F. and Strain, J.J.(1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Anal Biochem.*, **239** (1):70-76.

Corradini, M.G. and Pleg, M. (2006). Prediction of vitamins loss during non-isothermal heat processes and storage with non linear kinetic models. *Trends Food Sci. & Technol.*, **17**: 24-34.

Garau, M.C., Simal, S., Rosellü, C. and Femenia, A. (2007). Effect of air drying temperature on phphysico-chemical properties of dietary fibre and antioxidant capacity of orange (*Citrus aurantium v. Canoneta)* by-products. *Food Chem.*, **104** : 1014-1024.

Henriquez, C., Cordova, A., Almonacid, S. and Saavedra, J. (2014). Kinetic modeling of phenolic coupound degradation during drum drying of apple peel by-products. *J. Food Engg.*, **143** :146-153.

Jaiswal, A.K. and Abu-Ghannam, N. (2013). Degradation kinetic modeling of colour, texture, polyphenols and antioxidant capacity of York cabbage after microwave processing. *Food Res. Internat*., **53** (1): 125-133.

Jaiswal, A.K., Gupta, S. and Abu-Ghannam, N. (2012). Kinetic evaluation of colour, texture, polyphenols and antioxidant capacity of Irish York cabbage after blanching treatment. *Food Chem.,* **131**(1) : 63-72.

Janovitz-Klapp, A.H., Richard, F.C., Goupy, P.M. and Nicolas, J.J. (1990). Inhibition studies on apple polyphenol oxidase. *J. Agric. Food Chem.*, **38** (4) : 926-931.

Kenghe, R.N. and Zambre, A.V. (2009). Effect of preservation on biochemical qualities of blended bael RTS. *Bev. Food World*, **36** (4) : 51-52.

Lanny, Sapei and Lie, Hooa (2014). Study on the kinetics of vitamin C degradation in fresh strawberry juices. *Procedia Chem.*, **9** : 62-68.

Lin, Y.C. and Chou, C.C. (2009). Effect of heat treatment on total phenolic and anthocyanin contents as well as antioxidant activity of the extract from *Aspergillius* awamori-fermented black soyabins, a healthy food ingredient. *Internat. J. Food*

Sci. Nutr., **60**(7): 627-636.

Loannou, I., Hafsa, I., Hamdi, S., Charbonnel, C. and Ghoul, M. (2012). Review of the effects of food processing and formulation on flavonol and anthocyanin behaviour. *J. Food Engg.*, **111** : 208-217.

Maity, P., Hansda, D., Bandyopadhyay, U. and Mishra, D.K. (2009). Biological activities of crude extracts and chemical constituents of bael, *Aegle marmelos* (L.) Corr. *Indian J. Experimental Biol.*, **47** : 849-861.

Mazur, S.P., Nes, A., Wold, A.B., Remberg, S.F., Martisen, B.K. and Aaby, K. (2014). Effects of ripeness and cultivar on chemical composition of strawberry (Fragaria x ananassa Duch.) fruits and their suitability for jam production as a stable product at different storage temperature. *Food Chem.*, **146**: 412-422.

Mrad, N.D., Boudhrious, N., Kechaou, N., Courtois, F. and Bonazzi, C. (2012). Influence of air drying temperature on kinetics,physico-chemical properties, total phenolic content and ascorbic acid of pears. *Food & Bioprod. Proces.*, **90** : 433-441.

Nidhi, Gehlot, R., Singh, R. and Rana, M.K. (2008). Changes in chemical composition of ready-to-serve bael-guava blended beverage during storage. *J. Food Sci. Technol*., **45**(4):378-380.

Patel, P.K., Jyoti, S., Lokesh, S., Narendra, K.P. and Dubey, B.K. (2012). Aegle marmelos: A review on its medicinal properties. *Internat. J. Pharm. Phytopharmacal. Res.*, **1**(5): 332-341.

Paul, R. and Ghosh, U. (2012). Effect of thermal treatment on ascorbic acid content of pomrgranate juice. *Indian J. Biotechnol*., **11**(3): 309-313.

Rahman, S. and Pravin, R. (2014). Therapeutic potential of *Aegle mammelos* (L.)- An overview. *Asian Pac. J. Trop. Dis.*, **4** (1):71-77.

Rangana, S. (1986). Handbook of analysis and quality control for fruit and vegetable products, 2nd Edn (Tata McGraw Hill Publishing Company Ltd.New Delhi): 105-106.

Remini, H., Mertz, C., Belbahi, A., Achir, N., Dornier, M. and Madani, K. (2015). Degradation kinetic modelling of ascorbic acid and colour intensity in pasteurised blood orange juice during storage. *Food Chem*., **173** : 665-673.

Shi, J. and Le Maguer, M. (2000). Lycopene in tomatoes: Chemical and physical properties affected by food processing. *Critical Rev. Food Sci. & Nutr.*, **40**(1) : 1-42.

Singh, A., Sharma, H.K., Kumar, S. and Upadhyay, A. (2014). Effect of pretreatments on physical and thermal properties of bael (*Aegle marmelos* Correa) fruit pulp during storage. *Austin J. Nutr. Food Sci.*, **2**(4):1-8.

Singh, A., Sharma, H.K., Kumar, S., Upadhyay, A. and Mishra, K.P. (2013). Comparative effect of crude and commercial enzyme on the juice recovery from bael fruit (*Aegle marmelos* Correa) using principle component analysis. *Internat. J. Food Sci.*, doi:10.1155/2013/239839.

Singh, A.K. and Nath, N. (2004). Development and evaluation of whey protein enriched bael (*Aegle marmelos*) fruit beverage. *J. Food Sci. Techol*., **41**(4) :432-436.

Singleton, V.L. and Rossi, J.A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents. *Am. J. Enol. Viticult.*, **16** : 144-153.

Sonawane, S.K. and Arya, S.S. (2015). Effect of drying and storage on bioactive components of jambhul and wood apple. *J. Food Sci. Technol.*, **52**(5) : 2833-2841.

Suvimol, C. and Pranee, A. (2008). Bioactive compounds and volatile compounds of Thai bael fruit [*Aegle marmelos* (L.) Correa] as a valuable source for functional food ingredients. *Internat. Food Res. J.*, **15**: 45-63.

Verma, S. and Gehlot, R. (2006). Development and evaluation of bael beverages. *Haryana J. Hort. Sci.*, **35**(3/4) : 245-248.

Vikram, V.B., Ramesh, M.N. and Prapulla, S.G. (2005). Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional method. *J. Food Engg*., **69** : 31-40.

Youssef, K.M. and Mokhtar, S.M. (2014). Effect of drying methods on the antioxidant capacity, color and phytochemicals of *Portulaca oleracea* L. Leaves. *J. Nutr. & Food Sci.*, **4**(6). DOI: 10.4172/2155-9600.1000322.

Zhang, Dopnglin and Hamauza, Yasunori (2004). Phenolics, ascorbic acid,carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chem.*, **8**(4) : 503-509.

Zhou, Linyan, Zhenzhen, Cao, Jinfeng, Bi, Jianyong, Yi, Qinqin, Chen, Xinye, Wu and Mu Zhou (2016). Degradation kinetics of total phenolic compounds, capsaicinoids and antioxidant activity in red pepper during hot air and infrared drying process. *Internat. J. Food Sci. & Technol.*, **51**: 842-853.

Effect of pretreatments on drying attributes and quality assessment of bael powder

Ipsita banerjee, Research scholar, Jadavpur University, Kolkata, India,

ipsita.banerjee4@gmail.com

Uma Ghosh, Professor, Jadavpur University, Kolkata, India, ughoshftbe@yahoo.co.in

Abstract Drying is an important method in long term storage of agricultural products. Present experiment was performed to determine the effect of different pretreatment such as steam blanched, 1% sugar and 1% sodium benzoate in bael pulp along with untreated using hot air dryer at 50 to 70°C temperature during drying. Falling rate period was observed. The dehydration characteristic became analyzed through mathematically fitting the drying results which were obtained by experiments to Newton, Page and Two-term drying models. R^2, chi-square and root mean square error of moisture ratios were estimated to determine the best fit model. Result showed that Two term model is best to describe the dehydration characteristics of bael pulp. The bael powder was analyzed for its quality characteristics in respect of phenols, ascorbic acid, antioxidant, carotenoid and sensory test before packaging and during storage. The sample dried at 60°C pretreated with 1% KMS was showed best results.

Keywords - Antioxidant, ascorbic acid, carotenoid, drying, hot air dryer, models, phenol

I. INTRODUCTION

Bael (*Aegle marmelos*) is a native fruit of India which is belongs to family Rutaceae[1]. It is very important due to its medicinal value. Bael fruit consist of many useful compounds i.e. phenolics, alkaloids, carotenoids, flavonoids, coumarins, pectins, tannins and terpenoids [2], [3]. It is one of the nature's wealthy source of antioxidants and is very useful for health. It also has amazing aroma. As bael is a seasonal fruit and is not available throughout the year. So preservation can be used to reduce post harvest losses and retain of nutrition. Drying is one of the most common methods for preservation of bael fruit pulp for longer time. The dried products have very long shelf-life at ambient temperature. Drying can be described as the employment of heat under managed conditions to eliminate the maximum amount of water usually present in a food with the aid of evaporation. In drying heat penetrates into the product and moisture is eliminated by evaporation. Among different types of drying tray drying is the most cost effective method.

However excessive moisture content of bael can result rapid deterioration after cropping. Hence, the dehydration is used to enhance the stability of fruits by means of reducing the water activity to decrease physical and chemical reactions which could arise during storage. However thermal treatments result degradation reaction and are believed to cause destruction of natural antioxidants in food [4],[5],[6].Two important variables to be controlled are temperature of treatment and its duration[7]. There is also economic importance of dehydrated bael powder which used in formulated drinks, baby foods and other products. Very limited works have been done on bael powder. The objective of this study is to investigate effect of temperature and pretreatment on quality of bael powder.

II. MATERIALS AND METHODS

Mature fruits were bought from local market then fruits were washed under running water and scooped out the pulp after removing its hard shell. After removal of seeds1st part of pulp (200 g) dried without any pretreatment used as control. 2nd part (200 g) steam blanched for 5 min, 1% sugar added in 3rd part (200g) and 1% KMS added with 200 g pulp (4 th part). Samples were dried at 50^0C, 60^0C and 70^0C. Moisture removal was analyzed after every 30 mins interval until the equilibrium moisture reached.After drying samples were grounded in mixer grinder to produce bael powder and packed in polyethylene packet and stored for further studies.

A. Analytical parameters

The % moisture content of different substrates was measured on the basis of initial weight of the samples [8]. The loss in weight was reported as moisture %.

$$\% \text{ moisture (d.b)} = \frac{\text{moisture content (w.b)}}{100-\text{w.b}} \times 100$$

Total phenolic content of bael pulp was determined by folin-ciocalteu method [9] at a wavelength of 765 nm using gallic acid standard and expressed as mg of gallic acid/g of fruit. Ascorbic acid of bael pulp was determined by titrimetric method [8].

Antioxidant content was determined by FRAP method and the value expressed as mM $FeSO_4$ /g fruit [10].

 DOI : 10.18231/2454-9150.2018.1074

Total carotenoids of bael pulp had been measured in step with the method of Talcott and Howard (1999) [11].

Descriptive sensory evaluation became done to decide the impact of drying on the sensory quality of bael powder. A 10-untrained member of sensory panel [12] was used for evaluation. The characteristics considered were colour, taste, aroma and overall acceptability (OA).

B. Mathematical modeling of moisture removal

The reduction of moisture ratio with drying time was used to analyze the experimental drying data. The moisture ratio (MR) was calculated [13] as follows:

$$MR = \frac{M_t - M_e}{M_i - M_e}$$

Where MR= Moisture Ratio, M_t= Moisture content in time t (% db), M_e=Equilibrium moisture content (% db), M_i=Initial moisture content (% db)

To describe drying behaviour of pretreated bael three different established thin layer drying were used [14], [15], [16]:

Newton model: MR= exp(-kt)
Page model: MR= exp($-kt^n$)
Two term model : MR= a exp(-kt)+ b exp (-gt)

Chi-square value (χ^2) [17]:

$$\chi^2 = \frac{\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}{N - z}$$

Root mean square error [18]:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (MR_{exp,i} - MR_{pre,i})^2}$$

Where: MR_{exp} = Experimental moisture ratio, MR_{pred} = Predicted moisture ratio, N = Number of observations, z = Number of constants

III. RESULTS AND DISCUSSION

The initial moisture content of bael pulp was 66% (w.b). The experiments were performed at temperature ranging from 50-70º C until final moisture reached. In the initial stage of drying the decrease of moisture content was high due to the presence of high moisture. The amount of moisture reduction decreases with increasing time. These results were very similar with previous research work [16]. Results showed in fig 1-3 that drying time reduced with increasing temperature for all samples may be the result of increasing vapour pressure within the samples with increasing temperature. As a result of it moisture removed quickly from samples. The graph shows falling rate period.

Moisture ratio reduced constantly with drying process. Diffusion which has governed the inner mass transfer might be the reason of continuous decrease in moisture ratio. Decrease of moisture ratio was faster with increasing temperature[16]. Results showed that pretreatment have positive effect on moisture ratio.

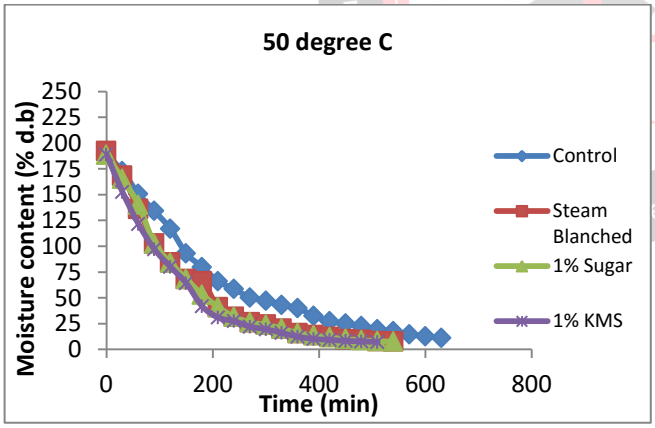


Fig.1

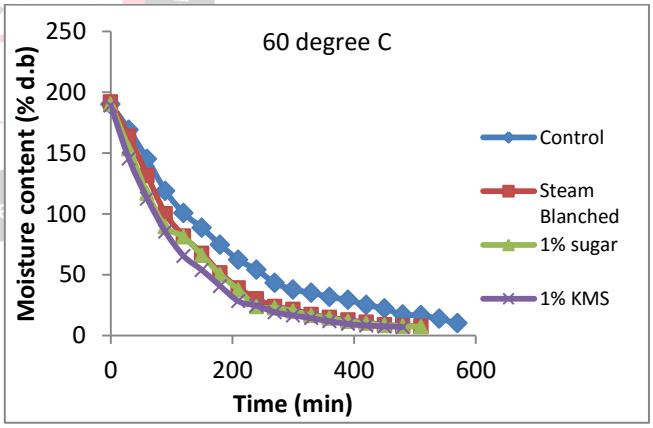


Fig.2

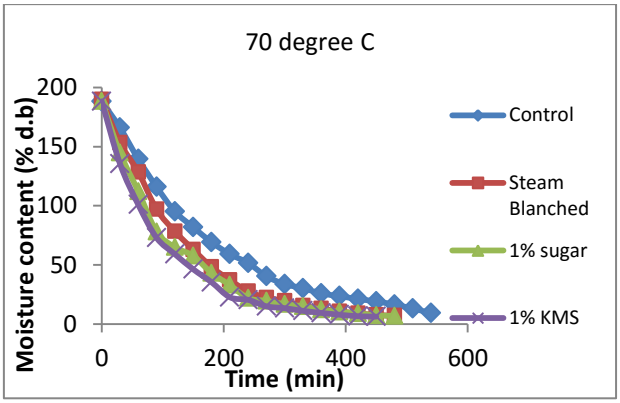


Fig.3 Moisture content against drying time curve of untreated and pretreated bael pulp dried at (Fig 1) 50, (Fig 2) 60 and (Fig 3) 70 °C

 DOI : 10.18231/2454-9150.2018.1074

In this experiment the most acceptable model was shown by statistical analysis (SPSS) among three drying models suggested by previous researchers[16], [19]. RMSE, chi-square values and R^2 values were given in table 1. Depending on lowest RMSE, chi-square value and highest R^2 value the suitable kinetic model was selected. All three models shown high R^2 value (0.984-0.999) which indicate drying characteristics of bael pulp could satisfactorily describe by these models. Among all models the Two term model shows the highest R^2 (0.999-0.996), lowest RMSE (0.009-0.0188) and χ^2 (0.00008-0.00039).

Table 1 Statistical results of three thin-layer drying models

Temperature	Sample	Model								
		Newton model			Page model			Two term model		
		R^2	Chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE	R^2	chi-square (χ^2)	RMSE
50^0C	Control	0.984	0.00157	0.039	0.995	0.0005	0.0211	0.996	0.00039	0.0188
	Steam Blanched	0.989	0.00104	0.031	0.996	0.0004	0.019	0.996	0.00049	0.0197
	1% sugar	0.993	0.0006	0.024	0.997	0.0003	0.016	0.997	0.0003	0.016
	1% KMS	0.991	0.0008	0.028	0.9975	0.0002	0.014	0.9975	0.0002	0.014
60^0C	Control	0.989	0.0011	0.032	0.996	0.0004	0.0183	0.9966	0.00035	0.01677
	Blanched	0.992	0.0008	0.027	0.998	0.0002	0.013	0.998	0.0002	0.013
	1% sugar	0.995	0.0004	0.02	0.997	0.0003	0.017	0.997	0.0003	0.016
	1% KMS	0.9965	0.0003	0.017	0.9979	0.0002	0.013	0.998	0.0002	0.012
70^0C	Control	0.989	0.0010	0.031	0.9976	0.0002	0.015	0.9976	0.00027	0.014
	Blanched	0.995	0.0005	0.022	0.9986	0.0001	0.0094	0.999	0.00009	0.009
	1% sugar	0.997	0.0003	0.015	0.997	0.0002	0.015	0.997	0.0003	0.015
	1% KMS	0.9984	0.0001	0.01	0.999	0.0001	0.010064	0.999	0.00008	0.009

The most acceptable model for bael pulp drying was estimated by comparing the predicted moisture ratio against experimental moisture ratio in fig 4-7. It was shown that Two term model was accurate for describing the drying attributes of bael pulp.

 DOI : 10.18231/2454-9150.2018.1074

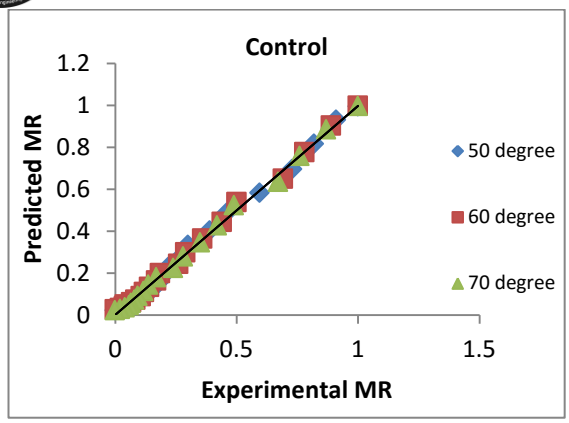


Fig 4

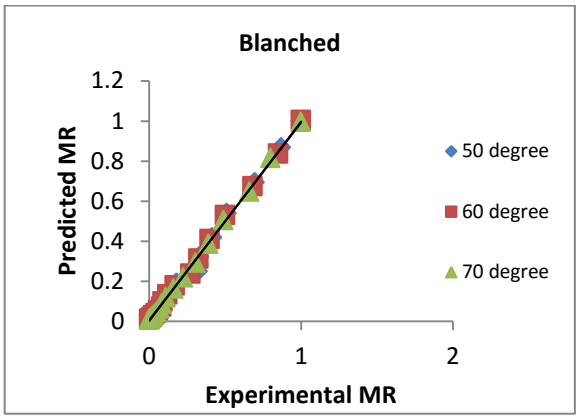


Fig 5

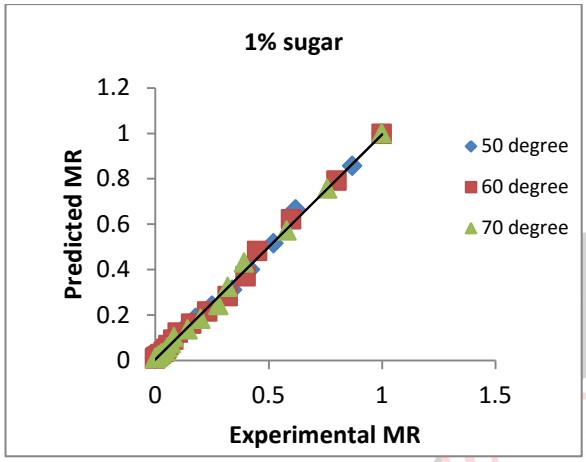


Fig 6

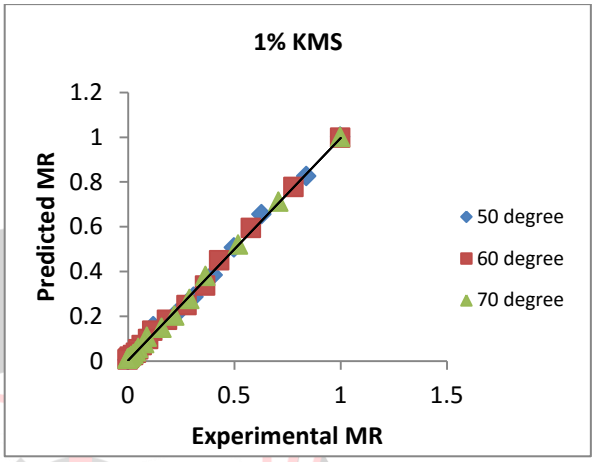


Fig 7

(Fig 4-7) Comparison of predicted vs experimental value

Results revealed that vitamin C degraded with increasing temperature. Vitamin C most affected by temperature and time of storage. Vitamin C is very unstable during heat treatment. Vitamin C content degenerated during drying involves oxidation and hydrolysis [20]. It was observed from fig 8 that all pretreated sample retained more vitamin C than untreated sample. Among all pretreatments sample with 1% KMS showed maximum amount of vitamin C (1.21 mg/100 g) at 60^0C after 3 months of storage which was followed by steam blanched and 1% sugar samples.

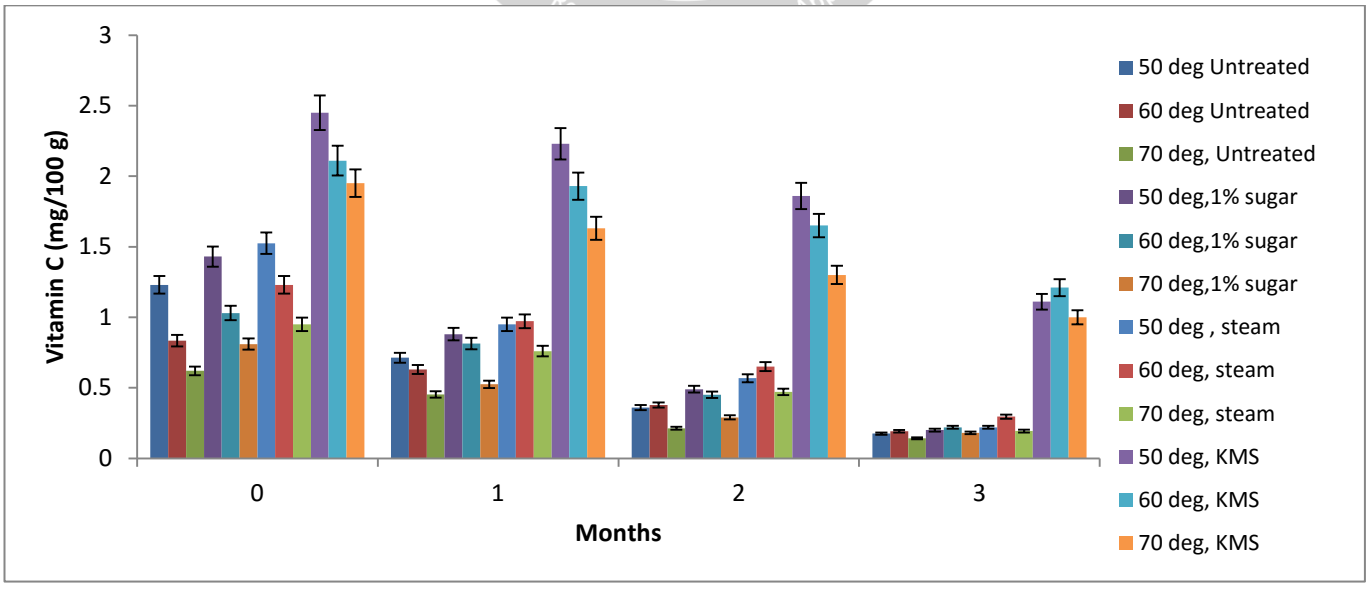


Fig 8: Storage study of vitamin C

Degradation of phenolic content increased with time and temperature. Thermal breakdown of polyphenols can happen during drying that can affect the cell structure [21]. Phenolic compounds degraded due to the effect of polyphenol oxidase (PPO)

 DOI : 10.18231/2454-9150.2018.1074

enzymatic activity [22]. Result showed that total phenol content degraded during storage [23]. PPO protein utilized polyphenols as substrate which cause degradation of phenolic compounds [24]. It was obtained from fig 9 that maximum retention of total phenol observed in sample with 1% KMS at 60°C (24.33 mg GAE/g) and steam blanched 24.05 mg GAE/g and sample with 1% sugar 19.69 mg GAE/g after 3 months of storage.

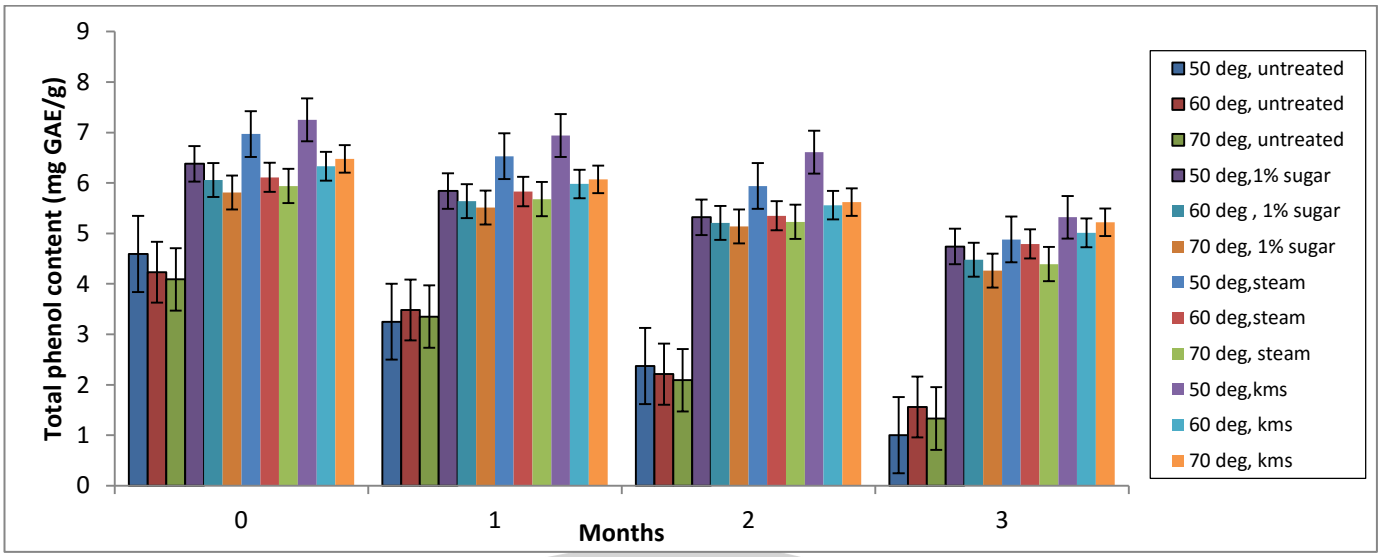


Fig: 9 Storage study of Total phenol content

Result showed that maximum retention of carotenoid in sample with KMS at 50^{0}C (6.61µg/g) which was followed by steam blanched (5.94 µg/g) and sample with 1% sugar (5.32 µg/g). As carotenoid was heat sensitive and sensitive to oxidative degradation [25] for this carotenoid degraded at higher temperature.

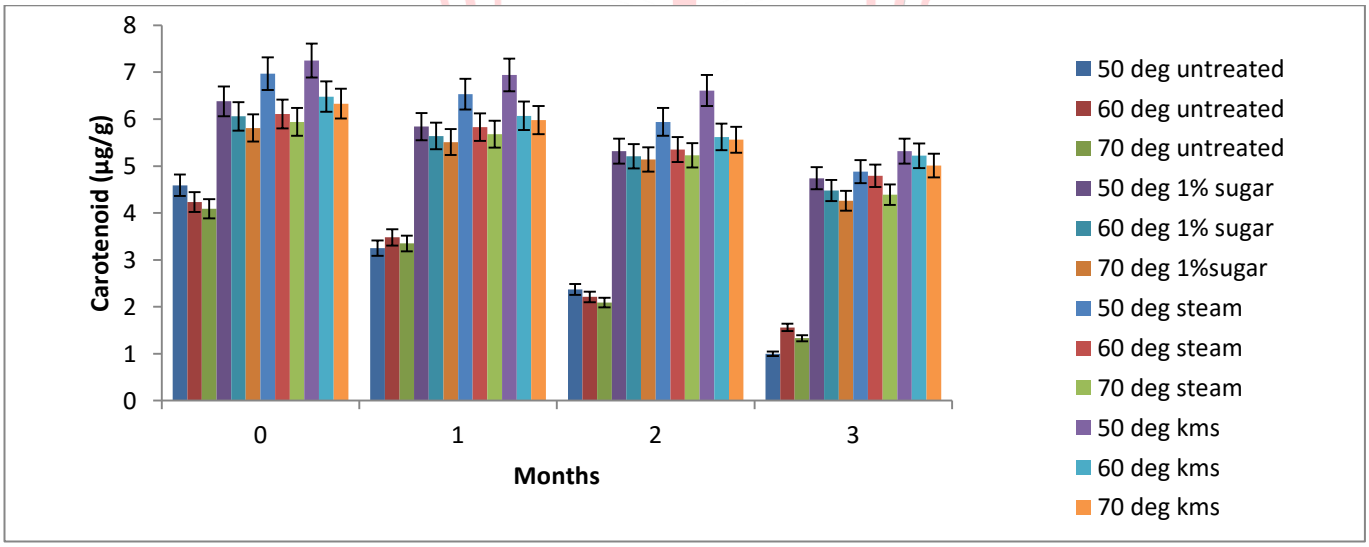


Fig: 10 Storage study of carotenoid content

. Result showed that antioxidant declined during storage in all temperature for all samples. Degradation of total antioxidant increased significantly with increasing storage period. This might be due to reduction of ascorbic acid and phenolic compounds during storage [26] that probably liable for HAP contribution in the powder. The loss of total antioxidant was slightly lower in the pretreated samples during storage. This might be due to pre treatment effect as well as effect of other factors like temperature and storage period on the powder which might have caused this change. Maximum retention of antioxidant showed in sample with KMS 18.89 mM $FeSO_4$/g.

 DOI : 10.18231/2454-9150.2018.1074

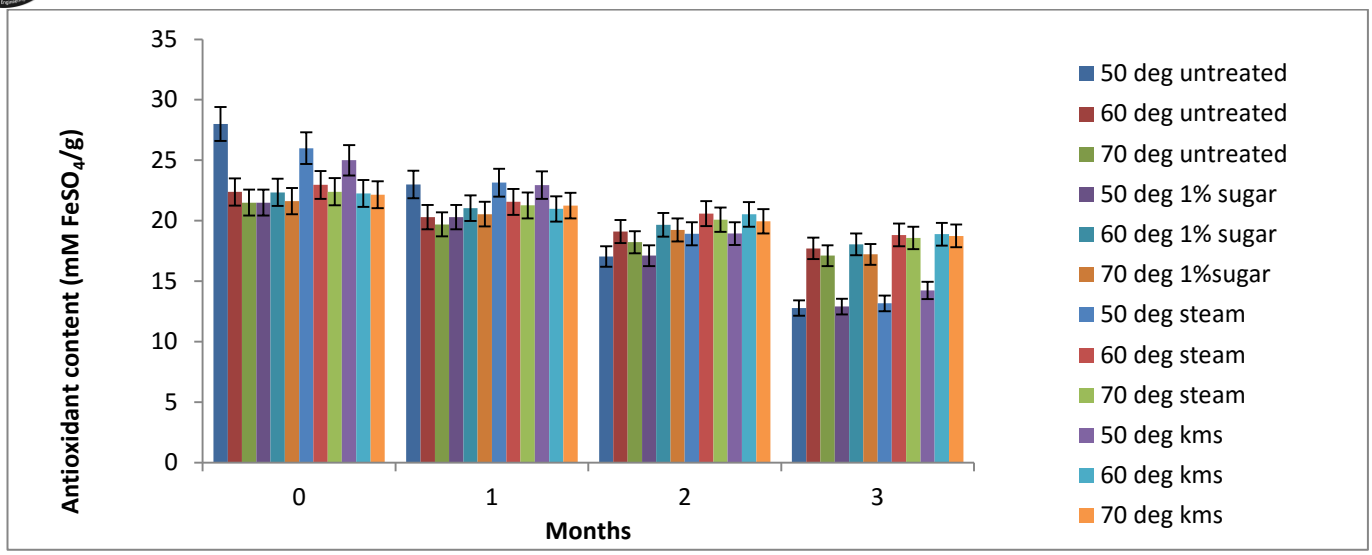


Fig: 11 Storage study of Antioxidant content

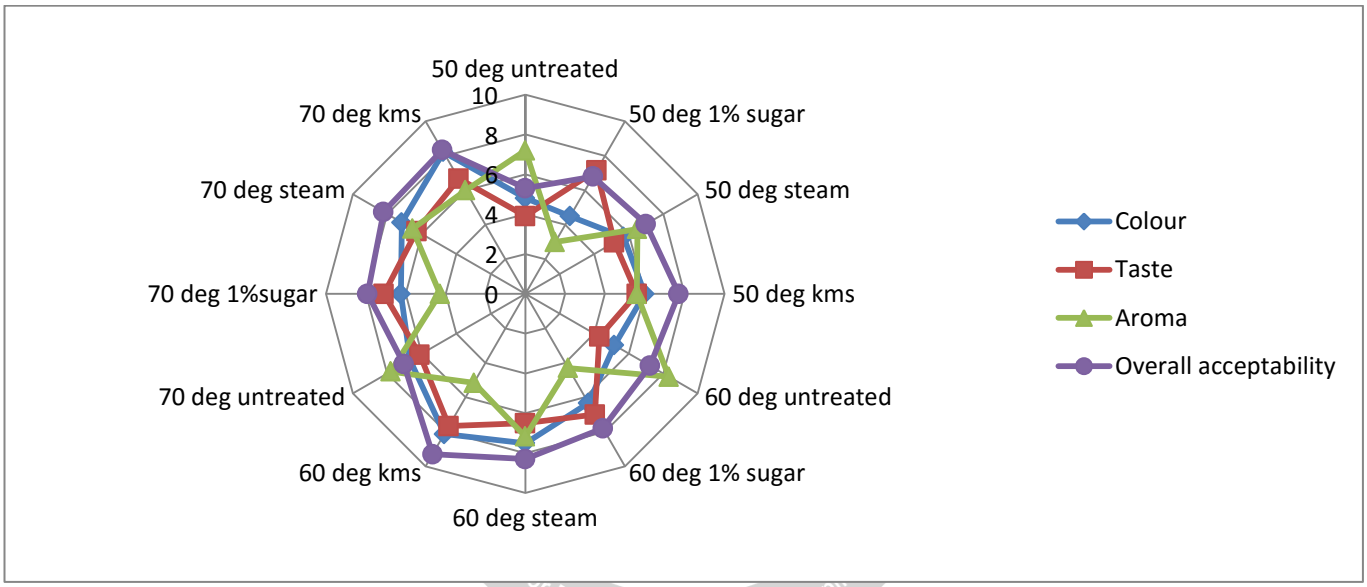


Fig 12: Descriptive analysis on sensory score of bael powder

It was observed that sensory score decreased gradually with increase in storage period at room temperature. The score was significantly decreased during storage. Similar findings were reported by Satkar et al. (2013) [27]. Temperature plays an important role in biochemical changes that leads to development of off flavour as well as discolouration in the beverages. The best sample with high sensory score was sample with 1% KMS.

IV. CONCLUSION

From this experiment it can be concluded that temperature and storage affect the nutritional quality of bael powder. Pretreatment have positive effect on bael powder. Best retention of nutritional quality was observed with samples pretreated with 1% KMS followed by dehydration at 60°C in tray dryer.

ACKNOWLEDGMENT

We would like to thank the University Grant Commission, Government of India for their financial assistance.

REFERENCES

[1] A K Singh, A K. Chaurasiya , "Post Harvest Management and value addition in Bael (Aegle marmelos Corr.)", International Journal of Interdisciplinary and Multidisciplinary Studies (IJIMS)., vol. 1, no.9, pp. 65-77, 2014.

[2] P Maity, D Hansda, U Bandyopadhyay, and D. K. Mishra, "Biological activities of crude extracts and chemical constituents of bael, Aegle marmelos (L.) Corr",. Indian Journal of Experimental Biology., vol.47, pp.849−861, 2009.

[3] C Suvimol, and A Pranee, "Bioactive compounds and volatile compounds of Thai bael fruit (Aegle marmelos

 DOI : 10.18231/2454-9150.2018.1074

(L.) Correa) as a valuable source for functional food ingredients", International Food Research Journal, vol.15, pp. 45−63, 2008.

[4] V B Vikram, M N Ramesh and S G Prapulla , "Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional method", J Food Eng. Vol.69, pp.31-40, 2005 .

[5] S P Mazur, A Nes, A B Wold, S F Remberg, B K Martinsen, K. Aaby , Effects of ripeness and cultivar on chemical composition of strawberry (Fragaria x ananassa Duch.) fruits and their suitability for jam production as a stable product at different storage temperatures. Food Chem. Vol.146, pp. 412–422, 2014.

[6] H Remini , C Mertz , A Belbahi , N Achir , M Dornier ,K Madani, " Degradation kinetic modelling of ascorbic acid and colour intensity in pasteurised blood orange juice during storage", Food Chemistry vol.173, pp.665-673, 2015.

[7] I Loannou , I Hafsa , S Hamdi , C Charbonnel and M Ghoul, "Review of the effects of food processing and formulation on flavonol and anthocyaninbehaviour", Journal of Food Engineering. Vol.111, no.2, pp.208-217, 2012.

[8] S Rangana , Handbook of analysis and quality control for fruit and vegetable products. 2nd edn (Tata McGraw Hill Publishing Company Ltd, New Delhi), 1986.

[9] V L Singleton and J A Rossi, " Colorimetry of total phenolics with phosphomolybdic-phosphotungestic acid reagents", Am J Enol Viticult. Vol.16, pp.144-153, 1965.

[10] R A Moyer, K E Hummer, C E Finn, B Frei, and R E Wrolstad, "Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: Vaccinium, Rubus, and Ribes", J. Agr. Food Chem. Vol.50, pp.519–525, 2002.

[11] S T Talcott and L R Howard, "Phenolic autoxidation is responsible for color degradation in processed carrot puree", Journal of Agricultural and Food Chemistry. Vol.47, no.5, pp.2109–2115, 1999.

[12] K P Suresh and V R Sagar, "Drying kinetics and physico-chemical characteristics of Osmo- dehydrated Mango, Guava and Aonla under different drying conditions", J Food Sci Technol vol.51, no.8, pp.1540-1546, 2014.

[13] T Y Tunde-Akintunde and G O Ogunlakin, "Mathematical modeling of drying of pretreated and untreated pumpkin", J Food Sci Technol vol.50, no.4, pp.705-713, 2013.

[14] A S Mujumdar , Handbook of industrial drying (second ed. New York): Marcel Dekker, 1995.

[15] S Singh, R Sharma, A S Bawa, D C Saxena , "Drying and rehydration characteristics of water chestnut (Trapa natans) as a function of drying air temperature. J Food Eng, vol.87, pp.213-221, 2008.

[16] A Singh , H K Sharma, N Kumar, A Upadhyay, and K P Mishra, "Thin layer hot air drying of bael (Aegle marmelos) fruit pulp", International Food Research Journal vol.22, no.1, pp.398-406, 2015.

[17] Qing-An Zhang, Yun Song, Xi Wang, Wu-Qi Zhao and Xue-Hui Fan, "Mathematical modeling of debittered apricot (Prunus armeniaca L.) kernels during thin-layer drying", CyTA - Journal of Food. Vol.14, no.4, pp.509-517, 2016.

[18] Akoy E O M, "Experimental characterization and modeling of thin-layer drying of mango slices", International Food Research Journal. Vol.21, no.5, pp.1911-1917, 2014.

[19] K Rayaguru, and W Routray, "Mathematical modeling of thin layer drying kinetics of stone apple slices", International Food Research Journal vol.19, no.4, pp.1503-1510, 2012.

[20] S Thankitsunthorn , C Thawornphiphatdit , N Laohaprasit and G Srzednicki, "Effects of drying temperature on quality of dried Indian Gooseberry powder", International Food Research Journal. Vol.16, pp.355-361, 2009.

[21] K M Youssef, S M Mokhtar, "Effect of Drying Methods on the Antioxidant Capacity, Color and Phytochemicals of Portulaca oleracea L. Leaves", J Nutr Food Sci 4:322. doi: 10.4172/2155-9600.1000322, 2014.

[22] S K Sonawane and S S Arya, "Effect of drying and storage on bioactive components of jambhul and wood apple", J Food Sci Technol. Vol.52, no.5, pp. 2833-2841, 2015.

[23] C Serea, O Barna, M Manley and M Kidd, "Effect of storage temperature on the ascorbic acid content, total phenolic content and antioxidant activity in Lettuce (Lactuca sativa L.)", The Journal of Animal & Plant Sciences. Vol.24, no.4, pp.1173-1177, 2014.

[24] A H Janovitz-Klapp, F C Richard, P M Goupy and J J Nicolas, "Inhibition studies on apple polyphenol oxidase", J. Agric. Food Chem. Vol.38, no.4, pp.926-931, 1990.

[25] R M N A Wijewardana, S B Nawarathne and I Wickramasinghe, "Effect of various dehydration methods on proximate composition and retention of antioxidants in different fruit powders", International Food Research Journa,l vol.23, no. 5, pp.2016-2020, 2016.

[26] I Klimczak, M Małecka, M Szlachta, and A Gliszczyńska-Świgło, "Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices". Journal of Food Composition and Analysis, vol.20, no.3, pp.313-322, 2007.

[27] K P Satkar, A A Kulthe and P R Chalke, "Preparation of bitter gourd ready-to-serve beverage and effect of storage temperature on its keeping quality. The Bioscan. Vol.8, no.1, pp.115-117, 2013.

 DOI : 10.18231/2454-9150.2018.1074