

**PRODUCTION TECHNOLOGY OF
DEHYDRATED BOTTLE GOURD SHREDS**

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ABSTRACT

Bottle gourd (*Lagenaria siceraria*) is an important vegetable which play a significant role in human diet and it is belonging to the Cucurbitaceae family. It is difficult to consume fresh bottle gourd to meet daily recommended requirement because of tedious task of processing. For convenience in adoption of bottle gourd for daily use or in diet, it is more convenient to be converted into dried/dehydrated shreds or powder form; so as to make it available as and when required. Preparation of bottle gourd shreds or powder is one of the viable technologies for utilization of bottle gourd fruits. Experiments were carried out for standardizing the processing and storage parameters for production of dehydrated bottle gourd shreds. Different sized shreds (3, 5 and 7 mm thickness) were prepared by shredding machine. Steam blanching was carried out to inactivate POD enzyme and the process was optimized based on minimum POD inactivation time, maximum ascorbic acid content, maximum TSS and minimum juice yield. The optimized steam blanching treatment was 6 min POD inactivation in 3 mm size shreds. The ascorbic acid content, TSS and juice yield was 7.084 mg/100 g, 2.83 °Brix and 62.93%, respectively. Optimized shreds were utilized for further dehydration process. The shreds were pre-dried in microwave continuous dryer (MCD) at constant conveyor speed (0.3 cm/s) and final dehydration was carried out by fluidized bed dryer (FBD) at different drying temperature (55, 60 and 65 °C) and air velocity (6, 8 and 10 m/s). Optimization of dehydration parameters were accomplished on the basis of dehydration time, ascorbic acid content, colour value (ΔE^{*ab}) and rehydration characteristics of bottle gourd shreds. The best results were found at 65 °C drying temperature and 10 m/s air velocity of fluidized bed dryer, as the ascorbic acid content was found 5.68 mg/100g, rehydration ratio was 12.93%, colour value (ΔE^{*ab}) was 1.33 and minimum dehydration time was 58.56 min. Pre-treated optimized dehydrated bottle gourd shreds were filled in polypropylene pouch and metalized laminated pouch to conduct storage study for 120 days at ambient condition. Stored samples were analysed for its sensory characteristics, physico-chemical characteristics and microbial characteristics at the interval of 15 days. Sensory score for optimized sample was more than the control samples. In ascorbic acid no significant difference was found for all samples but it decreases faster in control sample packed in polypropylene pouch and metalized laminated pouch during storage study. For colour values (ΔE^{*ab}) significant difference was found during storage period. Dehydrated sample packed in polypropylene pouch and metalized laminated pouch were microbiologically safe over the control samples. Calcium and potassium content were found more in optimized sample over the control samples. Dehydrated sample packed in metalized laminated pouch was found better than the other sample during shelf life study.

Key words: Bottle gourds; Blanching; POD; Dehydration; Storage; Sensory; Physicochemical; Microbiological



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CERTIFICATE

This is to certify that the thesis entitled “**PRODUCTION TECHNOLOGY OF DEHYDRATED BOTTLE GOURD SHREDS**” submitted by **Patel Hiralben Amrutbhai** (Reg. No. 04-3256-2017) in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Food Technology** at the Anand Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision.

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LIST OF ABBREVIATIONS AND SYMBOLS

Particular	Description
±	Plus or minus
%	Percent
°C	degree Celsius
µg	micro gram
AFD	atmospheric freeze-dried
ANOVA	Analysis of variance
Ca	Calcium
CD	Critical difference
CFD	Computational fluid dynamics
cfu	colony forming unit
cm	centimetre
cm ²	centimetre square
CRD	Completely randomized design
CuSO ₄	Cupric sulphate or copper (II) sulphate
CV	Co-efficient of variation
d.b	dry basis
DF	Degree of freedom
F cal	Calculated F value
F tab	Tabulated F value
FBD	Fluidized bed dryer
Fig.	Figure
FSSAI	Food Safety and Standards Authority of India
g	gram
h	hours
H ₂ SO ₄	Sulfuric acid
HCl	Hydrochloric acid
HDPE	High density polyethylene
Hg	mercury
hp	horse power
K	Potassium
K ₂ SO ₄	Potassium sulphate
KMS	Potassium Metabisulphite
kW	kilowatt
LDPE	Low density polyethylene
m	meter
m ³	meter cube
MAFBD	Microwave assisted fluidized bed drying
MCD	Microwave continuous dryer
MFIX	Multiphase flow with Interphase eXchange

mg	milligram
MHz	Mega hertz
Min	minute
mm	millimetre
MS	Mean of square
N	normal
NaOH	Sodium hydroxide
OAA	Overall acceptability
P	power
PDA	Potato dextrose agar
PET	Polyethylene terephthalate
POD	Peroxidase
s	second
SEm	Standard error of mean
SS	sum of square
TPC	Total plate count
USDA	United States Department of Agriculture
W	Watt
w.b	wet basis

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CHAPTER I

INTRODUCTION

India is that the second largest producer of fruits and vegetables in the world. Fruits and vegetables are reservoir of vital nutrients. Fruits and vegetables play a major role in Indian agriculture by providing food, nutritional and economic security and more importantly, producing higher returns per unit area. As compare to fruits, vegetables have higher productivity, shorter maturity cycle and greater income leading to improved livelihoods (Mattu, 2014). Among vegetables bottle gourd have higher place in daily diet. The bottle gourd fruit is yellowish green, having the shape of a bottle. It has white pulp, while white seeds embedded in spongy flesh. It contains glucose, pentose, lignin and shikimic acid while white raw fruits contain carotene and some vitamins and rich in calcium, iron and phosphorous. The nutritional value of the bottle gourd kernels is equal or better than that of cashew nut and almond kernels. The seed coats are low in fat and protein but quite rich in crude fiber and mineral matter. (Herwig, 2004).

The bottle gourd fruit contains moisture (94.5%), carbohydrates (2.9%), protein (1.2%), fat (0.2%), ash content (0.5%), fiber (0.7%), thiamine (0.03 mg), riboflavin (0.05 mg), niacin (0.3 mg) and ascorbic acid (12 mg) per 100 g . Bottle gourd contains calcium (12 mg), phosphorous (37 mg), sodium (1.7 mg), potassium (87 mg), chromium (0.05 mg), iron (0.8 mg) per 100 g. Minerals are important for vital body functions such as acid base and water balance (Hanif *et al.*, 2006). Bottle gourd contains 1.6% choline; a precursor to acetylcholine, a chemical used to transfer nerve impulses and hence, it is believed to have neurological effects (Thomas, 2008). Bottle gourd contains highest source of choline level, which gives a lipotropic factor, a healer of mental disorders, along with required metabolic and metabolite precursors for brain function, amongst any other vegetable. Bottle gourd is cardiogenic, laxative cooling, diuretic, antebellum whole some to the foetus, tonic to liver, anti-periodic, anti-pyretic according to ayurveda and unani (Kirtikar and Basu, 1991). Bottle gourd contains cucurbitacins, polyphenols and two sterols namely; campesterol and sitosterol (Ghule *et al.*, 2007).

Dry hard shells of bottle gourd fruits are used as domestic utensils like bottles, bowls, milkpots, spoons, containers and pipes. Dry shells also use for carrying liquor

(mahua drink, toddy), honey and water. (Sivaraj and Pandravada, 2005). The jelly prepared from bottle gourd pectin possesses good strengthening properties. Tutti frutti is also prepared from bottle gourd (Salunkhe and Kadam, 1998). Kofta is one of the important food recipe preparation in India. The fruit is also used for making raita, pudding like halwa and kheer; sweets like peda and barfi. Fruit juice of bottle gourd with lime is applied on pimple. The seeds are boiled in salt water and consumed as an appetizer. In Ethiopia, the seeds are used in soup preparation (Dhaliwal, 2017).

The bottle gourd fruit is having high medicinal value of considerable importance. Bottle gourd is having cooling effect on human body and easy to digest. It gives relief to patients suffering from urinary disorders, heart problems, and diabetes (Gopalan *et al.*, 1989). Bottle gourd pulp is good for overcoming constipation, cough, night blindness and as an antidote against certain poison. Bottle gourd has immunomodulatory, hepatoprotective, anti-oxidant, anti-stress, adaptogenic, analgesic, anti-inflammatory, cardioprotective, cardiotonic, anti-hyperlipidemic, diuretic, aphrodisiac, alternative purgative, antidote to certain poisons and cooling properties (Ahmad *et al.*, 2011). That's why consumption of bottle gourd is good for health. Thus, to prevent spoilage of bottle gourd, it can be converted to value added products like chutney, paste, juice, dried/dehydrated bottle gourd and many other products.

Drying is an ancient technique of food preservation and for extension of shelf life of foods. Sun drying is the most common method to preserve the agricultural products in many parts of world. It is low cost and easy method. It has some problems related to contamination with dust, soil, sand particles and insects and drying time is quite long. Therefore, in industries mechanical drying is in practice. The main aim of drying is to allow longer periods of storage, minimize packaging requirements and reduce shipping weight (Doymaz, 2006). Preservation of fruits and vegetables, meat, fish and food plants by drying in the sun or in the naturally dry air has been practiced. For the faster drying (i.e. time saving) and more versatility in commercial scale, mechanical drying is the common technique to preserve the foodstuffs (Kumar *et al.*, 2015).

Drying fruits permits their preservation by reducing the water content and therefore inhibiting enzymatic modifications and microbial growth. The important advantages of drying are the reduction in size and weight, facilitating transport and reducing storage space as well as avoiding the expensive cooling systems. Finally, it

increases food diversity, allowing alternative ways of consuming foods (Guine and Castro, 2002). Drying is assessed as batch and continuous supported methodology of operation. It is classified as direct (direct contact of heat) and indirect (indirect contact of heat) based on method of supplying heat. Batch dryers, vacuum shelf dryers, tray dryer, fluidized bed dryer, freeze dryers, microwave dryers and many other types of dryers are used for drying of various food and food products. Fluids and semi fluids are dried in drum dryers. For solutions like slurries and pastes, spray dryers are used (Kulkarni and Goswami, 2015).

Microwave drying has its inherent advantages over conventional heating such as reducing the drying time of biological material without quality loss. In an industrial level, food processing using this technique has been reported to be both cost-effective and feasible (Nindo *et al.*, 2003). Microwave drying targets the water at the core of particulate products that generates relatively high internal vapour pressure. It is possible to produce a porous product. Such a porous product reconstitutes much faster than the ones obtained by using conventional hot air drying. Microwave drying is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material. The most important characteristics of microwave drying is volumetric heating. Conventional heating occurs by convection followed by conduction where heat must diffuse in from the surface of material. Volumetric heating means that material can absorb microwave energy directly and internally convert into heat. In microwave drying, heat is generated throughout the material, leading to faster heating rates, compared to convection heating where heat is usually transferred from the surface to the interior. Microwave drying is caused by water vapor pressure differences between interior and surface regions, which provide a driving force for moisture transfer (Gowen *et al.* 2006).

Microwave dehydration has been successfully tried for different fruits and vegetables. The drying method comprises of subjecting the food pieces to microwave radiation supplying the heat of vaporization directly to water molecules to evaporate the moisture from within food pieces. The moisture content and water activity of the product are thus reduced within a short period of time. Due to short exposure time and maintenance of low temperature, the final product is of better quality. Moreover, the energy consumption is reported to be lower in comparison to other conventional methods of dehydration. (Vadivambal and Jayas, 2007). Microwave drying alone for

high moisture fruits and vegetables has been observed to cause charring of the product. Application of microwave energy in drying of foods may be a good approach to overcome the existing problems in conventional drying methods. On the other hand, the drying process using microwaves is known to yield low quality product if not appropriately applied (Wang *et al*, 2004). Hence, microwave drying has usually been combined with other drying techniques including convective hot air, osmotic, vacuum and freeze drying to achieve more uniform, fast and effective drying without significant quality loss. These combined methods have been observed to have enormous potential for high speed and high quality drying (Yongsawatdigul and Gunasekaran, 1996; Wang *et al.*, 2004).

The main objective of any drying process is to produce a product of desired quality at minimum cost, minimum time and maximum throughput. Drying is cost effective method for preservation of fruits and vegetables. Microwave drying alone can cause charring of the product which contains high moisture, therefore considerable research is being conducted for development of better quality dehydrated bottle gourd shreds with microwave continuous dryer and fluidized bed dryer. Thus, in order to maintain product quality and to reduce drying time, it is necessary to examine different drying parameters used for dehydration of bottle gourd shreds.

Fluidized bed drying is the drying technique in which fluidization of product is take place. Fluidization provides better surface area of heat and mass transfer. Fluidized bed dryer found throughout many industries, from heavy mining through food, fine chemicals and pharmaceuticals. They provide an effective methodology of drying comparatively free flowing particles with a reasonable narrow particles size distribution. The feed may take the form of powders, granules, crystals, seed and non-friable agglomerates. Fluidized bed dryer can process a wide variation of feed rates from pounds to several hundred tons per hour (Kumar and Belorkar, 2015).

Fluidized bed drying technique is a very convenient method of drying for heat sensitive food materials as it prevents them from overheating. Fluidized bed dryers have good possibilities for controlling grain damage as the solids maintain a uniform temperature below the inlet air temperature and it decreases drying time, therefore higher production rates (Giner and Cavelo, 1987). Drying of vegetables shreds or pieces in a fluidized bed dryer, produces final products of excellent quality in a much shorter time than in continuous belt dryers which are generally used for drying. Pre-treatments

are required to produce final products with having good organoleptic properties, good in colour, good rehydration ratio and uniform quality. Fluidized bed drying is very reliable and most economical method for drying of such type of vegetable pieces and shreds (Bobic *et al.* 2002).

It is difficult to consume fresh bottle gourd to meet daily recommended requirement because of tedious task of processing. For convenience in adoption of bottle gourd for daily use or in diet, it is more convenient to be converted into dried/dehydrated shreds or powder form; so as to make it available as and when required. Preparation of bottle gourd shreds or powder is one of the viable technologies for utilization of bottle gourd fruits. However, standard process for preparation of bottle gourd powder is not available having optimum quality attributes. Bottle Gourd contains high amount of water (96.1%) and due to high water activity, it has very short shelf life and deteriorates quickly. To preserve the bottle gourd fruit by removing water to stop water activity, drying is the most important process. Microwave drying takes less time to dry and provide good quality product. However, microwave drying alone for high moisture fruits and vegetables has been observed to cause charring of the product. Fluidized bed drying having selected because more uniform contact of air so, there is more uniform temperature distribution. Hence, microwave drying has been combining with fluidized bed drying to achieve more uniform, fast and effective drying without significant loss in quality of final product. Keeping the above view in mind, the present study was undertaken with the following objectives:

Objectives:-

- 1) Physico-chemical characterization of bottle gourd fruits
- 2) Optimization of steam blanching technique for bottle gourd shreds
- 3) Standardization of dehydration parameters for bottle gourd shreds using microwave assisted fluidized bed dryer and evaluation of quality characteristics
- 4) Shelf life studies of dehydrated bottle gourd shreds

CHAPTER II

REVIEW OF LITERATURE

This chapter illustrates the reviews related to work done on the research undertaken. The chapter covers published information on characterization i.e. proximate and physical analysis of bottle gourd, blanching different fruits and vegetables, drying of different fruits and vegetables and shelf-life of different fruits and vegetables.

2.1 PROXIMATE COMPOSITION OF FRESH BOTTLE GOURD

Bottle Gourd is rich in calcium, iron and phosphorous. It has white pulp, with white seeds embedded in spongy flesh. Bottle gourd contains glucose, pentosan, lignin and shikimic acid (Herwig, 2004). The chemical composition of raw bottle gourd fruit reported by Gopalan *et al.*, (1989), Hanif *et al.*, (2006) and USDA (2018) has been compiled in given following table.

Table 2.1 Composition of fresh bottle gourd fruit

Constituent	Gopalan <i>et al.</i> , (1989)	Hanif <i>et al.</i> , (2006)	USDA (2018)
Moisture content (%)	96.10	94.50 ± 0.06	95.54
Ash content (%)	-	00.50 ± 0.01	-
Protein content (%)	01.20	01.20 ± 0.06	00.62
Total fiber content (%)	00.60	00.70 ± 0.01	00.50
Fat content (%)	00.10	00.20 ± 0.02	00.02
Total carbohydrate content (%)	02.50	03.75 ± 0.03	03.39
Ascorbic acid (mg/100g)	00.00	12.00 ± 0.07	10.10
Calcium (mg/100g)	-	12.00 ± 0.03	26.00
Phosphorous (mg/100g)	-	37.00 ± 0.01	13.00
Sodium (mg/100g)	01.80	01.70 ± 0.01	02.00
Potassium (mg/100g)	87.00	87.00 ± 0.02	150.0
Chromium (mg/100g)	00.04	00.05 ± 0.06	-
Iron (mg/100g)	-	00.80 ± 0.01	00.20

Source: Gopalan *et al.*, (1989), Hanif *et al.*, (2006), USDA (2018)

2.2 HEALTH BENEFITS OF BOTTLE GOURD

Lagenaria siceraria fruits are traditionally used for its cardioprotective, cardiotonic, general tonic, diuretic, aphrodisiac and scorpion strings, alternative purgative, cooling effects. It cures pain, ulcers and fever and used for pectoral cough, asthma and other bronchial disorders-especially syrup prepared from the tender fruits.

The pulp of the fruit is taken in to account cool, diuretic, antibilious and useful in coughs and as antidote to certain poisons. (Sivarajan and Balchandra, 1994). Loukou *et al.*, (2011) reported that bottle gourd seed kernel is rich in protein, oil and energy. Apart from these nutritional uses, bottle gourd has been used for decades in Asia as a root stock for water melon to promote the root system under stressful conditions of water deficit and salinity, low temperature (Yetisir *et al.*, 2008) as well as root borne pathogens (Han *et al.*, 2004).

The gourd is used as a curative plant for mental health disorders. Among cucurbits, the bottle gourd is the only plant, which contains highest choline level along with required metabolites/ metabolic precursors for brain function (Rahman, 2003). Chloroform and alcoholic extracts of bottle gourd shows different lowering of total cholesterol, triglyceride and low density lipoproteins along with an increased high density lipoprotein level. Choline content of bottle gourd serves as the precursor of neurotransmitter acetylcholine, which in turn is crucial for retaining and enhancing memory. *Lagenaria siceraria* is a vegetable helpful with in the management of the many diseases like cardiac disorders, hepatic diseases and ulcer. Bottle gourd juice helps to control vital sign of hypertensive patients, because of its high potassium content. It helps in losing weight quickly, because of its high dietary fiber and low fat and cholesterol content (Milind and Satbir, 2011).

Bottle gourd is one of the lowest calorie vegetables carrying just 14 calories per 100 g. The dieticians in weight-control programs recommend it. Fresh gourds contain little quantities of folates, contain about 6 µg/100 g. Folate helps reduce the incidence of neural tube defects in the new-borns when taken by antcipant mothers during their early months of pregnancy. Fresh calabash gourd is a modest supply of vitamin C (10 mg/100g). Vitamin C, one of the powerful natural antioxidants that help the human body scavenges harmful free radicals, which labeled as one of the reasons for cancer development. Calabash facilitates easy digestion and movement of food through the gut tilt it is excreted from the body. Thus, it helps in relieving indigestion and constipation problems. The vegetable is also a modest source of thiamin, niacin (vitamin B3), pantothenic acid (vitamin B5), pyridoxine (vitamin B6) and minerals such as calcium, iron, zinc, potassium, manganese and magnesium. Bottle gourd tender leaves and

tendrils are also edible and indeed contain higher concentrations of vitamins and minerals than its fruit (Anon. 2018).

The vitamins, minerals and dietary fiber in bottle gourd keep the body well-nourished and curb unnecessary appetite, especially if juice of bottle gourd is drink in the morning on an empty stomach. Its fat and cholesterol content is extremely low. It consists of roughly 96% of water and is so a great thirst quencher. It additionally prevents fatigue and keeps the body cool and invigorated throughout summers. It also contains sodium, potassium, essential minerals and trace elements, which regulate blood pressure and prevent the risk of heart ailments. High in sodium and potassium, bottle gourd is also an excellent vegetable for people with hypertension. It is an acceptable vegetable for light-weight, low-calorie diets as well as for children, people with digestive problems, diabetics and those recovering from an illness or injury. Bottle gourd is usually recommended by ayurveda physicians for equalization the liver function, when the liver is inflamed and unable to process food efficiently for nutrition and assimilation (Kapoor, 2015).

Traditional healers for controlling diabetes mellitus, hypertension, liver diseases, weight loss and other associated benefits (Dhiman *et al.*, 2012) advocate bottle gourd consumption *Lagenaria siceraria*, *L. leucantha*, *L. vulgaris* leaves can be eaten as a vegetable. Sweet and green fruit is popular as a cooked vegetable. It is used to treat abdominal swelling, with crushed leaves (Thomas, 2006). Cooked bottle gourd is a calming, soothing food that acts as a diuretic. It is extremely low in calories, high in dietary fiber and makes an excellent food for people who are dieting. Raw bottle gourd juice has been promoted as a miracle drink for weight loss. It is advisable to consume cooked bottle gourd because raw vegetable could harm the stomach and digestive system, causing ulcers and rarely multi-organ damage (Sukhlencha, 2012).

2.3 BLANCHING

Blanching is a unit operation before freezing, canning, or drying in which fruits or vegetables are treated for the purpose of inactivating enzymes; modifying texture; preserving colour, flavour and nutritional value; and removing trapped air. Hot water and steam are the most usually used heating media for blanching in industry, however microwave and hot gas blanching have also been studied. Different hot water and steam

blanchers are designed to enhance product quality, increase yield and facilitate processing of products with different thermal properties and geometries. The design of blanching systems, depends on the product, the process following it and the final use of the product (Reyes De Corcuera *et al.*, 2004).

Ralls *et al.*, (1973) reported that the new process for hot gas blanching produces commercially acceptable canned spinach with higher percentage retention of ascorbic acid compared to hot water blanching. The amount of oxygen content of headspace gases in hot gas blanched samples of canned spinach was lower than in headspace as from hot water blanched samples. In hot gas spinach blanching oxygen was displaced by carbon dioxide during the exposure to combustion gases in the hot gas blancher. They concluded that hot gas blanched canned spinach had a different flavour than hot water blanched canned spinach and that flavour was accepted by consumers. There was no significance difference in calcium, magnesium and phosphorus content in both method of blanching. Hot gas blanching of spinach may yield a nutritionally improved canned product with respect to certain water soluble vitamins.

Quenzer and Burns (1981) reported that microwave blanching of spinach was superior to water and steam in ascorbic acid retention and inferior for β -carotene. Microwave blanching resulted in internal structural damage which accounts for the lower rehydration ratio. Steam blanching caused less cellular disruption and resulted in high rehydration ratio and acceptable textural characteristics. Microwave blanching induced coagulation of protoplasmic material surrounding the cell walls. Cell structure thus remained intact causing microwave retaining ascorbic acid and textural quality attributes. The steam and microwave blanched samples were rated as more desirable in texture.

Rossi *et al.*, (2003) had found effect of fruit blanching on phenolics and radical scavenging activity of high bush blueberry juice. This study demonstrated that the inactivation of polyphenol oxidase through steam blanching step of blueberry fruit significantly increased the anthocyanin and cinnamate recovery when blueberries are processed into juice as compared to unblanched blue berry juice. Juices obtained from blanched blueberry have higher content of phenolic compounds, so it led to increase of the radical scavenging activity of the juice.

Gajera (2014) had studied the blanching of bottle gourd slices (5, 10 and 15 mm thickness) at a temperature range over 85 – 100 °C, up to 60 min to inactivate the peroxidase enzyme to produce bottle gourd based blended juice. It was found that the inactivation time of peroxidase enzyme in bottle gourd slices decreased when slices surface area increased. Higher juice yield was obtained from blanched slices of bottle gourds and most effective juice yield was obtained to be 69.40% at 100 °C in 5 mm bottle gourd slices for 3.67 min peroxidase inactivation time during water blanching. High temperature blanching process increased juice yield and pH of inactivated bottle gourd slices while thickened slices decreased juices pH.

Njoroge *et al.*, (2015) studied effect of blanching time/temperature combination coupled with solar drying of indigenous leafy vegetables. Two water blanching conditions (80 °C/10min and 90 °C /5 min) were tested. Blanching at 100 °C for 30 min, followed by open sun drying was used as control, while conventional oven drying of the indigenous leafy vegetables was used as standard for comparison. Greatest nutrient loss was observed for indigenous leafy vegetables that were blanched at 100 °C for 30 min, then sundried. Most nutrients were retained at 80 °C /10 min compared to those retained at 90 °C /5 min. Microbial load (5.3 to 5.6 cfu/g) was significantly lower for solar dried indigenous leafy vegetables blanched at 90 °C /5 min. This indicates that blanching at 80 °C /10 min followed by solar drying is a potential option to be used as a local preservation technique for indigenous leafy vegetables.

Bhatt and Sharma (2016) studied the combined effect of water blanching and sonication on quality parameters of bottle gourd juice. It was found that combined effect on bottle gourd juice significantly increase in total phenolics, total carotenoids and total soluble solids. The blanched and ultrasonicated bottle gourd juice showed very good stability, while decrease in ascorbic acid content, pH and browning index as compared to control. It was concluded that blanching with sonication proved to be better for extractability of total carotenoids and total phenolics, reduction in particle size, increase in total soluble solids, decrease in total plate count and yeast and mould count.

Shinde *et al.*, (2016) had studied that steam blanching treatment to bottle gourd shreds prior to hot air drying was found to be most effective pre-treatment for better quality attributes of bottle gourd powder. They found that 6min blanching time was better for hot air drying. Steam blanching pre-treatment prior to hot air drying (60 °C)

by using tray dryer was found to be the most effective treatment to obtain better quality bottle gourd powder.

Bhat *et al.* (2017) reported the blanching effect on total phenolic content of bottle gourd juice. Bottle gourd was blanched using conventional thermal and alternate thermal ohmic heating methods using different combinations of temperature (60-90 °C) and time (1-5 min), and the effect of these methods on total phenolic content and colour was examined. They studied phenolic profile of unblanched, ohmically blanched, and conventionally blanched samples of bottle gourd. Gas chromatography-mass spectrometry and liquid chromatography-mass spectrometry were used to detect volatile and non-volatile phenolic compounds, respectively. The colour profiles of the unblanched and conventionally and ohmically blanched samples were studied via hunterLab colorimeter using L*, a*, and b* co-ordinates. The highest increase in total phenolic content was observed at 80 °C, 4 min and 90 °C, 5 min in the case of ohmic and conventional blanching, respectively. The conventionally and ohmically blanched samples both produced desirable green-colour retention in comparison to the unblanched samples; however, highest retention was observed in the ohmically blanched samples. The ohmically blanched samples exhibited the maximum extraction of phenolic compounds and better colour of bottle gourd juice in comparison to the other samples.

2.4 DEHYDRATION/DRYING

Drying is that the most cost-effective way to increase shelf-life of food products. A range of food products are routinely preserved using dehydration, that embody grains, marine products, meat products as well as all fruits and vegetables. The food products can have wide ranges of moisture content; as low as 11% in grains and as high as 94% or more in some fruits which needs to be reduced to an acceptable value so as to avoid microbial growth. This is generally represented in terms of water activity which simply means that free water out there for microbial growth in solids. The limits are reported for different microorganism in terms of water activity by Mujumdar and Devahastin, 2008. In addition, each food product needs to be dried in a different way using a suitable dryer type and by use of appropriate pre and post-processing to gain a satisfactory value addition to the dried product. The pre and/or post processing steps are very important to reduce the drying load also to make product of a better quality.

The usually used methods for pre-treatment are osmotic dehydration, blanching, salting and soaking. Whereas post-processing such as coating, blending, packaging etc., are also important after drying of foods (Chen and Mujumdar, 2008).

Thermal dehydration is that the most typical and cost-efficient technique for preservation of foods and for the production of traditional as well as innovative processed product like snacks with desired functionalities. Some examples of emerging drying technologies such as heat-pump-assisted drying, microwave-assisted drying, low pressure superheated steam drying, fluidized bed drying, pulse combustion spray drying, pulsed and ultrasound-assisted osmotic dehydration as well as novel gas-particle contactors like impinging streams and pulsed fluidized beds. Multi-stage drying, intermittent drying and use of hybrid drying technologies that combine advantages of different dryers without some of their limitations will be outlined (Mujumdar, 2004).

Giner and Cavelo (1987) studied drying behaviour of wheat in a batch fluid bed dryer with glass lateral walls. Drying experiments in fluidized beds were performed at different inlet air temperatures and different bed heights. The drying operation in batch fluid bed was modelled by assuming perfect mixing of solids. Drying time could be decreased about four fold by raising the air temperature from 40 °C to 70 °C. It was also calculated that inlet air temperatures much higher than that of wheat damage could be used without deterioration of grains during drying. In this respect, with 30 cm bed heights, temperatures of inlet air near 10 °C beyond that of grain damage could be used. This would lead to shorter drying time and therefore to higher production rates. Model simulations also showed that it was possible to reduce the operation times more by using inlet air temperatures about 30 °C higher than that of damaging temperature during the first drying stage and reducing later air temperature. Fluidized bed dryers have good possibilities for controlling grain damage as the solids maintain a uniform temperature below the inlet temperature. They concluded that fluid bed drying was a convenient method for heat sensitive food materials.

Bouraoui *et al.*, (1994) studied drying of potato slices using microwave drying, combined microwave and convective drying, convective drying. Rehydration kinetics was also studied. The thickness of potato slice 1, 1.5 and 2 cm was used for drying at temperature of 18 °C and 65 °C and air flow rate 0.032 m³/s. Drying rates of the various

drying methods were determined and microwave drying was compared with convective drying. Microwave drying has a potential for producing better quality dried products while significantly reducing drying duration (i.e. 10 min vs 10 h). Drying duration in microwave drying was about 10 min, no case hardening was observed and shrinkages were less than that in convective drying. Rehydration of dried potato slices was more in microwave drying. Results obtained for combined microwave and convective drying were similar to the results of microwave drying. They concluded that lower the microwave power setting, the longer the drying duration and lower the product internal temperatures.

Krokida and Maroulis (1999) studied the effect of microwave and microwave-vacuum drying on some quality properties such as density, porosity and colour and viscoelastic behaviour of dehydrated apple, banana, carrot and potato. Conventional drying was carried out in an air dryer at 70 ± 0.2 °C and 7% air relative humidity. In microwave and microwave-vacuum drying was carried out in microwave oven at atmospheric or 15 mmHg pressure both for 1.5 min. After that all samples were dried in the air dryer at 70 ± 0.2 °C and 7% air relative humidity and then analysed for different properties. It is concluded that microwave drying and microwave-vacuum drying decrease bulk density and tends to increase the product porosity of dehydrated products compared to convective drying. It decreases maximum stress and strain values, whereas increase elasticity and prevent colour degradation.

Swasdisevi *et al.* (1999) conducted fluidized bed drying of chopped spring onion and found air temperature and specific air velocity as major parameters affecting the drying characteristics. Drying was conducted in two steps, first step include drying behaviour of chopped spring onion at minimum air velocity with various bed depths (8, 10, 12 and 14 cm) with inlet air temperature of 32 °C. In second step, chopped spring onion was dried at various inlet drying air temperatures (75, 90 and 105 °C) and specific air flow rate (0.787-1.704 kg/s per kg of dry solid). Experimental results showed that at air temperature of 32 °C and relative humidity of 62%, the minimum fluidization velocities were approximately 1.36, 1.20, 0.95 and 0.62 m/s at initial moisture contents of 95, 71, 56 and 5% w.b., respectively. They recommended Page's model to predict the experimental data accurately. The air-product temperature should be kept lower than 53 °C to maintain the acceptable green colour of the dried product.

Pragati *et al.*, (2000) evaluated the nutritional quality of aonla (Indian gooseberry) variety by four different methods of dehydration, viz. direct solar drying, indirect solar drying, hot air oven drying and osmo-air drying. The drying was accomplished in 3 days each in hot-air oven drying and osmo-air drying method; whereas, it took 6 and 11 days for direct and indirect heating methods, respectively. The yield of fruit was maximum in osmo air drying method. Total ascorbic acid, total sugar and reducing sugar content of osmo air dried aonla were found to be highest and the tannin content and browning were observed to be the least. Indirect solar drying methodology was found to be relatively better than direct solar drying method for dehydration of aonla fruit.

Maskan (2001) studied drying characteristics of kiwi fruits by hot air, microwave and hot air-microwave drying. Drying rates, shrinkage and rehydration capacities of these drying regimes were compared. Sample was peeled and cut into 5.03 ± 0.236 mm thick and 40 ± 0.812 mm diameter slices with a cutting machine. The programmable domestic microwave oven with maximum output of 700 W at 2450 MHz was used. Different microwave power intensities (210, 350 and 490 W) were investigated in microwave drying. There was charring and sample boiling occurred at 350 and 490 W power, therefore, 210 W power level was selected for drying. Combination of hot air and microwave techniques was also carried out for sample, in which kiwi fruit was initially dried in hot air for 135 min and then dried in microwave at 210 W level. It was concluded that microwave and microwave assisted heating reduced the drying times by 89-40%. The hot air-microwave finish dried products had less shrinkage; hence, they had better rehydration capacity and faster water absorption rate than the other drying methods studied.

Bobic *et al.*, (2002) had studied drying of vegetables such as potatoes, parsley roots, celery roots and carrots in a continuous fluidized bed dryer to produce dry pieces. Initial moisture content was potatoes 78%, parsley roots 85.1%, celery roots 93.6% and carrots 88.6%. Temperature of fluidization was varied from 60 °C to 100 °C at a velocity of 0.71 m/s. The objective was to obtain dry vegetables with 6% to 10% of water content having good rehydration quality. The researcher was found that fluidized bed drying offers more advantages compared to other drying methods and it requires short time. Rehydration times are up to 30% better than other methods normally used

and the quality is very uniform at lower drying temperature. Author concluded that the fluidized bed drying is most reliable and the most economical method for drying vegetable pieces.

Baysal *et al.*, (2003) studied on the effects of microwave and infrared drying on the quality of carrot and garlic and compared with the effects of conventional hot air drying (tray dryer for carrot and fluidized bed dryer for garlic). They concluded that in the carrot rehydration capacity was lowest in hot air drying whereas infrared dehydrated carrot had best rehydration capacity. When dry matter of dried carrot was evaluated, it was found that microwave dried carrot had higher dry matter. In garlic dehydration process, no significant difference was found between fluidized bed drying, infrared drying and microwave drying except colour. They recommended that where colour is an important parameter, hot air or microwave drying instead of infrared drying should be used.

Beurdy *et al.* (2004) were dried dehydrated cranberries (osmotically dehydrated) by using following four methods: hot air drying; microwave-assisted convective drying; freeze-drying; and vacuum drying. Shortest time was taken by microwave-assisted drying while longest time was observed for hot air drying. Quality evaluation was performed on all samples, including sensory evaluation (appearance and taste), texture, colour, water activity, and rehydration ratio. Freeze dried cranberries had highest rehydration ratio, whereas hot air dried cranberries had best visual appearance. There was no significant difference in colour measurements and water activity. Few differences in texture were found, except for freeze-dried cranberries, which had a lower toughness compared to the other drying methods including commercially available dried cranberries. They indicate that all four drying methods can be applied for drying of osmotically dehydrated cranberries.

Sharma and Prasad (2004) dried fresh garlic cloves using microwave convective technique. They had used microwave power in the range of 10-40 W in steps of 10 W was applied continuously, in conjunction with hot air at temperatures of 40, 50, 60 and 70 °C and air velocities of 1 and 2 m/s. They reported that effective moisture diffusivity depends on the moisture content, and increased with decrease in moisture content. It increased with increase in both drying air temperature and microwave power at a given air velocity, but with increase in air velocity, diffusivity values were lower for the

similar drying conditions resulting into slower drying of the product. The activation energy in the microwave-convective drying process was much lower than the convectionally heating activation energy values for moisture diffusivity for vegetables.

Sowjanya (2004) studied on quality of solar and tray dried figs. Before drying, blanching (water blanching for 4 min), sulphitation (2% potassium metabisulphite solution for 30 min) and lye treatment (2% alkali solution of sodium hydroxide for 3min) were given to figs. Drying was carried out by solar dryer and tray dryer. In solar dryer temperature ranged between 45 – 56 °C for 3 days and 5.30 h and in solar dryer temperature was 70 ± 5 °C for 2 days and 7 h. It was found that tray dried figs had maximum reducing sugar, highest crude fiber, whereas calcium content, protein content was, recorded high in solar dried figs. Score of appearance, texture and overall acceptability was high in tray dried figs. Minimum microbial load was recorded in solar dried sample; maximum bacterial load was recorded in tray dried figs. It was concluded that tray drying method was more acceptable than solar drying method.

Wang and Xi (2005) experiments were made to study microwave drying characteristics and dried product quality of carrot. A two-stage microwave power system using a first and second stage power input for varying times throughout drying was used. Carrots were hand peeled and cut into 1.5, 3, 4.5, 6, 7.5 and 9 mm thick slices with cutting machine. Drying was carried out by laboratory microwave oven at power intensity of 120, 160 and 240 W. The study focused on describing microwave drying characteristics of carrot and discussing the effect of sample thickness, power applied during first-stage, power applied throughout the second stage and duration of first-stage on β -carotene content and rehydration ratio. The dehydration rate increased and the drying energy consumption decreased, as the thickness of sample decreased. The rehydration ratio of the dried products decreased with increase of duration of first-stage and slice thickness; β -carotene content decreased with increase of second-stage power and duration of first-stage.

Hema (2006) was studied the osmotic dehydration technique has yield encouraging results on dehydration of bottle gourd cubes. The salt solutions with 5, 10, 15, 20 and 25% (w/w) concentrations were prepared and cubes were immersed in osmotic solutions with a fruit to osmotic solution mass ratio of 10:1, 20:1 and 30:1 at temperature of osmotic solutions 40, 50 and 60 °C. The osmotic dehydration was done

for a period of 1, 3, 6 and 9 hours. The dewatering of product moisture varied from 2.4 to 47.8% (wb); weight loss varied from 38.7 to 10.61% and the solid gain varied from 20.85 to 4.19%. This suggested that a total sum of 47.8% moisture (wb) can be removed without putting much energy to the process. At the same time, the solid gain by the product acts as a good preservation, which may lead to the extension of shelf life. The dehydrated product was possible to rehydrate and at normal room temperature condition, the value of rehydration ratio varied 5.44 to 13.07, which was a good indication. The result of the sensory evaluation indicated that the panelist liked the product moderately.

Mishra *et al.*, (2006) was studied drying characteristics of carrot under microwave vacuum condition. Drying phenomenon and characteristics were studied for carrot under four completely different conditions of power and vacuum. Drying was carried out at power level 10 and 5 P with vacuum of 23 inch of Hg and with same power level without vacuum. It was found that microwave vacuum drying has advantages over microwave drying. Vacuum created within the chamber reduces the boiling point and effects drying at a reduced temperature. The results show that the target moisture content could be achieved in much lesser time of drying when vacuum is supplemented to microwave drying.

Murthy and Joshi (2007) reported the effect of drying on aonla slices by fluidized bed dryer. Drying carried out at temperature of 60, 70 and 80 °C and 95, 105 and 115 m/min air velocity. Sun drying and tray drying (50 m/min air velocity and 70 °C temperature) was taken as control samples. They concluded that the sun drying required the longest period of drying (660 min), tray drying required 270 min at 70 °C temperature with air velocity 50 m/min, while the shortest time (120 min) of drying was with fluidized bed drying at 80°C with 115 m/min air velocity for drying of aonla slices. The results indicated that there was a great loss of ascorbic acid in the aonla slices. The retention of ascorbic acid in the samples dried in fluidized bed drying was greater compared to those dried under sun and hot air tray.

Pereira *et al.* (2007) studied impact of microwave power, air velocity and temperature on the final drying of osmotically dehydrated bananas. Their drying process was divided into three periods: phase I (760 W; 2 kg moisture/kg dry matter); phase II (380 W; 0.67 kg moisture/kg dry matter); and phase III (0 W, 76 W, 150 W or

230 W) up to the final sample moisture of 0.17 kg water/kg dry matter). Three conditions for the hot air were tested: 50 °C and 3.3 m/s; 70 °C and 3.3 m/s; 70 °C and 5.7 m/s. Their results show that increasing the microwave power, it increases the drying rate and thus decreases drying time. However, higher microwave power also caused temperature runaway leading to charring of the dried product. Therefore, it is necessary to control the microwave power during drying. It was found that a lower air temperature or high air velocity can cause cooling on the product. This interaction can improve product appearance and quality; and decrease the quantity of charred pieces. Colour, porosity and apparent volume was not strongly affected by processing parameters such as microwave power, air temperature and velocity.

Bisnoi *et al.*, (2008) studied the dehydration characteristics of garlic. Blanching was carried out at a temperature of 80-85 °C for 5 min and sample treated with 0.5% sodium metabisulphite for 20 min. For dehydration of garlic open sun drying, solar cabinet drying, electric tray drying, microwave oven drying was used. It was resulted that the product quality of blanched sample for 55 °C and sodium metabisulphite treated sample for 65 °C in electric tray dryer was best as compared to other technique.

Abbasi and Azari (2009) studied the rehydration ratio, colour (L^* , a^* and b^*) and micro-structure of white onion slices of various thicknesses dried using commercial freeze dryer at an absolute pressure of 0.005 mbar and 45 °C; in a microwave-vacuum drier at absolute pressure down to 300 mbar under various microwave powers of 120 to 1,200 W and microwave-vacuum-freeze drier at -20 °C for 2 h. They found that microwave-vacuum-freeze drier is practically a rapid, simple, efficient, economic and novel dehydration technique which can be used for dehydration of foodstuffs. This novel method was also found superior over commercial freeze drier with over 96% saving in processing time coupled with considerable saving in energy and capital investments.

Momenzadeh *et al.*, (2011) studied the drying characteristics of shelled corn (*Zea mays* L.) with an initial moisture content of 26% dry basis in a fluidized bed dryer assisted by microwave heating. They used four air temperatures (30, 40, 50 and 60 °C) and five microwave powers (180, 360, 540, 720 and 900 W). Increased in drying air temperature caused up to 5% decrease in drying time whereas in microwave assisted fluidized bed system, drying time decreased up to 50%. Therefore, addition of

microwave energy to fluidized bed drying is recommended to enhance the drying rate of shelled corn.

DaSilva *et al.*, (2012) studied experimentally and computationally the soybean meal drying in a fluidized bed dryer. They have determined influence of temperature, speed of drying agent, and bed height on the fluidized bed drying process. The experimental results show that the drying rate of soybean meal has solely the decreasing period, so the factor that controls this process is the diffusion inside the material. Temperature had a significant influence on the process, while the height of the bed of particles and the speed of the drying agent did not have significant influence in the range of experimental conditions investigated. An Eulerian–Eulerian model was used to simulate fluid dynamics and fluidized bed drying and the numerical simulations were performed with the computational fluid dynamics (CFD) code MFIX. A mass transfer model was incorporated into the available fluid dynamics model so as to check the soybean meal drying within the fluidized bed. The comparison of the numerical results obtained through computer simulations with experimental results showed good agreement. The mathematical model is thus suitable to describe both fluid dynamics and drying of soybean meal in the fluidized bed, indicating potential use of CFD in fluidized bed drying problems.

Patel (2013) carried out the study of drying characteristics of elephant foot yam slices with hybrid (osmotic and microwave vacuum) drying. Osmotic dehydration was carried out using three variables i.e sucrose concentration (30, 40, 50 and 60% w/w), salt concentration (5, 7.5, 10 and 12.5% w/w) and dehydration time (10, 20, 30, 50, 70, 90 and 120 min). It was observed that both the moisture loss and the solid gain increased with increasing concentration of osmotic solution. The best conditions found for osmotic dehydration were 40% w/w sucrose concentration, 6% w/w salt concentration and 70 min osmotic dehydration time, which gave 42.80% moisture loss and 14.65% solid gain. Further sample were dried using microwave vacuum at power density of 2, 4, 6 and 8 W/g and pulsating ratio of 1.312, 1.625, 1.983 and 2.250. The microwave vacuum drying at 1.625 pulsating ratio with microwave power density 4 W/g yielded product with highest overall acceptability score.

Ambrose and Naik (2014) studied curry leaf drying by mechanical drying method. Fresh curry leaves were dried at 40, 45 and 50 °C temperature and air velocity

of 2, 3 and 4 m/s in fluidized bed dryer. The curry leaves were dried up to final moisture content of 2 to 5% at 45 °C temperature and air velocity of 4 m/s. This combination resulted in maximum volatile oil content and rehydration ratio in terms of quality. They concluded that the removal of water, restricts the growth of micro-organisms and hence increases the shelf-life.

Kumar *et al.*, (2014) used fluidized bed drying for drying of beetroot (*Beta vulgaris*). They carried out studies on the effect of inlet air temperature and velocity on the drying characteristics of beetroot pieces in microwave assisted fluidized bed drying (MAFBD) system and in fluidized bed dryer. Air velocities of 9, 10.50 and 12 m/s and temperatures of 60, 67.50 and 75 °C were used for drying in both FBD and MAFBD. The drying time was reduced 2 to 3 times and lower final moisture content using MAFBD.

Liman *et al.*, (2014) studied effect of three drying techniques on three different green leafy vegetables (*Moringa oleifera*, *Spinacea oleraceae* and *Vernonia amygdalina*). The three drying techniques were sun drying at ambient temperature for 4 days, oven drying at 150 °C for 4 h and drying with electrical moisture analyser stabilized at 70 °C for 1 day. In spinach, ability to retain nutrients was more in sundried sample. In drumstick, it was found that retention of nutrients was higher in electric moisture analyser. Whereas, in bitter leaf, nutrients were more in oven dried sample. Therefore, author stated that it was not possible to draw conclusion about best drying method as no definite pattern was followed by all the samples considered in their retention of different nutrients when subjected to different drying methods.

Mattu (2014) studied on drying characteristics of bottle gourd slabs by using tray dryer (air velocity of 3 m/s) and fluidized bed dryer (air velocity of 10 m/s) at temperature of 50, 60, 70 °C. It was found that drying time for slabs was less in fluidized bed dryer as compare to tray dryer and drying rate was higher in fluidized bed dryer. Moisture diffusivity for fluidized bed dryer was higher as compared to tray dryer. The fluidized bed dried product found best in fat, protein and carbohydrate content comparatively to tray dried product. Taste and overall acceptability of fluidized bed dried bottle gourd was highly appreciable than other drying temperature.

Moursy *et al.*, (2014) studied the effect of hot-air drying temperature on ascorbic acid content of whole lemon fruit and fruit cut into halves, quarters and slices

were determined. It was found that ascorbic acid was affected by drying temperature. Ascorbic acid content increases with increasing temperature and after certain temperature it begins to decrease for all samples studied except for whole fruit it increases continuously until 110 °C. The optimum temperatures were 90 °C for samples cut into halves and 100 °C for samples cut into quarters and slices.

Mehta *et al.*, (2017) had studied the effect of drying techniques and treatment with blanching on the physicochemical analysis of bitter melon and capsicum. The researcher had found that hot water blanched vegetables (bitter melon and capsicum) had higher moisture removal and rehydration ratio than unblanched hot air cabinet and open sun dried vegetables. The chlorophyll, flavonoid, polyphenol content, vitamin A and vitamin C content was higher in hot water blanched solar dried over cabinet and open sun drying. It was resulted that solar drying of vegetables proved to be effective in terms of nutrient retention and increased functional quality.

Yarrakula (2017) reported the study of drying of nutmeg mace using microwave assisted fluidized bed dryer. The developed microwave assisted fluidized bed drying system consists of fluidized bed dryer and microwave oven unit. The microwave assisted fluidized bed dryer was made by making a hole of 14 cm at bottom and inserting the fluidized bed dryer through the hole. To evaluate the developed microwave assisted fluidized bed dryer for nutmeg mace, the process parameters such as microwave powers of 480, 640 and 800 W and drying air temperatures of 40, 45 and 50 °C were selected as independent variables. Drying was optimized based on drying rate, energy consumption and physico-chemical parameters such as colour, moisture content, bulk density and essential oil yield. The optimized conditions of drying temperature and microwave power for microwave assisted fluidized bed dryer were found to be 47.76 °C and 681.73 W.

Colucci *et al.*, (2018) studied the drying characteristics of eggplant at (-10) and (-5) °C temperature, 2 and 5 m/s air velocity and acoustic power at 0 to 50 W in ultrasound assisted atmospheric freeze-dryer. The researcher found that increase in temperature and air velocity can reduce ascorbic acid content, total phenolic content and antioxidant capacity of atmospheric freeze-dried (AFD) eggplant samples while; the application of power ultrasound proved to be effective at shortening the drying time and at the ultrasonic power level tested did not significantly affect the eggplant

antioxidant content. In the case of the large samples, it can lead to ice melting and the presence of liquid water can harm the final product quality. It can be concluded that power ultrasound is a promising technology for accelerating the AFD process but attention must be paid to the optimization of the operating conditions in order to limit the thermal effects of acoustic energy and to ensure the preservation of the nutritional properties of the samples.

9.5 SHELF-LIFE STUDY

Yadav and Sehgal (1997) studied the effect of selected processing and storage methods on the concentration of ascorbic acid and β -carotene in bathua and fenugreek leaves. Methods included blanching, drying and storage of bathua and fenugreek leaves. Water blanching was performed for 5, 10, 15 min and excess water was drained after blanching. Drying was carried out in sun for 10 h and in oven at 65 °C for 10 h. Samples were stored with or without packing in polythene bags for 24 and 48 h in refrigeration and ambient condition. Losses of ascorbic acid were higher than the β -carotene during storage. Losses of both vitamins were higher with storage at ambient condition. The loss of ascorbic acid ranged from 2.03 to 8.77% while lower losses of β -carotene were observed in leaves, stored in the refrigerator and at ambient condition. A markedly greater reduction in ascorbic acid and β -carotene was observed in blanched or cooked and dried leaves. The study suggest that storage of leaves in refrigeration resulted in better retention of these two vitamins.

Negi and Roy (2001) studied the effect of drying, packaging and storage conditions on the retention of β -carotene and ascorbic acid and browning during storage of savoy beet and amaranth leaves was determined. Water blanching was carried out in hot water at 95 °C for 60 s and dipping in 0.5% solution of potassium metabisulphite for 60 s. Blanched samples were dried in cabinet dryer and solar dryer. Drying conditions for cabinet drying were temperature 65 ± 5 °C, air flow 1.2 – 1.8 m/s and in solar drying, temperature varied from 40 to 50 °C. Dried samples were packed in single and double layers of HDPE bags and stored at ambient and cold storage conditions for 9 months. Higher losses of β -carotene and ascorbic acid were observed in solar drying compared to cabinet drying. Chlorophyll loss was also higher in solar drying. During storage of dehydrated green leaves, a continuous decline in nutrients and chlorophyll

and an increase in browning were observed. Storage at low temperature and packaging in double layers of polyethylene film contained loss of quality parameters.

Shoba (2009) studied the drying of methi leaves. Dehydrated methi powder had packed and sealed in polyethylene of 300, 400 and 500 gauge film packages and stored at atmospheric and 10 °C temperature condition. Author had used open sun drying, tray drying, microwave drying and vacuum oven drying for drying of fenugreek leaves. The loss of ascorbic acid was maximum in tray dried methi powder packed in 300 gauge polyethylene pouch. Chlorophyll retention was maximum in microwave dried methi leaves, which was stored in 500 gauge polyethylene bag stored at 10 °C. The rehydration ratio and rehydration co-efficient values were also recorded highest in microwave dried methi powder packed in 500 gauge.

Maxwell (2011) studied the effect of different packaging materials on the quality and shelf life of Moringa (*Moringa oleifera*) leaf powder during storage. Moring leaves were dried using solar dryer with ventilation holes which is constructed with wood, transparent glass and transparent plastic roofing sheets. Wooden tray with wire mesh based was used for sample. Transparent and opaque PET and glass bottles, transparent and opaque LDPE bags, brown paper bags, waxed paper and cardboard boxes were used to package the Moringa leaf powder. The result of various packaging materials on the quality and shelf life of Moringa leaf powder under ambient conditions were studied for a period of 180 days. Each treatment package was evaluated for moisture content, bacteria load, nutrients, colour and particle size. Bacterial and fungal identification was also carried out. Glass packaging was found to be the foremost appropriate packaging material preventing moisture absorption and growth and activities of microorganisms. They were conjointly effective in preventing undesirable colour changes and particle size changes.

Sahoo (2011) studied two packaging material for the storage of dried onion shreds. Drying was carried out by hot air convective, heat pump and microwave assisted convective dryer. Dehydrated onion shreds were packed in transparent polyethylene terephthalate (PET) bottle and metalized polyester polyethylene (MPP) and samples were stored under ambient condition for 6 months. The stored samples were evaluated for its moisture content, rehydration ratio, surface colour change, pyruvic acid content and ascorbic acid content after every 2 months of storage interval. Author concluded

that metalized polyester polyethylene packaging was found most suitable packaging material in order to retain the quality parameters better up to 6 months of storage of onion shreds.

Parikh (2014) studied the preservation of eggplant (*Solanum melongena*) applying osmotic and microwave- vacuum drying. Blanching was carried out by hot water (70 and 80 °C), steam (atmospheric pressure), and microwave (0.5, 1, 2, 3 and 4 W/g) for one to five min and different chemicals- citric acid, ascorbic acid and malic acid and salts for two to seventeen min. The drying of eggplant slices were dried using osmotic dehydration process at 10% w/v salt concentration, 20 kPa vacuum and 60 min osmotic dehydration time, which gave 15.37% moisture loss and 3.379% solid gain and further dehydration was carried by microwave vacuum dryer at 10 kPa vacuum with microwave power density 2 W/g yielded products with highest overall acceptability score. Then packed and sealed in LDPE and HDPE bags and kept at room temperature. Study of the sorption behaviour of dehydrated eggplant slices and shelf-life was predicted using GAB model, to be on 135 days in LDPE and 438 days in HDPE bags.

Kotecha (2015) studied the dehydration of onion flakes in cabinet dryer by uniformly spreading them on the trays of cabinet dryer. Different varieties of onion bulbs i.e Phule Safed, Phule Samarth, Basvant-780, Jain Valley-5 and Local white were used for dehydration. Drying was performed at 55 °C for 8 to 9 h. Dried samples were packed in polyethylene bag and aluminium foil bags for 90 days. The storage studies indicated that the TSS and reducing sugar increased with the advancement of storage period, while non-reducing sugar decreased. The flakes prepared from Phule Safed variety by giving pre-treatment of 0.2% KMS stored in aluminium foil bag was found superior than the samples packed in polyethylene bag throughout storage period.

CHAPTER III

MATERIALS AND METHODS

This chapter includes experimental procedures and various methods used for the study of production technology for dehydrated bottle gourd shreds. The entire study was carried out at College of Food Processing Technology and Bio-energy, Anand Agricultural University (AAU), Anand.

3.1 RAW MATERIAL

Fresh bottle gourd fruits of average size and shape as shown in Fig. 3.1 were procured from the local market of Anand for research work. The required quantities of material were procured fresh when required from same place.



Fig. 3.1 Fresh bottle gourds

3.2 PREPARATION OF DEHYDRATED BOTTLE GOURD SHREDS

Fresh bottle gourd fruits were had uniform size, colour and firm texture was selected for dehydration experiment. The process flow chart as shown in Fig. 3.2 was used for preparation of dehydrated bottle gourd shreds. This includes various operations like washing/cleaning, cutting, shredding, blanching, dehydration and packaging followed by storage.

Selected bottle gourd fruits were washed under tap water to remove dust, dirt or any other foreign matter. Washed fruits were cut and shredded with peel for effective heat transfer during blanching and dehydration. The fruits were shredded to 3, 5 and 7 mm thickness by using different sized shredding plates (Fig. 3.3) of shredding machine as shown in Fig. 3.4. Shreds were prepared for blanching treatment. The shreds were steam blanched in hot water bath having temperature range between 0-100 °C as shown

in Fig. 3.5. For this, sieves were put in water bath and samples were put on sieves for steam blanching. At the interval of 1 min, sample were drawn continuously from water bath up to 8 min to check inactivation of peroxidase (POD) enzyme in the sample. Approximately 1 g blanched sample were drawn out and immediately cooled in water to stop further heat transfer activity.

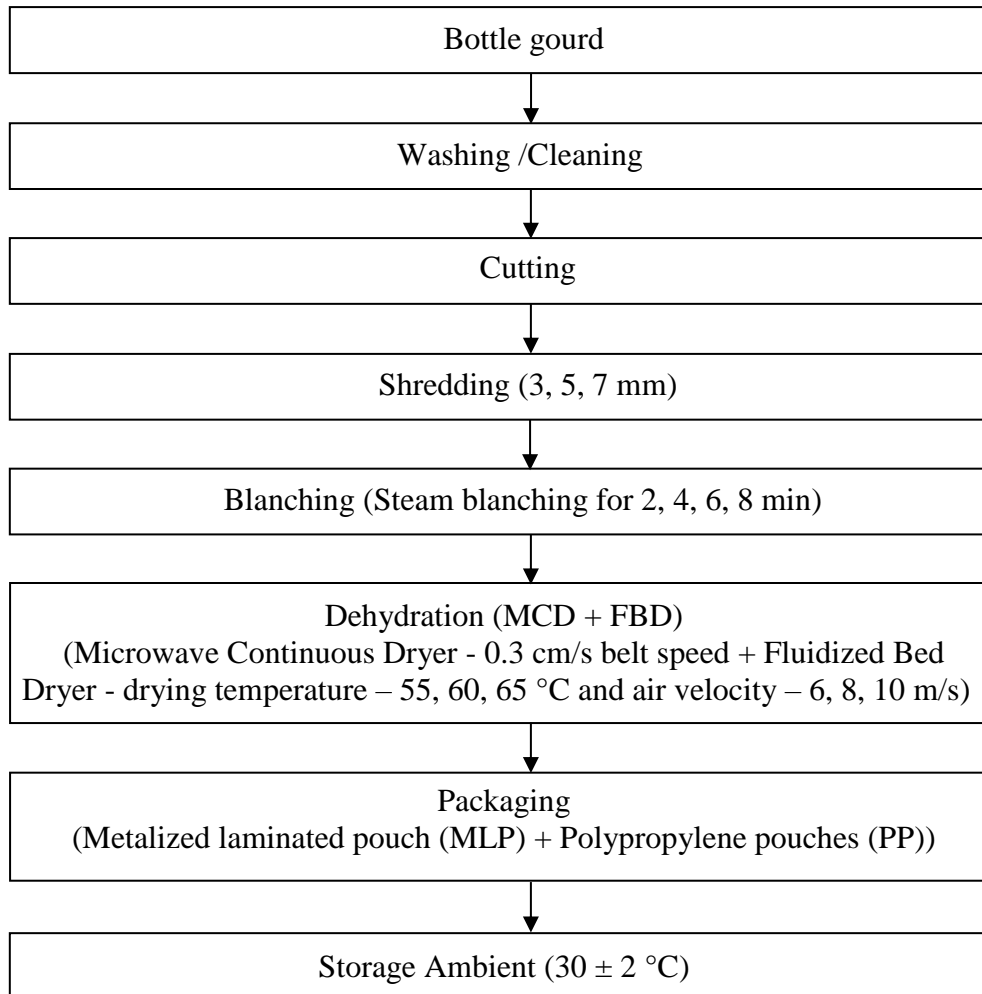
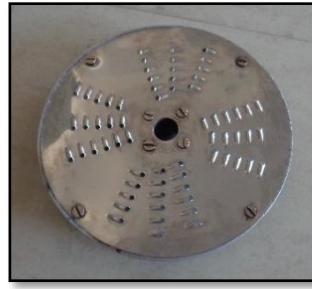


Fig. 3.2 Process flow chart for production of dehydrated bottle gourd shreds.

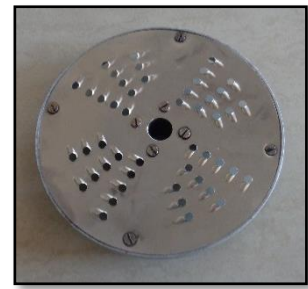
After inactivation of enzyme the bottle gourd shreds were evaluated for total soluble solids, ascorbic acid content and juice yield. Experimental levels of shreds thickness and blanching time are described later in experimental design (Part-1). All the experiments were replicated thrice and average values were used in analysis. Optimization of shreds thickness for further dehydration was carried out based on minimum inactivation time of POD enzyme, higher TSS and higher ascorbic acid content.



(a) 3 mm



(b) 5 mm



(c) 7 mm

Fig. 3.3 Shredding plate



Fig. 3.4 Shredding machine



Fig. 3.5 Hot water bath



Fig. 3.6 Microwave continuous dryer



Fig. 3.7 Fluidized bed dryer



(a) Polypropylene pouch



(b) Metalized laminated pouch

Fig. 3.8 Dehydrated bottle gourd shreds in microwave assisted fluidized bed dryer



(a) Polypropylene pouch



(b) Metalized laminated pouch

Fig. 3.9 Shade dried bottle gourd shreds

The optimized steam blanched bottle gourd shreds were utilized for further dehydration. The shreds were first dried in microwave continuous dryer (MCD) (Fig. 3.6) and then dehydrated in fluidized bed dryer (FBD) (Fig. 3.7). In microwave continuous dryer belt speed were kept constant at 0.3 cm/s. In this dryer drying temperature changes automatically according to product and only belt speed and cut off time are required to be set. Experimental levels of temperature and air velocity in fluidized bed dryer are shown in experimental design described later (Part-2). All experiments were replicated thrice and average values were used in analysis. Optimization of dehydration parameters for bottle gourd shreds were accomplished on the basis of dehydration time, ascorbic acid content, colour value (ΔE^*ab) and its rehydration characteristics. Optimized bottle gourd shreds were packed in polypropylene pouches (25.8 x 17.7 cm²) and metalized laminated pouches (30 x 19.9 cm²) as shown in Fig. 3.8. Shade dried dehydrated bottle gourd shreds were taken as control and also packed in polypropylene pouches and metalized laminated pouches as shown in Fig. 3.9. The samples were stored at ambient condition (30 ± 2 °C) for 120 days to carry out shelf life studies. Experimental levels for shelf life study are later described in experimental design (Part-3).

3.3 EXPERIMENTAL DESIGN

Part – 1 Blanching of Bottle Gourd Shreds

- a. Independent variables
 - Thickness of shreds 3, 5 and 7 mm
 - Blanching time – 2, 4, 6 and 8 min
- b. Dependent variables
 - Inactivation of POD enzyme
 - Total soluble solids
 - Ascorbic acid content
 - Juice yield
- c. Experimental details
 - Statistical design – CRD
 - No. of treatments – 12
 - No. of replication – 3

Treatment was standardized on the basis of inactivation of peroxidase enzyme and then higher TSS and higher retention of ascorbic acid.

Part – 2 Dehydration of Bottle Gourd Shreds (Microwave Assisted Fluidized Bed Dryer)

Initial dehydration was carried out by microwave continuous dryer up to 30% moisture content at the conveyor speed 0.3 cm/s and further dehydration was carried out by fluidized bed dryer.

a. Independent variables

- Fluidized bed dryer
 - I. Drying temperature – 55, 60 and 65 °C
 - II. Drying air velocity – 6, 8 and 10 m/s
- Control – Shade drying (3 mm shreds thickness)

b. Observation

- Time required for dehydration
- Ascorbic acid content
- Colour value (ΔE^*ab)
- Rehydration characteristics

c. Experimental details

- Statistical design - CRD
- No. of treatments – $3 \times 3 = 9$
- No. of replication – 3

Part – 3 Shelf-life Study of Dehydrated Bottle Gourd Shreds

Sample was packed in polypropylene and metalized laminated pouches. Packed samples were stored for 120 days at ambient temperature.

a. Independent variables

- Ambient storage (30 ± 2 °C) for 0, 15, 30, 45, 60, 75, 90, 105, 120 days

b. Observation

- Sensory characteristics – Colour and appearance, Aroma, Texture, Overall acceptability
- Physico-chemical characteristics – Colour value, Moisture content, Ascorbic acid content, Minerals (Ca, K), Ash content

- Microbial characteristics – Total Plate Count, Yeast and Mold count, Coliform count
- c. Experimental details
- Experimental design – CRD
 - No. of observations – $9 \times 1 \times 13 = 117$
 - No. of replication – 3

3.4 PHYSICO-CHEMICAL CHARACTERIZATION OF BOTTLE GOURD FRUITS

3.4.1 Seed/ Pulp/ Peel Ratio

Twenty bottle gourd fruits were randomly taken from the bulk heap, marked and weighed. The washed bottle gourd was first peeled by stainless steel peeler. Peeled bottle gourds were cut and pulp and seeds were separated using stainless steel knife. The content of seed, pulp and peel from individual bottle gourd was estimated by measuring the weight of each fraction. The weight was measured by using an electronic weighing balance of 5 kg capacity having least count of 0.01g. The average values for twenty fruits were recorded and ratio were calculated for individual fruit and the overall average was reported.

3.4.2 Moisture Content

The method described by Ranganna (1986) was used to determine moisture content of the fresh bottle gourd samples. A metallic dish was dried in oven at 110 °C for a period of an hour. It was cooled in desiccator and weighed. A 10g sample was weighed in dish and kept in hot air oven (Fig. 3.10) at 100 ± 5 °C till the final weight remained constant. It was cooled in desiccator and weighed after the sample attained room temperature. The sample was replicated thrice. The data were recorded and the moisture content was calculated using the following formula:

$$\text{Moisture content (\% w. b)} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 = Initial weight of sample (g)

W_2 = Weight of sample after drying (g)

3.4.3 Ash Content

The sample of 5 g was weighed into a previously weighed porcelain crucible. Before, placing in muffle furnace sample was first burned on burner or hot plate till

fumes stops. The sample was kept in muffle furnace (Fig. 3.11) at 550 °C for 5-6 hours. When it has become completely ashed, it was cooled in the desiccators and weighed. The weight of ash obtained was calculated using following formula:

$$\text{Ash (\%)} = \frac{W_2 - W_1}{W_3} \times 100$$

Where,

W_1 = Weight of empty crucible (g)

W_2 = Weight of crucible + ash (g)

W_3 = Weight of Sample (g)

3.4.4 Protein Content

Protein content was determined using micro-Kjeldahl method. Sample of 0.5 - 1 g was digested with concentrated sulphuric acid containing 3-4 g of catalyst mixture (K_2SO_4 : $CuSO_4$, 5:1) at 400 °C. Digested sample was distilled with 40% NaOH and liberated ammonia was trapped in 4% boric acid solution. After distillation, mixed indicator (methyl red:bromocresol green, 1:5) was added and condensate get bluish green colour. Condensate was titrated with standard 0.1 N HCl until bluish green colour turn into red wine colour. The percent nitrogen was estimated from Kjeldahl method and the protein content was quantified by multiplying with factor 6.25. Automatic Kjeldahl (Make: Kel-plus) set up was used which consisted of two units namely digestion assembly and distillation unit as shown in Fig. 3.12 (a and b) (Ranganna, 1986).

$$\text{Nitrogen (\%)} = \frac{14 \times N \text{ of acid} \times (T - B) \times V_1 \times 100}{W \times V_2 \times 1000}$$

Where,

T = Titre value burette reading (ml)

B = Blank burette reading (ml)

N = Normality of acid (N)

W = Weight of sample (g)

V_1 = Volume made up of digest (ml)

V_2 = Aliquot of digest taken (ml)

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

3.4.5 Fat Content

Crude fat of sample was determined by method described in Ranganna (1986). Crude fat is soluble in hexane which is extracted by soxhlet extraction apparatus (Fig. 3.13).



Fig. 3.10 Hot air oven



Fig. 3.11 Muffle furnace

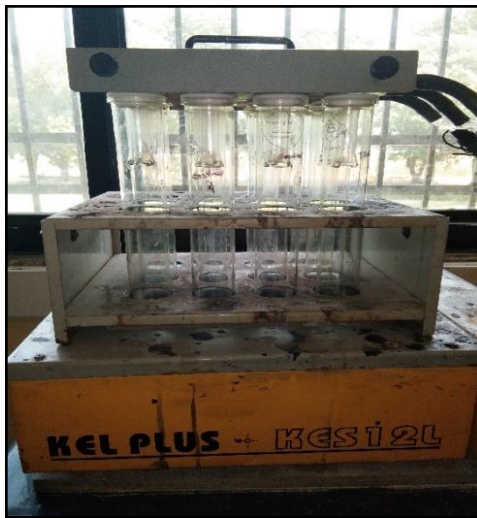


Fig. 3.12 (a) Digestion assembly



Fig. 3.12 (b) Distillation unit

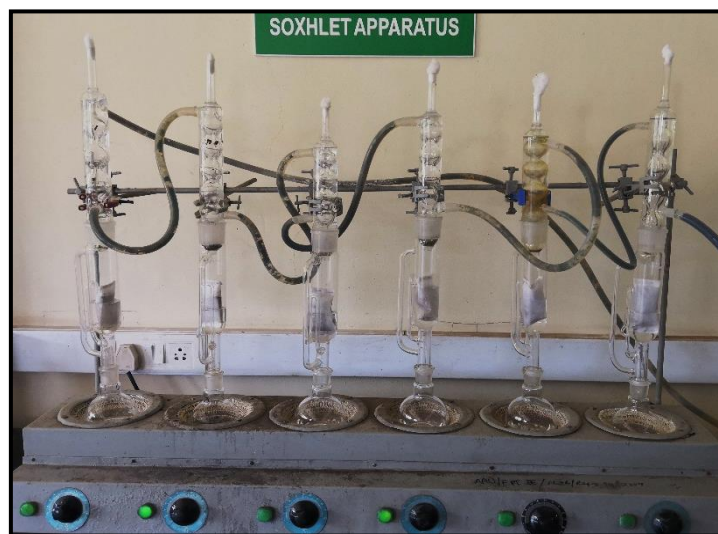


Fig. 3.13 Soxhlet apparatus



Fig. 3.14 Fibra – plus

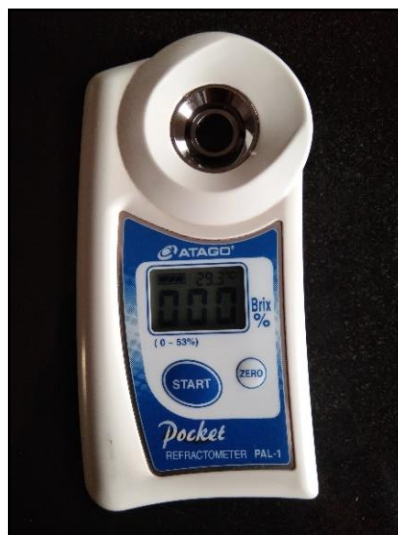


Fig. 3.15 Digital refractometer

The sample was weighed and transferred in thimble and plugged with cotton. The plugged thimble was placed in to the fat extractor of soxhlet apparatus. Pour approximately 150 ml of hexane was poured through the sample into the soxhlet flask attached to the bottom of extraction tube. The condenser was attached at the top of the extraction tube. The sample was extracted for 8 hours. At the end of extraction period, thimble was removed and most of the hexane was recovered by allowing it to collect in the soxhlet tube. Remaining hexane was evaporated at low temperature under a current of air. Then it was dried at 100 °C for 1 hour, cooled and weighed.

The crude fat was calculated by formula given below:

$$\text{Fat (\%)} = \frac{\text{weight of hexane soluble material}}{\text{weight of sample}} \times 100$$

3.4.6 Total Fibre Content

The defatted sample of 2 g was weighed in pre-weighed fibra crucible. Sample was boiled in 150 ml of 1.25% H₂SO₄ solution for 30 minutes and drained properly. Then washed with water and water was allowed to drain. Then after sample was boiled in 150 ml of 1.25% NaOH solution for 30 minutes and NaOH was removed. Again washed with water and the sample was allowed to drain and crucible was dried in the oven at 105 °C to a constant weight. Sample was ignited in muffle furnace until only ash was left. The weight of fiber was obtained and expressed as percentage of weight of sample analysed and calculated by formula which given below. Fibra-Plus equipment (Make: Pelican Equipments, Chennai) as shown in Fig. 3.14.

$$\text{Crude fibre (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

Where,

W_1 = Weight of sample (g)

W_2 = Weight of crucible + sample after washing and drying (g)

W_3 = Weight of crucible + ash (g)

3.4.7 Total Carbohydrate Content

Carbohydrate content was calculated by difference. It was calculated using the formula as given below.

Carbohydrate (%) = 100 – % (moisture + crude protein + ash + crude fibre + crude fat)

3.4.8 Total Soluble Solids

Total soluble solids present in sample was estimated by digital hand refractometer-PAL-1 (Make: ERMA, Japan) having measuring range 0-53 °Brix as shown in Fig. 3.15.

3.4.9 Ascorbic Acid Content

The ascorbic acid content of the sample was determined by 2, 6-dichlorophenol indophenol visual titration method (Ranganna, 1986). Titre value was noted as mg of ascorbic acid per ml of the dye and the dye factor was calculated using following equation:

$$\text{Dye factor} = \frac{0.5}{\text{titre value}}$$

Further, 10-20 g sample was blended with 3% HPO₃ solution and made up to 100 ml. The solution was filtered through whatman No. 1 filter paper. Two to ten ml of the sample extract was taken in a 100 ml conical flask and titrated against the dye solution. Then the ascorbic acid content was computed using following equation:

$$\text{Ascorbic acid} \left(\frac{\text{mg}}{100 \text{ g}} \right) = \frac{\text{Titre value} \times \text{Dye factor} \times V_2 \times 100}{V_1 \times W}$$

Where,

W = Weight of sample taken for estimation, (g)

V_1 = Volume of sample taken for estimation, (ml)

V_2 = Volume made up, (ml)

3.4.10 Minerals (Ca, K)

3.4.10.1 Calcium content

Calcium content was determined by using method described in Ranganna (1986). Aliquot of ash solution 20-100 ml, obtained by dry ashing was taken into a 250 ml beaker and diluted with 25-50 ml water (If necessary). 10 ml of saturated ammonium oxalate solution and 2 drops of methyl red indicator was added. The solution was made slightly alkaline by the addition of dilute ammonia and then slightly acid with a few drops of acetic acid until the colour becomes faint pink (pH 5.0). The solution was heated to its boiling point. It was allowed to stand for overnight. It was filtered through whatman No. 42 paper and washed with water till the filtrate is oxalate free. The point of filter paper was broken and the precipitate was washed first using hot dilute H₂SO₄ and then with hot water and titrated with 0.01 N KMnO₄ to the first permanent pink colour and finally filter paper was added to the solution and again titrated.

Calcium of the sample was calculated by following formula:

$$\text{Calcium content} \left(\frac{\text{mg}}{100 \text{ g}} \right) = \frac{\text{Titre} \times 0.2 \times V_1 \times 100}{V_2 \times W}$$

Where,

V₁ = Total volume of ash solution, (ml)

V₂ = volume taken for estimation, (ml)

W = Weight of sample taken for ashing, (g)

3.4.10.2 Potassium content

The potassium content of bottle gourd was determined by 0.01 N potassium permanganate (KMnO₄) volumetric method as described in Ranganna (1986).

Potassium content of sample was calculated by following formula:

$$\text{Potassium content} \left(\frac{\text{mg}}{100 \text{ g}} \right) = \frac{\text{Titre} \times 0.07 \times V_1 \times 100}{V_2 \times W}$$

Where,

V₁ = Total volume of ash solution, (ml)

V₂ = volume taken for estimation, (ml)

W = Weight of sample taken for ashing, (g)

3.4.11 Peroxidase (POD) Test

Steam blanched bottle gourd shreds of different thickness were estimated for qualitative test. About 1 g of shreds were taken out into a test tube at every 1min interval of steam blanching to check inactivation of enzyme. Method described by Ranganna (1986) was used to check POD inactivation. Guaiacol (1%) and hydrogen peroxide (0.3%) were prepared and added into test tubes. The contents were thoroughly mixed. A rapid and more pronounced brown-reddish colour indicated a high POD activity. If there is no discolouration after 5 to 10 min at the reaction was negative and POD was considered inactivated. Light brown colour indicated low POD activity or incomplete inactivation.

3.4.12 Rehydration Ratio

Rehydration means refreshing the dehydrated or dried products in water. Rehydration ratio was determined using method described in Pervin *et al.* (2008). 5 g Dehydrated samples of each treatment were weighed in a beaker and 150 ml of water were poured into beaker. After that samples were kept for 50 to 60 min for pre-soaking. The samples were transferred to another beakers with 150 ml boiling water. As boiling started, counting of time was started. After that liquid portion was drained off and solid content were transferred to funnel separately fitted with filter paper. Then rehydrated materials were removed from the funnel and the weights taken individually and rehydration ratio was calculated by following equation:

$$\text{Rehydration ratio (\%)} = \frac{\text{Weight of rehydrated material}}{\text{Weight of dehydrated material}}$$

3.4.13 Colour Value (ΔE^*ab)

The colour value of fresh and dehydrated samples were measured by Lovibind colorimeter (Fig. 3.16) (Model RT850i). It expresses colour as numerical values, L* for lightness, a* for green – red and b* for blue - yellow colour components. ΔE^*ab is difference between two colours designated as two points in lab colour space which assigned to each of the L*, a* and b* attributes of two colours. The calibration of lovibind colorimeter was done with a standard white and black plate provided with the instrument. ΔE^*ab values was taken for colour value of bottle gourd shreds. All experiments were conducted 3 times for each sample and the average values were reported.

3.5 MICROBIAL CHARACTERISTICS

Stored sample were analysed for microbial characteristics from 0 day and thereafter at every 15 days interval up to 120 days. The samples were subjected to microbial analysis for total plate count using Nutrient Agar (Hi-Media Laboratories Pvt. Ltd.), yeast and mold count using Potato Dextrose Agar (PDA) (pH adjusted 3.5 by sterile 10% tartaric acid, Hi-Media Laboratories Pvt. Ltd.), coliform count using MacConkey Agar (Hi-Media Laboratories Pvt. Ltd.) as per the standard procedure (Ranganna, 1986). A 1 g sample was added in test tube containing 9 ml sterile water to obtain 1:10 dilutions. Subsequently 1 ml of above dilution was poured in to another test tube containing 9 ml sterile water for further dilutions. Suited dilutions were prepared and 1 ml dilution was poured in set of sterile petri plates containing agar in triplicate. Then plates were incubated in inverted position at suitable temperature and suitable time in incubator (Make: Electroquip) as shown in Fig. 3.17. Microbial characterization was carried out in sterile environment by using laminar air flow chamber. The data of microbial characterization were log transformed.

3.5.1 Total Plate Count

A 15-20 ml molten Nutrient Agar was poured aseptically in to the 1 ml of the dilution kept in sterile petri plates. The sample were mixed with the medium and plates were leaved until the medium solidify. Then plates were placed inverted in incubator maintained at 37 °C for 24 ± 3 hours and colony forming units (cfu/g) were noted.

3.5.2 Yeast and Mold Count

The 1 ml of sample prepared as described above was used for plating in triplicate. 1 ml of tartaric acid was added in to 100 ml of PDA agar. The 15-20 ml melted PDA was poured in petri plates and contents were mixed and agar was allowed to solidify. The plates were inverted and incubated at 27 °C for 72 ± 3 hours and number of colony forming units (cfu/g) were noted.

3.5.3 Coliform Count

A 1 ml of sample prepared as described above was added in to sterile petri plates and thereafter 15-20 ml MacConkey Agar. Then content were mixed and agar was allowed to solidify. The petri plates were inverted and incubated at 37 °C for 24 ± 3 hours and colony forming units (cfu/g) were recorded.



Fig. 3.16 Lovibond colorimeter



Fig. 3.17 Incubator

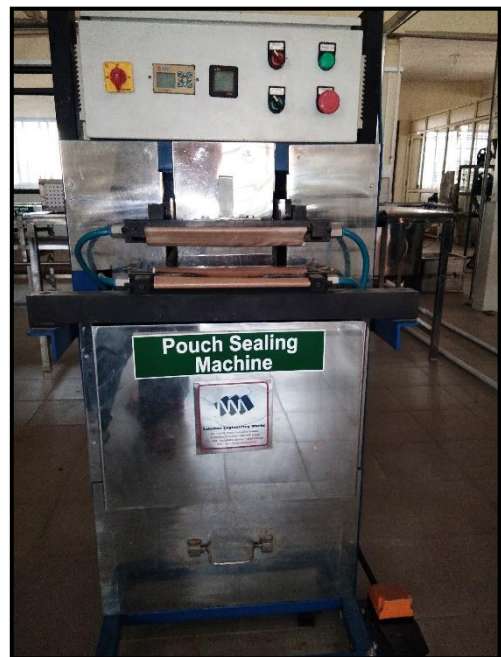


Fig. 3.18 Retortable pouch sealing machine



Fig. 3.19 Hand sealing machine



Fig. 3.20 Digital anemometer

3.6 OPTIMIZATION OF STEAM BLANCHING TECHNIQUE FOR BOTTLE GOURD SHREDS

Blanching is an important unit operation and necessary for inactivation of enzyme which cause browning. Steam blanching was carried out in hot water bath for inactivation POD enzyme. For steam blanching independent variables were thickness of shreds (3, 5 and 7 mm) and blanching time (2, 4, 6 and 8 min). Shreds were estimated for enzyme inactivation at the interval of 1 min up to 8 min. Time of blanching was considered as a co-factor for inactivation of enzyme. The dependent variables were inactivation of POD enzyme, total soluble solids and ascorbic acid content. These experiments were replicated three times and average values were subjected for statistical analysis. Completely randomized design (CRD) was used for statistical analysis. ANOVA tables were prepared and significance of the influence of each parameter on the specific observation was tested to optimize the steam blanching treatment for bottle gourd shreds.

3.7 DEHYDRATION OF BOTTLE GOURD SHREDS (MICROWAVE ASSISTED FLUIDIZED BED DRYER)

Dehydration is profitable operation to increase shelf life of food products by reducing water content and inhibiting microbial growth. Optimized shreds were dehydrated by microwave assisted fluidized bed dryer. First shreds were dried in MCD up to 30% moisture content at a constant conveyor speed 0.3 cm/s. Further dehydration was carried out by FBD up to 5-6% moisture content.

3.7.1 Microwave Continuous Drying

The drying experiments were performed in laboratory microwave conveyor dryer. Microwave conveyor dryer (Fig. 3.6) (Make: Twin Engineers) having the frequency of 2450 ± 50 MHz and 4 kW power. This dryer was continuous dryer having 300 mm belt width and four magnetron at the top of the dryer. Infrared sensors were used to measure the product temperature and the dryer was operated at selected parameter (0.3 cm/s conveyor speed). There were 2 glass coated silicon sheet on which product have to spread. On each sheet 100 g pretreated sample was spread in a single layer. In MCD sample were dried up to 30% and further dehydration was carried out by FBD.

3.7.2 Fluidized Bed Drying

The drying experiments were performed in laboratory fluidized bed dryer (Fig. 3.7). Plenum chamber of dryer consists of a truncated conical base having bottom diameter of 0.21 m and top diameter of 0.30 m. The height of cylindrical column is 0.73 m. An air supply unit to fluidize the sample is provided at the bottom with centrifugal blower coupled with three phase 1 hp electric motor and a flow regulating device to regulate the air flow rate. Air is heated with two electric heaters, 1 kW each to regulate the temperature of hot air. Pretreated samples of selected size were dried by spreading them in single layer which were already dried up to 30% in MCD. The hot air was supplied through the bottom of the plenum chamber at specified temperature and air velocity as mentioned in experimental design Part-2. The air velocity were maintained using adjustable flab at the air inlet and digital anemometer (Fig. 3.20). The moisture loss in shreds was recorded at every 30 min interval during drying. The drying process was stopped when the moisture content reached to 5-6%. The product was then cooled for 15 min after drying and packed in polypropylene and metalized laminated pouches. To seal metalized laminated pouches retortable pouch sealing machine was used as shown in Fig. 3.18 and for polypropylene pouches, hand sealing machine was used as shown in Fig. 3.19. All experiments were conducted in triplicate for each air velocity and temperature and the average values were reported.

3.8 STORAGE STUDY

Dehydrated shreds packed in polypropylene and metalized laminated pouches were stored for 120 days at ambient temperature. Packed and stored samples were analysed for sensory characteristics, physico-chemical characteristics and microbial characteristics. Sensory characteristics were carried out in terms of colour and appearance, aroma, texture and overall acceptability (OAA) of both dehydrated shreds and control samples. Physico-chemical characteristics include colour value, moisture content, ascorbic acid content, ash content and minerals (K, Ca). Microbial characteristics include total plate count, yeast and mold count and coliform count. The data were replicated for 3 times and average values were reported.

3.8.1 Sensory Characteristics

All samples of bottle gourd shreds were further subjected to sensory evaluation by using 9 hedonic scale. The score-card suggested by Ranganna (1986) was used for judging the dehydrated products during this study (Appendix-VI). A sensory judging

panel was constituted with 9 panelists including staff and students of the college and the samples were served. The panelists were instructed to rate each sample on 9 point hedonic scale which include score for colour and appearance, aroma, texture and overall acceptability. The final score for each attribute was obtained by averaging the score of all the panelists. The data were replicated for 3 times and average values were reported.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results and discussion of the experiment entitled “Production technology for dehydrated bottle gourd shreds” conducted at College of Food Processing Technology & Bio-energy, Anand Agricultural University, Anand. The data collected during the investigation are covered under following sub sections.

4.1 Physico-chemical characterization of bottle gourd fruits

4.2 Optimization of steam blanching technique for bottle gourd shreds

4.3 Standardization of dehydration parameters for bottle gourd shreds using microwave assisted fluidized bed dryer and evaluation of quality characteristics

4.4 Shelf life studies of dehydrated bottle gourd shreds

4.1 PHYSICO-CHEMICAL CHARACTERIZATION OF BOTTLE GOURD FRUITS

Fresh bottle gourd were washed using tap water and cut. Then analysed for the physico-chemical characteristics i.e. seed/pulp/peel ratio, moisture content, ash content, protein content, total fibre content, total carbohydrate content, total soluble content, ascorbic acid content and minerals (Ca, K). Physico-chemical characterization was carried out as per methods explained in chapter III. The individual replication data related to physico-chemical characterization of bottle gourd shreds are presented in Appendix-I and the average of 3 replicated data are shown in Table 4.1.

Table 4.1 physico-chemical characterization of bottle gourd fruits

Constituent	Average value
Seed/pulp/peel ratio (%)	20.61:70.23:9.16
Moisture content (%)	94.36 ± 0.25
Ash content (%)	00.55 ± 0.02
Protein content (%)	01.23 ± 0.07
Total fibre content (%)	00.63 ± 0.05
Total fat content (%)	00.23 ± 0.05
Total carbohydrate content (%)	02.98 ± 0.24
Total soluble solids (°Brix)	04.03 ± 0.05
Ascorbic acid content (mg/100g)	09.24 ± 0.07
Calcium (mg/100g)	13.60 ± 0.28
Potassium (mg/100g)	87.41 ± 0.62

The results indicated that the bottle gourd had very high moisture content of 94.36% (wb). The ash content, protein content, and total fibre content were estimated to the tune of 0.55%, 1.23% and 0.63% respectively. Total fat content and total carbohydrate content were found to be 0.23% and 2.98% respectively. Total soluble solids were 4.03 °Brix and ascorbic acid content was 9.24 mg/100g. Calcium content and potassium content were 13.60 mg/100g and 87.41 mg/100g respectively. The results obtained are in good accordance with the results reported by several other investigators [Gopalan *et al.* (1989), Hanif *et al.* (2006), USDA (2018)]. However, the possibility of differences in the composition of bottle gourd may be due to variety, environment, harvesting time and other factors.

4.2 OPTIMIZATION OF BLANCHING

Blanching is an important parameter for dehydration of bottle gourd shreds. This treatment help in accelerating the drying process and also maintain the quality of the products during processing and storage. Steam blanching was carried out to inactivate enzymes (i.e. peroxidase) in bottle gourd shreds. Which is responsible for quality deterioration and discolouration of the processed product. The individual replication reading related to effect of steam blanching of bottle gourd shreds are presented in Appendix-II and the average of 3 replicated data are shown in Table 4.2. The statically mean analysed data showing effect of shreds thickness and blanching time on various parameters during steam blanching are presented in Table 4.3. The data of total soluble solids, ascorbic acid and juice yield for both control and blanched sample were shown in Table 4.2 and showed that the TSS and ascorbic acid were reduced after blanching and juice yield also decreased.

Tables 4.2 Effect of steam blanching on quality of bottle gourd shreds

Shreds thickness (mm)	POD inactivation time (min)	Total soluble solids (°Brix)	Ascorbic acid (mg/100g)	Juice yield (%)
Control				
3	-	4.10 ± 0.00	9.80 ± 0.04	77.12 ± 0.18
5	-	4.00 ± 0.01	9.24 ± 0.00	79.40 ± 0.33
7	-	4.10 ± 0.00	9.24 ± 0.02	79.41 ± 0.23
Blanched				
3	6.0 ± 0.50	2.83 ± 0.05	7.08 ± 0.00	62.93 ± 0.26
5	7.5 ± 0.50	2.70 ± 0.10	6.77 ± 0.08	64.25 ± 0.34
7	8.3 ± 0.28	2.63 ± 0.05	6.26 ± 0.09	65.39 ± 0.19

Table 4.3 Statistically mean analysed data showing effect of shreds thickness and blanching time on various parameters during steam blanching

Treatment	TSS (°Brix)	Ascorbic acid (mg/100g)	Juice yield (%)
Shreds Thickness (ST)			
ST ₁	2.766	7.110	63.098
ST ₂	2.616	6.895	64.671
ST ₃	2.516	6.471	65.678
SEm	0.015	0.014	0.061
CD	0.044	0.041	0.177
Blanching Time (BT)			
BT ₁	2.477	6.934	64.810
BT ₂	2.577	6.853	64.698
BT ₃	2.700	6.796	64.282
BT ₄	2.777	6.718	64.140
SEm	0.018	0.014	0.070
CD	0.051	0.016	0.204
Interaction (ST x BT)			
SEm	0.030	0.028	0.121
CD	NS	0.082	NS
CV %	2.00	0.72	0.33

ST₁ = 3 mm, ST₂ = 5 mm, ST₃ = 7 mm, BT₁ = 2 min, BT₂ = 4 min, BT₃ = 6 min, BT₄ = 8 min

4.2.1 Effect of Steam Blanching on POD Inactivation Time

Bottle gourd shreds 3, 5 and 7 mm were subjected to steam blanching to inactivate POD enzyme. Time required for POD inactivation was found 6, 7.5 and 8.3 min for 3, 5, and 7 mm shred thickness respectively. Time required for POD inactivation was less in 3 mm shreds thickness as compared to 5 and 7 mm. Result indicated that as shred thickness (ST) increases, the blanching time (BT) for inactivation of POD enzyme was also increased. This might be due to more surface area in 3 mm shreds thickness to expose fast penetration of steam at the centre. The most effective bottle gourd shred thickness was 3 mm, where POD inactivation time was minimum i.e. 6 min.

4.2.2 Effect of Steam Blanching on Total Soluble Solids

The TSS was decreased as compared to raw bottle gourd shreds after blanching. TSS in bottle gourd shreds were decreases as the shred thickness increases (Fig 4.1). In 7 mm shreds thickness, TSS was minimum i.e. 2.63 °Brix and blanching time was higher i.e. 8.3 min whereas maximum TSS was found 2.83 °Brix in 3 mm shreds thickness and minimum blanching time i.e. 6 min. TSS in 5 mm shreds thickness was

2.70 °Brix and blanching time was 7.5 min. The total soluble solids was decreased significantly as shreds thickness (ST) and blanching time (BT) increased as shown in Table 4.3. Although, the combined effect (ST*BT) of shreds thickness and blanching time was found non-significant. The TSS of unblanched bottle gourd shreds were higher than the blanched one, might be due to removal of moisture during steam blanching as data shown in Table 4.2. Decreased in TSS during blanching, showed a progressive loss of solids with increase in thickness of shreds (Fig. 4.1). The extent of loss in TSS from the bottle gourd shreds varied with different blanching time, as blanching time increases, loss of solids also increases.

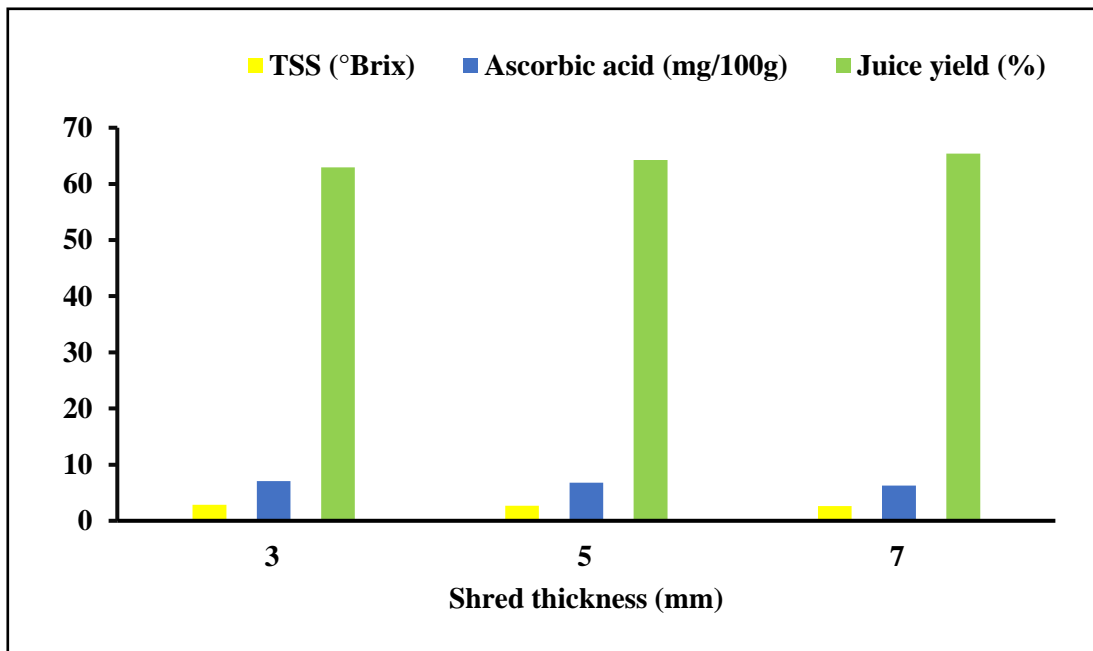


Fig. 4.1 Effect of steam blanching on quality parameters

The statistical analysis of the data (Table 4.4) revealed that the calculated F values (F_c) for blanching time (BT) and shreds thickness (ST) were higher than the

Table 4.4 ANOVA for effect of blanching time and shreds thickness on total soluble solids during steam blanching

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
Shreds thickness (ST)	2	0.380	0.190	68.400	3.400	0.015	0.044	*
Blanching time (BT)	3	0.473	0.158	56.800	3.010	0.018	0.051	*
ST*BT	6	0.020	0.003	01.200	2.510	0.030	NS	NS
Error	24	0.067	0.003	C V % : 2.00				

* Significant at 5% level of significant; NS: non-significant

tabulated F values (F tab). This, indicating significant effect of blanching time and shreds thickness on TSS at 5% level of significance. Whereas, calculated F value (Fc) of their interaction (ST*BT) is less than tabulated F value (F tab), showing non-significant effect of the interaction of the above factors on TSS.

4.2.3 Effect of Steam Blanching on Ascorbic Acid Content

The data obtained on the ascorbic acid content for blanched bottle gourd shreds are presented in Table 4.2. There was slight variation in the ascorbic acid content among different shreds thickness. The maximum ascorbic acid was found to be 7.08 mg/100g in 3 mm shreds thickness at 6 min blanching time (Fig 4.1). The maximum ascorbic acid content of unblanched bottle gourd shreds was 9.80 mg/100g and decreased after blanching i.e 7.08, 6.77 and 6.26 mg/100g for 3, 5 and 7 mm shreds thickness respectively. The ascorbic acid content was decreased significantly as shreds thickness (ST) and blanching time (BT) increases as shown in Table 4.3. The result and their interaction (ST*BT) were as shown in Table 4.3. The result and their interaction (ST*BT) were highly significant at 5% level of significance. After blanching, 7 mm thick shreds takes longer time to cool than 3 mm thick shreds and this thermal lag causing heat expose in 7 mm shreds which may be a reason of reduction in ascorbic acid content of bottle gourd shreds as ascorbic acid is heat sensitive vitamin. Decreased in ascorbic acid content in blanched shreds might be due to the leaching loss as the time for POD inactivation was more or higher expose time during steam blanching. Thus result revealed that increasing the blanching time, increased the ascorbic acid loss.

The statistical analysis of the data (Table 4.5) showed that the calculated F values (Fc) for blanching time (BT) and shreds thickness (ST) i.e. 531.130 and 31.200 were higher than the tabulated F value (F tab) i.e. 3.400 and 3.010 respectively.

Table 4.5 ANOVA for effect of blanching time and shreds thickness on ascorbic acid during steam blanching

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
Shreds thickness (ST)	2	2.537	1.269	531.130	3.400	0.014	0.041	*
Blanching time (BT)	3	0.224	0.075	031.200	3.010	0.016	0.048	*
ST*BT	6	0.041	0.007	002.865	2.510	0.028	0.082	*
Error	24	0.057	0.002	C V % : 0.72				

* Significant at 5% level of significant; NS: non-significant

Thus, indicating significant influence of blanching time and shreds thickness on ascorbic acid content at 5% level of significance. However, calculated F value (F_c) of their interaction (ST*BT) is also more than tabulated F value (F_{tab}), this showing significant influence of their interaction of the above factors on ascorbic acid.

4.2.4 Effect of Steam Blanching on Juice Yield

The data obtained on juice recovery of bottle gourd shreds were presented in Table 4.2. The Juice yield of 3 mm control sample was 77.12% which decreased to 62.93% after 6 min blanching, similarly for 5 mm it was 79.40% which was decreased to 64.25% after 7.5 min blanching and for 7 mm, it was 79.41% which was decreased to 65.39% after 8.3 min blanching. Juice yield was decreased significantly after blanching which can be seen in Fig. 4.1. This might be due to leaching loss and softening of texture of the bottle gourd shreds thus makes juice extraction difficult. In 7 mm thick shreds juice yield was more than 3 and 5 mm thick shreds. This might be due to more thickness of 7 mm shreds because it may retain more juice than the 3 and 5 mm thick shreds. But, shreds were prepared for further dehydration process thus, juice yield should be less required so that it takes less time to dehydrate.

The statistical analysis of the data (Table 4.6) showed that the calculated F values (F_c) for shreds thickness (ST) and blanching time (BT) i.e. 461.050 and 21.258 were higher than the tabulated F value (F_{tab}) i.e. 3.400 and 3.010 respectively. Thus, indicating significant influence of blanching time and shreds thickness on juice yield at 5% level of significance.

Table 4.6 ANOVA for effect of blanching time and shreds thickness on juice yield during steam blanching

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
Shreds thickness (ST)	2	40.584	20.292	461.050	3.400	0.061	0.177	*
Blanching time (BT)	3	2.807	0.936	21.258	3.010	0.070	0.204	*
ST*BT	6	0.477	0.079	1.805	2.510	0.121	NS	NS
Error	24	1.056	0.044	C V % : 0.33				

* Significant at 5% level of significant; NS: non-significant

However, calculated F value (F_c) of their interaction (ST*BT) is also less than tabulated F value (F_{tab}), this showing non-significant influence of their interaction of the above factors on juice yield.

4.2.5 Optimization of Steam Blanching Process

Blanching is mostly used as pre-treatment prior to further processing in most of vegetables. Blanching is used to inactivate the enzymes, reduce loss of vitamins and other nutrients during dehydration. Blanching of bottle gourd shreds was very important to inactivate of POD enzyme for further dehydration of bottle gourd shreds. Steam blanching was optimized for 3, 5 and 7 mm bottle gourd shred thickness based on POD inactivation time and then maximum TSS, maximum ascorbic acid content and minimum juice yield. The best response was found in 3 mm bottle gourd shreds thickness at 6 min POD inactivation time with maximum TSS i.e 2.83 °Brix, maximum ascorbic acid content i.e 7.084 mg/100g and minimum juice yield i.e 62.93%. The obtained optimized process parameters were standardized, as it satisfies the statistical and physical criteria. Decrease in ascorbic acid content in blanched shreds might be due to higher exposure time during steam blanching process as it is heat sensitive. Result revealed that prolonging the blanching time increased the ascorbic acid losses in bottle gourd shreds. Juice yield was less in 3 mm thick shreds, it might be due to less thickness which cannot retain more moisture in it. Therefore, 3 mm shreds was optimized for further dehydration.

4.3 STANDARDIZATION OF DEHYDRATION PARAMETERS

Dehydration is one of the most important method for preservation of fruits and vegetables and production of wide varieties of products with major aim to prolong storage life. The optimized steam blanched 3 mm thick bottle gourd shreds were carried out for further dehydration. For this, 3 mm thick shreds were dehydrated by two dryer i.e. microwave continuous dryer and fluidized bed dryer. The details of operating parameters were mentioned in the previous chapter. The 3 mm bottle gourd shreds were first dried up to 30% in microwave continuous dryer at 0.3 cm/s conveyor speed and pulsation time for microwave magnetron was 25 sec on and 15 sec off. Further dehydration was carried out in fluidized bed dryer at different drying temperature and air velocity. Time required to dehydrate bottle gourd shreds of all sides were 45 min approximately in MCD, and after that further dehydration was carried out by FBD at 55, 60 and 65 °C temperature and air velocity of 6, 8 and 10 m/s combination until final moisture content at 6%.

Table 4.7 Effect of drying temperature and air velocity of fluidized bed dryer on pretreated bottle gourd shreds

Air velocity (m/s)	Total Time required for dehydration (min)	Ascorbic acid content (mg/100g)	Colour value (ΔE^*ab)	Rehydration ratio (%)
At 55 °C temperature				
6	75.26 ± 0.25	5.39 ± 0.07	1.86 ± 0.32	09.47 ± 0.34
8	74.00 ± 0.50	5.42 ± 0.05	1.83 ± 0.34	09.83 ± 0.63
10	73.30 ± 0.25	5.47 ± 0.02	2.02 ± 0.33	11.94 ± 0.28
At 60 °C temperature				
6	65.46 ± 0.25	5.54 ± 0.03	1.47 ± 0.19	09.60 ± 0.36
8	64.30 ± 0.15	5.53 ± 0.04	1.39 ± 0.79	10.49 ± 0.16
10	63.10 ± 0.10	5.60 ± 0.01	1.81 ± 0.66	12.76 ± 0.16
At 65 °C temperature				
6	60.50 ± 0.30	5.61 ± 0.03	1.62 ± 0.98	11.07 ± 0.21
8	60.00 ± 0.17	5.65 ± 0.01	1.45 ± 0.61	11.13 ± 0.23
10	58.56 ± 0.55	5.68 ± 0.01	1.33 ± 0.25	12.93 ± 0.02

Table 4.8 Statistically mean analysed data showing the effect of dryer temperature and air velocity of fluidized bed dryer on bottle gourd shreds on various parameters

Treatment	Total Time required for dehydration (min)	Ascorbic acid (mg/100g)	Colour value (ΔE^*ab)	Rehydration ratio (%)
Fluidized bed dryer temperature (FBT)				
FBT ₁	74.1889	5.4289	1.9089	10.4200
FBT ₂	64.3000	5.5578	1.5300	10.9522
FBT ₃	59.7222	5.6389	1.4722	11.7133
SEm	0.106	0.013	0.107	0.105
CD	0.314	0.040	0.318	0.313
Air velocity (AV)				
AV ₁	67.0778	5.5133	1.6522	10.0522
AV ₂	66.1444	5.5367	1.5344	10.4867
AV ₃	64.9889	5.5756	1.7244	12.5467
SEm	0.106	0.013	0.107	0.105
CD	0.314	0.040	NS	0.313
Interaction (FBT*AV)				
SEm	0.183	0.023	0.185	0.182
CD	NS	NS	NS	0.542
CV %	0.48	0.72	19.62	2.87

FBT₁ = 55 °C, FBT₂ = 60 °C, FBT₃ = 65 °C and AV₁ = 6m/s, AV₂ = 8m/s, AV₃ = 10m/s

The total time required for dehydration was presented in Table 4.7. The individual replication data related to effect of drying temperature and air velocity of fluidized bed dryer on bottle gourd shreds are presented in Appendix-III and the average of 3 replicated data are shown in Table 4.7. The statically mean analysed data showing effect of temperature and air velocity of fluidized bed dryer on various parameters during dehydration are presented in Table 4.8.

4.3.1 Effect of Fluidized Bed Drying Temperature and Air Velocity on Dehydration Time

During pre-drying in MCD, it was found that there was a burning in the shreds, therefore, complete dehydration was not carried out by MCD. Thus dehydration was carried out in two stages, first in MCD and then FBD up to 6% moisture level in final products. Time for dehydration was decrease as the fluidized bed dryer temperature and air velocity was increased. As temperature and air velocity increases, more moisture evaporate from the sample and it increases drying rate of samples. Time required for dehydration was maximum at low temperature and low air velocity i.e. at 55 °C and 6 m/s air velocity, and time for dehydration was 75.26 min. At 65 °C and 10 m/s air velocity, minimum time was needed for dehydration of bottle gourd shreds i.e. 58.56

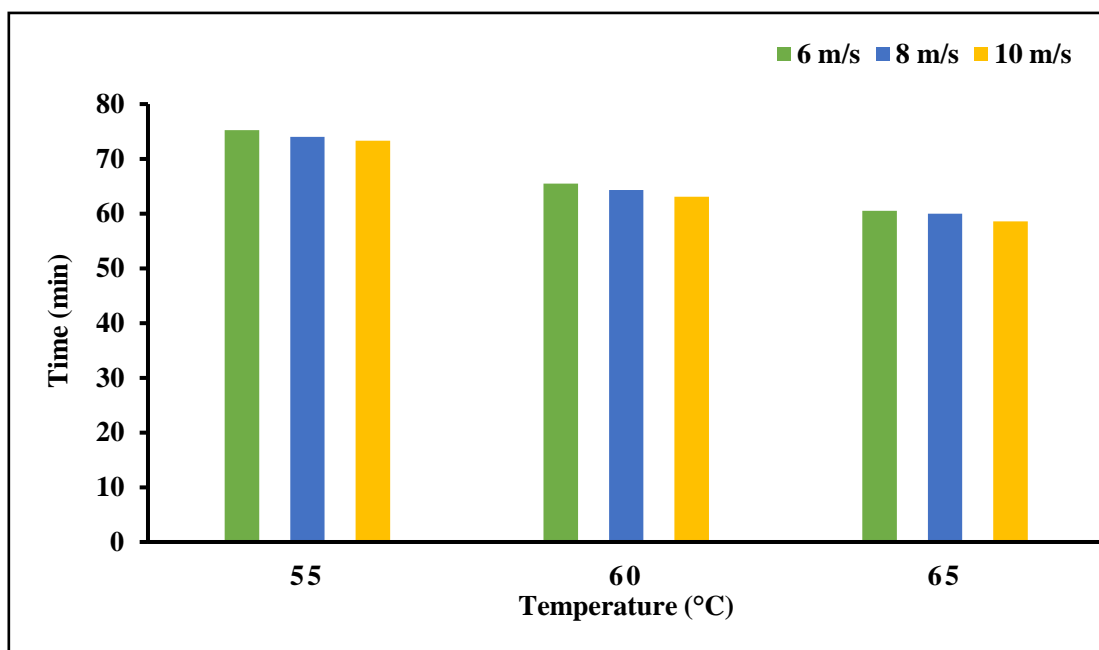


Fig. 4.2 Effect of fluidized bed drying temperature and air velocity on dehydration time

min, which is lesser than all other drying time. Time for dehydration was decreased significantly as fluidized bed drying temperature (FBT) and air velocity (AV) increased as shown in Table 4.8. However, their interaction (FBT*AV) was found non-significant.

Table 4.9 ANOVA for effect of fluidized bed dryer temperature and air velocity on dehydration time of bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
FBD temperature (FBT)	2	984.095	492.047	4910.089	3.550	0.106	0.314	*
FBD air velocity (AV)	2	19.712	9.856	98.353	3.550	0.106	0.314	*
FBT*AV	4	0.906	0.226	2.259	2.930	0.183	NS	NS
Error	18	1.804	0.100	C V % : 0.48				

* Significant at 5% level of significance; NS: non-significant

The ANOVA (Table 4.9) showed that the calculated F value (Fc) for drying temperature (FBT) and air velocity (AV) was higher than the tabulated F (F tab). Thus, indicating significant influence of drying temperature and air velocity on dehydration time at 5% level of significance. However, calculated F value (F Cal) of their interaction (FBT*AV) was less than tabulated F value (F tab) showed that interaction between above factor is non-significant.

4.3.2 Effect of Fluidized Bed Drying Temperature and Air Velocity on Ascorbic Acid Content

The data obtained on ascorbic acid from dehydrated bottle gourd shreds are presented in Table 4.7 and graphically represented in Fig. 4.3. The maximum ascorbic acid content was found to be 5.68 mg/100g at 65 °C temperature and 10 m/s air velocity. The ascorbic acid content of raw bottle gourd was 9.24 mg/100g and was decreased to 38.52% after drying at 65 °C temperature and 10 m/s air velocity in 3 mm shreds thickness. The ascorbic acid content was increased significantly as drying temperature (FBT) as well as air velocity (AV) increased resulting dehydration time was decreased (Table 4.8). The interaction (FBT*AV) was non-significant. As ascorbic acid is heat sensitive vitamin, it decreases with lower temperature and higher expose time during dehydration. In dehydration, water was removed which cause the reduction in ascorbic acid content of shreds, because it is water soluble vitamin. Results showed that, lower

temperature and higher holding time decreases the ascorbic acid content of bottle gourd shreds. From experimentation, it was revealed that 65 °C drying temperature and 10 m/s air velocity had higher ascorbic acid retention for dehydrated of bottle gourd shreds.

The statistical analysis of data (Table 4.10) revealed that the calculated F value (F_c) for interaction of drying temperature (FBT) and air velocity (AV) was less than the tabulated F value (F_{tab}), thus indicating that the effect of both on ascorbic acid was non-significant.

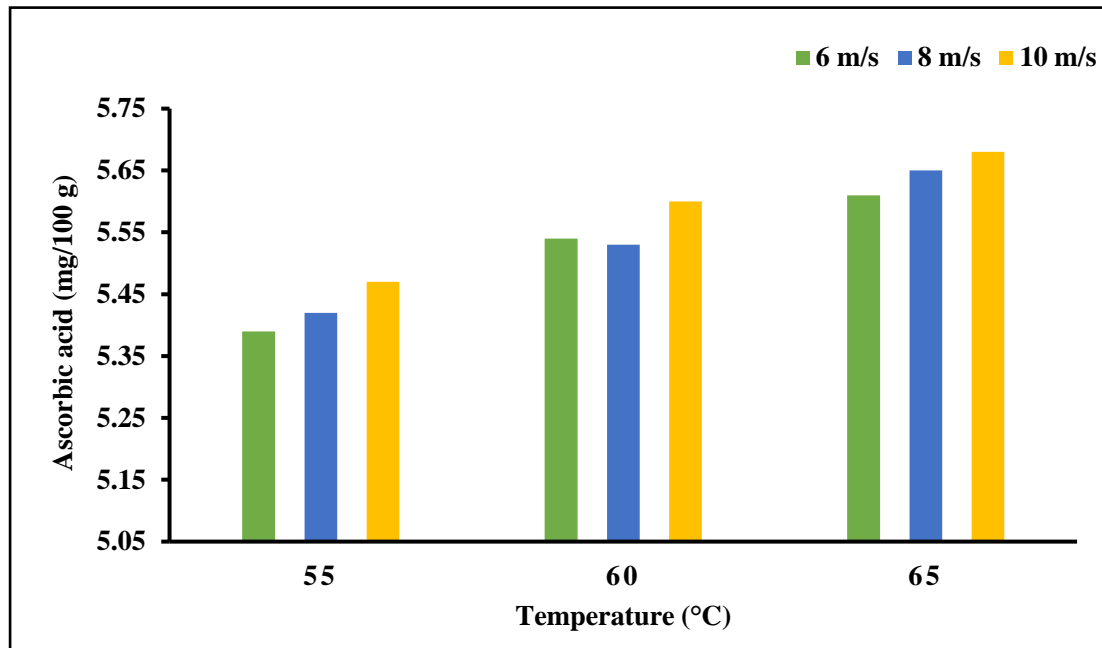


Fig 4.3 Effect of fluidized bed drying temperature and air velocity on ascorbic acid content

Table 4.10 ANOVA for effect of fluidized bed dryer temperature and air velocity on ascorbic acid content of bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
FBD temperature (FBT)	2	0.202	0.101	62.533	3.550	0.013	0.040	*
FBD air velocity (AV)	2	0.018	0.009	5.512	3.550	0.013	0.040	*
FBT*AV	4	0.004	0.001	0.661	2.930	0.023	NS	NS
Error	18	0.029	0.002	CV % : 0.72				

* Significant at 5% level of significance; NS: non-significant

Calculated F value for drying temperature (FBT) and air velocity (AV) was more than the tabulated F value, which indicate significant influence on the ascorbic acid content of bottle gourd shreds.

4.3.3 Effect of Fluidized Bed Drying Temperature and Air Velocity on Colour Value (ΔE^*ab)

The colour value of dehydrated bottle gourd shreds was measured by lovibond colorimeter (Model RT850i). The data on colour value of dehydrated bottle gourd shreds is presented in Table 4.7.

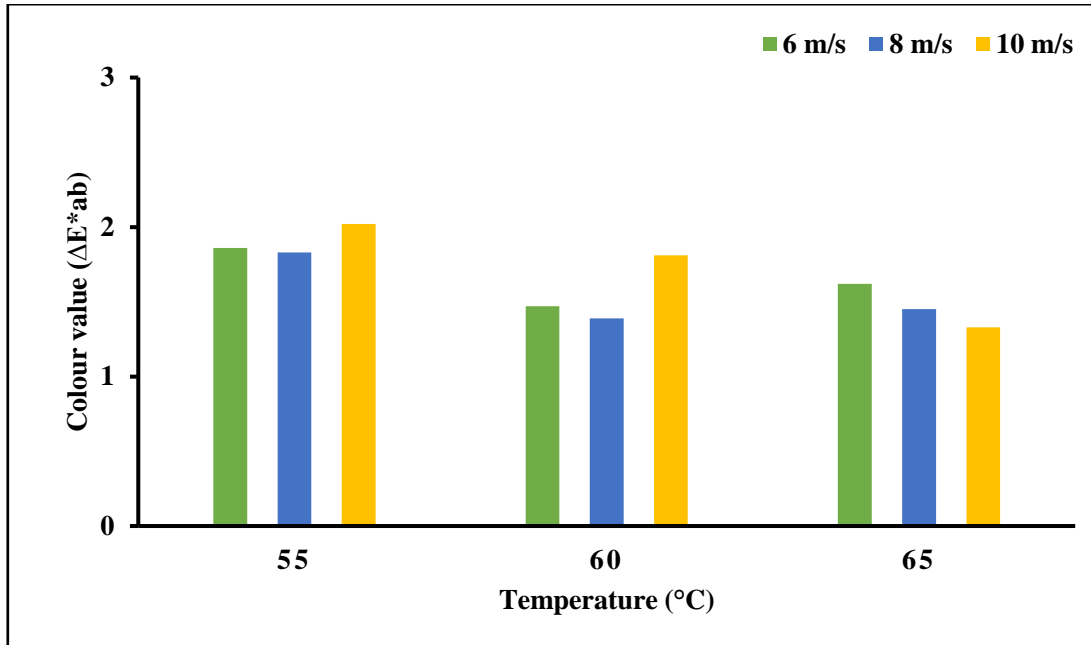


Fig. 4.4 Effect of fluidized bed drying temperature and air velocity on colour value (ΔE^*ab)

The data in Fig. 4.4 shows the effect of fluidized bed drying temperature and air velocity on colour value for bottle gourd shreds. The ΔE^*ab value for raw bottle gourd was 2.33 and ΔE^*ab value shows the difference between two colours designated as two points in lab colour space which assigned to each of the L^* , a^* and b^* attributes of two colours.

Table 4.11 ANOVA for effect of fluidized bed dryer temperature and air velocity on colour value (ΔE^*ab) of bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
FBD temperature (FBT)	2	1.013	0.506	4.911	3.550	0.107	0.318	*
FBD air velocity (AV)	2	0.166	0.083	0.803	3.550	0.107	NS	NS
FBT*AV	4	0.413	0.103	1.003	2.930	0.185	NS	NS
Error	18	1.856	0.103	C V %: 19.62				

* Significant at 5% level of significance; NS: non-significant

The ΔE^*_{ab} value for raw bottle gourd shreds was taken as standard. The ΔE^*_{ab} value of sample shows the difference between L^* , a^* and b^* of standard and L^* , a^* and b^* of samples. The ΔE^*_{ab} value of dehydrated bottle gourd shreds was minimum at 65 °C fluidized bed drying temperature and 10 m/s air velocity i.e. 1.33 and maximum at 55 °C temperature and 10 m/s air velocity i.e. 2.02.

The statistical analysis of data (Table 4.11) revealed that the calculated F value (F_c) for drying temperature (FBT) was higher than the tabulated F value (F_{tab}), that indicates influence of drying temperature on colour value was significant at 5% level of significance. However, calculated F value (F_c) for air velocity and interaction (FBT*AV) was less than the tabulated F value (F_{tab}). That indicated that the insignificant influence of air velocity and interaction of above factors on colour value.

4.3.4 Effect of Fluidized Bed Drying Temperature and Air Velocity on Rehydration Characteristics

After dehydration of bottle gourd shreds rehydration ratio was determined by method described in materials and methods (3.4.12). The data obtained on the rehydration ratio of dehydrated bottle gourd shreds is presented in Table 4.7. The Fig. 4.5 shows the effect of drying temperature and air velocity on rehydration ratio.

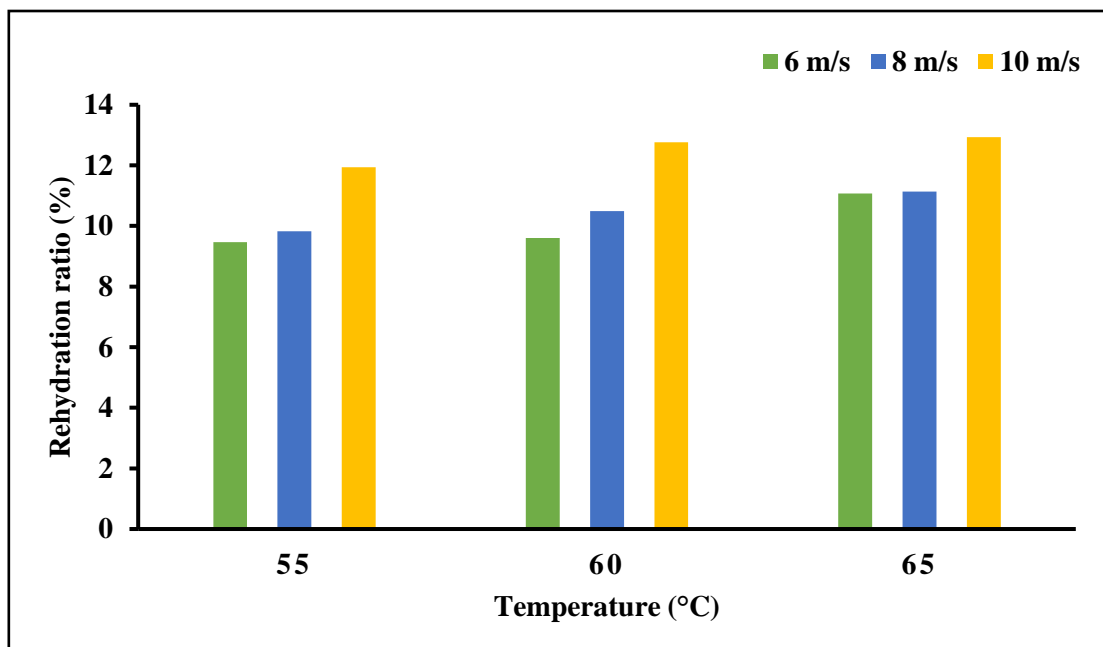


Fig. 4.5 Effect of fluidized bed drying temperature and air velocity on rehydration ratio

The Fig. 4.5 illustrates that as temperature and air velocity of fluidized bed dryer increased, rehydration ratio was also increased. The minimum rehydration was 9.47% at 55 °C drying temperature and 6 m/s air velocity. The maximum rehydration ratio was found 12.93% at 65 °C drying temperature and 10 m/s air velocity. This might be due to cellular and structural disruption of shreds at high temperature during drying. The cellular and structural disruption may also occur at low temperature during dehydration but it might be more at high temperatures which might have increased the rehydration ratio of shreds. It was also observed that after 15 min boiling of pre-soaked sample, the regained weight remain near about the same as the samples approached saturated condition.

The statistically analysed data on rehydration ratio is presented in Table 4.12. The calculated F value (F_c) for fluidized bed drying temperature (FBT) and air velocity (AV) was higher than the tabulated F value (F_{tab}), that indicating significant influence on rehydration ratio of dehydrated bottle gourd shreds. Interaction between FBD temperature and FBD air velocity i.e FBT*AV was also significant at 5% level of significance.

Table 4.12 ANOVA for effect of fluidized bed dryer temperature and air velocity on rehydration ratio of bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
FBD temperature (FBT)	2	7.606	3.803	38.089	3.550	0.105	0.313	*
FBD air velocity (AV)	2	31.964	15.982	160.072	3.550	0.105	0.313	*
FBT*AV	4	1.299	0.325	3.252	2.930	0.182	0.542	*
Error	18	1.797	0.100	C V %: 2.87				

* Significant at 5% level of significance; NS: non-significant

4.3.5 Optimization of Dehydration Parameters

It is necessary to decide the dehydration parameters to produce the dehydrated bottle gourd shreds with higher nutrient content. Dehydration increases the protein content, carbohydrate content and mineral content in bottle gourd shreds. Optimization of dehydration parameters were performed based on minimum dehydration time, maximum ascorbic acid content, minimum colour value (ΔE^*ab) and maximum rehydration ratio. The dehydration time for 3 mm shreds was found maximum at 55 °C drying temperature and 6 m/s air velocity. The dehydration time was less i.e. 58.56 min

at 65 °C drying temperature and 10 m/s air velocity. There is no significant difference between ascorbic acid content at different temperature and air velocity. Maximum ascorbic acid content was found 5.68 mg/100g at the drying temperature of 65 °C and 10 m/s air velocity. The ΔE^*_{ab} value should be minimum, which was also found minimum at 65 °C drying temperature and 10 m/s air velocity. Rehydration ratio is important parameter of dehydrated products, therefore it is good that more rehydration of dehydrated product. Rehydration ratio was also maximum at 65 °C drying temperature and 10 m/s air velocity, which was 12.93%. Thus, statically, fluidized bed drying temperature 65 °C and 10 m/s air velocity was optimized for shelf life study of dehydrated bottle gourd shreds. After dehydration, optimized shreds were packed in metalized laminated pouches and polypropylene pouches.

4.4 CHEMICAL ANALYSIS OF DEHYDRATED BOTTLE GOURD SHREDS

The dehydrated bottle gourd shreds produced using optimized dehydration parameters was analysed for its various chemical properties. Dehydration increases the protein content, ash content, fat content as well as mineral content but ascorbic acid was decreased as presented in Table 4.13. The individual replication reading related to chemical analysis of dehydrated bottle gourd shreds are presented in Appendix-IV.

Table 4.13 Chemical analysis of dehydrated bottle gourd shreds

Parameters	Values
Moisture content (%)	06.30 ± 0.26
Ash content (%)	03.60 ± 0.30
Protein content (%)	12.77 ± 0.08
Total fibre content (%)	04.40 ± 0.05
Total fat content (%)	03.37 ± 0.00
Total carbohydrate content (%)	69.56 ± 0.03
Ascorbic acid content (mg/100g)	05.67 ± 0.02
Calcium content (mg/100g)	59.34 ± 0.05
Potassium content (mg/100g)	396.18 ± 0.26

4.5 SHELF LIFE STUDY OF DEHYDRATED BOTTLE GOURD SHREDS

Optimized dehydrated bottle gourd shreds produced using MCD assisted FBD as described in previous section was evaluated for its storability. This was necessary to determine the shelf-life study and storage quality of the optimized shreds in packaging materials for this, thirty five gram dehydrated bottle gourd shreds were filled in two packaging materials i.e metalized laminated pouches and polypropylene pouches and were heat sealed. The samples were stored under ambient condition (30 ± 2 °C) and were evaluated for sensory characteristics (colour and appearance, aroma, texture and overall acceptability), physico-chemical characteristics (colour value, moisture content, ascorbic acid content, ash content, calcium and potassium content) and microbial characteristics (total plate count, yeast and mold count and coliform count) of stored samples. The shelf-life study was continued for 120 days. The evaluations of the different parameters of stored sample were carried out at the interval of fifteen days. The individual replication data related to effect of storage condition on dehydrated bottle gourd shreds are presented in Appendix-V and the average of 3 replicated data are shown below in respected tables.

4.5.1 Effect of Storage on Colour and Appearance

The colour and appearance of product is very important for the consumer appeal. The effect of storage period on colour and appearance score of dehydrated bottle gourd shreds in two different packaging material is presented in Table 4.14 and represented graphically in Fig 4.8. Based on sensory score of colour and appearance CP and CMP products was not acceptable from the beginning of the shelf-life because sensory score were less than the acceptable limit. The colour and appearance score of dehydrated bottle gourd shreds was maximum for MLP i.e. 7.56 and decreased up to 6.73 and for PP initial score was 7.55 which was decreased up to 5.20 after 120 days of storage. MLP and PP products were acceptable up to 120 days based on colour and appearance score.

The statistical analysis of the data (Table 4.15) revealed that the calculated F values (F_c) for sample in both packaging material (i.e polypropylene and metalized laminated pouch) (P), packaging material for both sample (i.e control and dehydrated shreds) (S) and days of storage (D) were higher than the tabulated F values (F_{tab}). This indicating that the influence of above factors was significant at 5% level of significance.

Table 4.14 Effect of storage on colour and appearance of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	7.55 ± 0.05	4.98 ± 0.07	7.56 ± 0.05	4.96 ± 0.15
15	7.33 ± 0.15	4.22 ± 0.01	7.22 ± 0.03	4.27 ± 0.04
30	7.17 ± 0.04	5.05 ± 0.04	7.36 ± 0.05	4.88 ± 0.05
45	7.10 ± 0.36	4.64 ± 0.02	7.20 ± 0.17	5.01 ± 0.02
60	7.11 ± 0.07	4.60 ± 0.16	7.18 ± 0.10	5.03 ± 0.05
75	6.89 ± 0.04	4.61 ± 0.01	6.95 ± 0.02	5.03 ± 0.07
90	6.80 ± 0.14	4.60 ± 0.09	6.91 ± 0.01	5.00 ± 0.40
105	6.40 ± 0.20	4.30 ± 0.09	6.82 ± 0.09	4.80 ± 0.12
120	5.20 ± 0.03	4.11 ± 0.03	6.73 ± 0.01	5.00 ± 0.03

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

The interaction between samples and packaging materials (P*S) was non- significant. Interaction between samples and days of storage (P*D); interaction of packaging material and days of storage (S*D); interaction of three factors were found significant.

Table 4.15 ANOVA for effect of storage on colour and appearance of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	134.603	134.603	8903.19	3.98	1.673	4.727	*
S	1	2.475	2.475	163.72	3.98	1.673	4.727	*
P*S	1	0.040	0.040	2.64	3.98	2.366	NS	NS
D	8	8.178	1.022	67.62	2.07	3.549	0.100	*
P*D	8	4.748	0.594	39.26	2.07	5.019	0.141	*
S*D	8	3.582	0.448	29.61	2.07	5.019	0.100	*
P*S*D	8	0.755	0.094	6.25	2.07	7.098	0.200	*
Error	72	1.088	1.511	C V % : 2.100				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

Fig 4.6 illustrates the variation in colour and appearance score up to 120 days of shelf life study. After 120 days storage colour and appearance score was maximum for MLP product.

4.5.2 Effect of Storage on Aroma

The mean values sensory score for aroma of different sample is showed in Table 4.16. It was observed that score for smell was higher for PP and MLP than the CP and

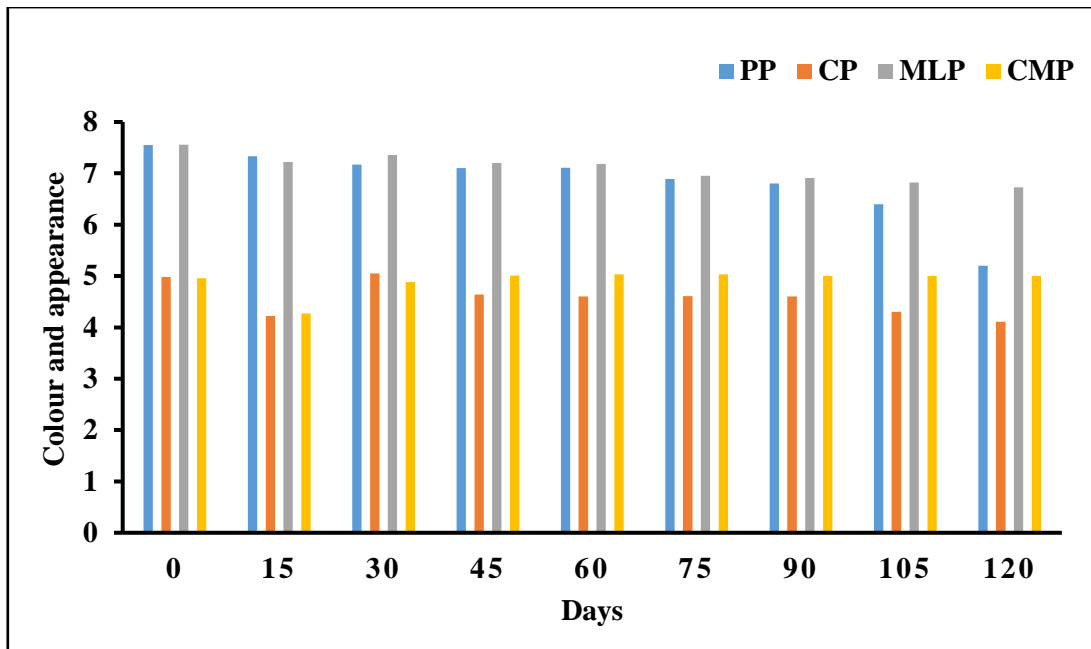


Fig. 4.6 Effect of storage condition on colour and appearance

CMP samples. The initial mean of score for PP was 7.62 which decreases to 5.76 after 120 days, for CP was 5.27 which decreases to 4.18 after 120 days, for MLP was 7.62 which again decreases to 6.17 and for CMP it is 5.26 and decreases to 4.32 after 120 days. Here, CP was unacceptable after 60 days and CMP was unacceptable after 75 days due to sensory score which were below the acceptable limit. The score of smell for PP and MLP product was acceptable up to 120 days.

Table 4.16 Effect of storage on aroma of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	7.62 ± 0.01	5.27 ± 0.03	7.62 ± 0.01	5.26 ± 0.02
15	7.13 ± 0.05	5.39 ± 0.01	6.67 ± 0.01	5.67 ± 0.01
30	7.02 ± 0.03	5.13 ± 0.02	6.80 ± 0.06	4.94 ± 0.01
45	7.00 ± 0.04	5.01 ± 0.04	6.50 ± 0.03	5.03 ± 0.04
60	7.02 ± 0.03	4.98 ± 0.03	6.50 ± 0.09	5.01 ± 0.01
75	6.90 ± 0.09	4.51 ± 0.09	6.12 ± 0.03	4.97 ± 0.01
90	6.91 ± 0.04	4.50 ± 0.01	6.10 ± 0.10	4.90 ± 0.01
105	6.87 ± 0.05	4.30 ± 0.21	6.20 ± 0.04	4.80 ± 0.12
120	5.76 ± 0.02	4.18 ± 0.01	6.17 ± 0.04	4.32 ± 0.14

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

The ANOVA table on effect of storage on aroma is presented in Table 4.17. The statistical analysis of the data revealed that the calculated F values (Fc) for sample in

both packaging material (i.e polypropylene and metalized laminated pouch) (P), packaging material for both sample (i.e control and dehydrated shreds) (S) and days of

Table 4.17 ANOVA for effect of storage on aroma of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	27.00	27.00	1039.85	3.98	2.192	6.189	*
S	1	0.801	0.801	30.84	3.98	2.192	6.189	*
P*S	1	1.334	1.334	51.37	3.98	3.101	8.753	*
D	8	15.865	1.983	76.38	2.07	4.651	0.131	*
P*D	8	8.105	1.013	39.02	2.07	6.578	0.185	*
S*D	8	0.753	0.094	3.62	2.07	6.578	0.131	*
P*S*D	8	3.674	0.459	17.69	2.07	9.303	0.262	*
Error	72	1.869	2.596	C V % : 2.591				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

storage (D) were higher than the tabulated F values (F tab). Thus indicating that the influence of above factors was significant at 5% level of significance. It was observed that interaction of all factors had also significant influence at 5% level of significance.

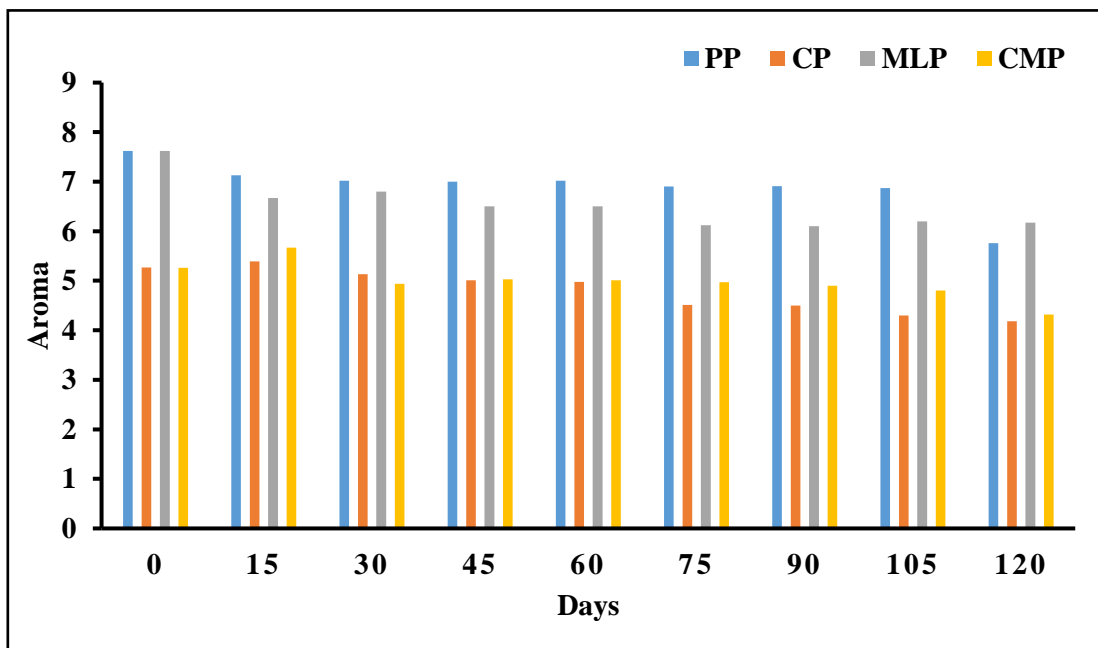


Fig. 4.7 Effect of storage on aroma

Fig 4.7 represent the effect of storage on sensory score of aroma on dehydrated bottle gourd shreds. It decreases as storage days increases, and MLP had high score after 120 days of storage.

4.5.3 Effect of Storage on Texture

The mean score for texture is shown in Table 4.18 which varied from 4.74 to 7.34. The maximum score for texture was 7.34 for PP product and minimum for CMP i.e 5.70 on first day of shelf-life study. The sensory score for texture decreased with increase in days of storage. CMP product was unacceptable after 120 days from the texture point of view. As days passes, products gains moisture and its texture becomes soft.

Table 4.18 Effect of storage on texture of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	7.34 ± 0.12	5.80 ± 0.75	7.33 ± 0.04	5.70 ± 0.17
15	7.11 ± 0.39	5.55 ± 0.06	7.08 ± 0.02	5.00 ± 0.17
30	6.90 ± 0.89	6.13 ± 0.05	7.28 ± 0.02	6.30 ± 0.20
45	6.70 ± 0.10	6.08 ± 0.02	7.36 ± 0.05	6.23 ± 0.06
60	6.66 ± 0.09	6.13 ± 0.06	7.35 ± 0.04	6.21 ± 0.07
75	6.52 ± 0.05	6.03 ± 0.04	7.11 ± 0.04	6.90 ± 0.01
90	6.41 ± 0.03	5.00 ± 0.10	7.00 ± 0.22	5.50 ± 0.17
105	6.35 ± 0.02	5.20 ± 0.36	6.80 ± 0.08	5.10 ± 0.10
120	6.00 ± 0.20	5.31 ± 0.07	6.63 ± 0.02	4.74 ± 0.02

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

Table 4.19 ANOVA for effect of storage on texture of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	38.593	38.593	708.70	3.98	3.175	8.963	*
S	1	01.267	01.267	23.27	3.98	3.175	8.963	*
P*S	1	01.333	01.333	24.90	3.98	4.490	0.126	*
D	8	15.206	01.901	34.91	2.07	6.736	0.190	*
P*D	8	05.739	00.717	13.17	2.07	9.526	0.268	*
S*D	8	02.112	00.264	04.85	2.07	9.526	0.190	*
P*S*D	8	01.010	00.126	02.32	2.07	0.134	0.380	*
Error	72	03.920	05.445	C V % : 3.711				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

The statically analysed data of effect of texture is presented in Table 4.19. It was observed that all factors had significant influence on texture of dehydrated product as the calculated F (Fc) values was higher than tabulated F value (F tab) in all factors. Influence of sample in both packaging material (i.e polypropylene and metalized

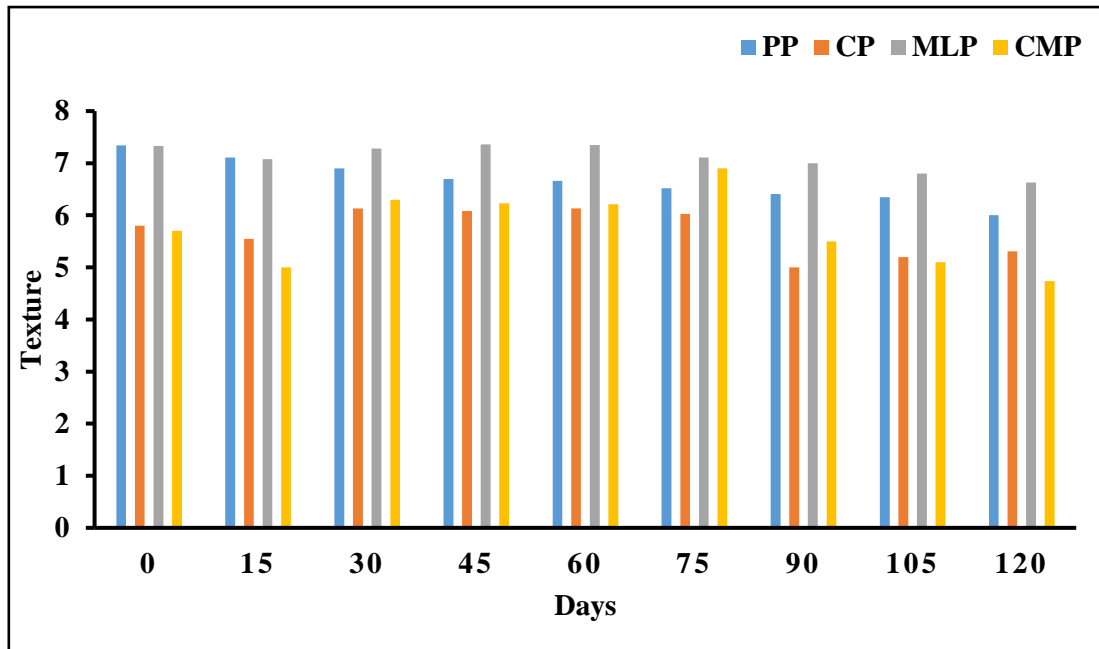


Fig. 4.8 Effect of storage on texture

laminated pouch) (P), packaging material for both sample (i.e control and dehydrated shreds) (S) and days of storage (D) were significant at 5% level of significance. Graphical representation of sensory score for texture is shown in Fig. 4.8. It could be seen that PP and MLP products had more score than the CP and CMP products.

4.5.4 Effect of Storage on Overall Acceptability

The data obtained on score for overall acceptability was presented in Table 4.20. The score card of the product contained 9 point for overall acceptability from 9 point hedonic scale. The initial mean overall acceptability score for PP product was 7.59 at first day which decreased to 6.89 after 120 days, for CP product it was 5.04 which decreased to 4.50 after 120 days, for MLP product it was 7.57 which also decreased to 6.47 and for CMP product it was 5.03 which decreased to 4.38 after 120 days. Based on overall acceptability PP and MLP samples were acceptable for 120 days, but CP and CMP were unacceptable due to less sensory score than the acceptable limit.

The statistically analysed data for effect of storage on overall acceptability is shown in Table 4.21. It was observed that influence of sample (P), packaging material (S) and days of storage (D) were significant at 5% level of significance because calculated F values (F_c) were more than tabulated F values (F_{tab}) for all these factors. The interaction of sample and packaging material (P*S) was significant; interaction of sample and days of storage (P*D) was also significant; interaction of packaging

Table 4.20 Effect of storage on overall acceptability of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	7.59 ± 0.03	5.04 ± 0.05	7.57 ± 0.03	5.03 ± 0.02
15	7.44 ± 0.07	5.40 ± 0.40	7.28 ± 0.02	5.57 ± 0.02
30	7.28 ± 0.04	5.30 ± 0.26	7.50 ± 0.09	5.41 ± 0.05
45	7.17 ± 0.01	5.20 ± 0.36	7.48 ± 0.03	5.32 ± 0.05
60	7.19 ± 0.05	5.12 ± 0.05	7.43 ± 0.05	5.28 ± 0.02
75	7.09 ± 0.01	5.04 ± 0.05	7.37 ± 0.03	5.08 ± 0.02
90	7.00 ± 0.09	4.91 ± 0.06	7.40 ± 0.42	4.95 ± 0.01
105	6.83 ± 0.05	4.57 ± 0.06	7.30 ± 0.17	4.39 ± 0.02
120	6.89 ± 0.02	4.50 ± 0.02	6.47 ± 0.03	4.38 ± 0.02

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

Table 4.21 ANOVA for effect of storage on overall acceptability of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	131.937	131.937	7448.78	3.98	1.811	5.112	*
S	1	00.227	00.227	12.80	3.98	1.811	5.112	*
P*S	1	00.081	00.081	04.59	3.98	2.561	7.229	*
D	8	08.100	01.013	57.16	2.07	3.841	0.108	*
P*D	8	01.298	00.162	09.16	2.07	5.433	0.153	*
S*D	8	00.618	00.077	04.36	2.07	5.433	0.108	*
P*S*D	8	00.566	00.071	04.00	2.07	7.683	0.216	*
Error	72	01.275	01.771	C V % : 2.170				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

material and days storage was significant; interaction of sample (P), packaging material (S) and days of storage (D) (P*S*D) was also significant. Fig. 4.9 illustrates the effect of storage on overall acceptability on dehydrated bottle gourd shreds. The overall acceptability score for dehydrated bottle gourd shreds was observed better in MLP than the other packaged product at ambient storage condition.

4.5.5 Effect of Storage on Colour Value (ΔE^*ab)

The result obtained for colour value is presented in Table 4.22 for shelf-life study of 120 days. It could be seen that CP and CMP has maximum ΔE^*ab value than the PP and MLP. This might be due to difference between raw bottle gourd shreds and which was increased to 3.56, for CP was 2.10 which was increased to 8.13, for MLP it

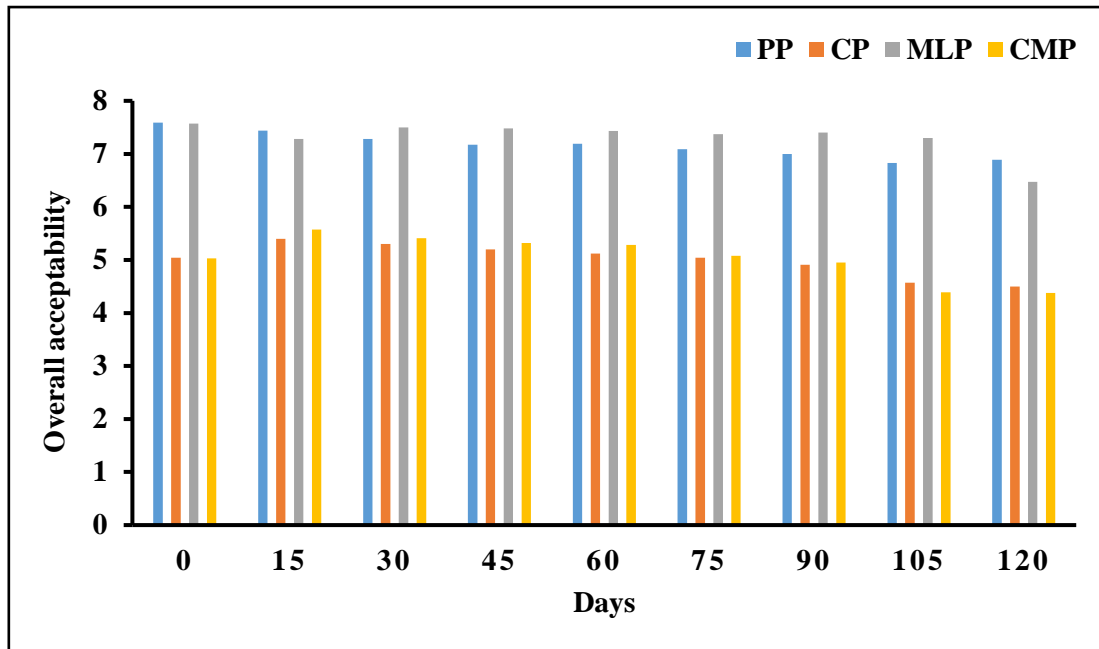


Fig. 4.9 Effect of storage on overall acceptability

Table 4.22 Effect of storage on colour value (ΔE^*ab) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	1.33 ± 0.02	2.10 ± 0.19	1.33 ± 0.02	2.10 ± 0.190
15	2.24 ± 0.02	3.78 ± 0.02	2.64 ± 0.03	3.63 ± 0.02
30	3.12 ± 0.01	3.95 ± 0.02	3.44 ± 0.01	3.87 ± 0.01
45	3.21 ± 0.01	4.82 ± 0.01	3.48 ± 0.01	4.90 ± 0.10
60	3.32 ± 0.02	5.10 ± 0.17	3.50 ± 0.08	5.82 ± 0.01
75	3.32 ± 0.01	5.98 ± 0.02	3.61 ± 0.01	6.90 ± .010
90	3.40 ± 0.10	6.22 ± 0.01	3.63 ± 0.01	7.80 ± 0.26
105	3.47 ± 0.01	7.83 ± 0.02	3.76 ± 0.01	8.72 ± 0.03
120	3.56 ± 0.02	8.13 ± 0.01	3.82 ± 0.02	9.82 ± 0.01

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

was 1.33 which was again increased to 3.82 and for CMP it was 2.10 which was also increased to 9.82 after 120 days of shelf-life study.

The ANOVA table for effect of storage on colour value of dehydrated bottle gourd shreds is shown in Table 4.23. The interaction of sample and packaging material (P*S) was significant; interaction of sample and days of storage (P*D) was also significant; interaction of packaging material and days storage (S*D) was significant; interaction of sample (P), packaging material (S) and days of storage (D) (P*S*D) was

also significant for all these factors. It was observed that influence of sample in both packaging material (i.e polypropylene and metalized laminated pouch) (P), packaging material for both sample (i.e control and dehydrated shreds) (S) and days of storage (D) were significant at 5% level of significance because calculated F values (F_c) were more than tabulated F values (F_{tab}) for all these factors.

Table 4.23 ANOVA for effect of storage on colour value (ΔE^*ab) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	170.932	170.932	27734.95	3.98	1.068	3.015	*
S	1	05.188	05.188	841.75	3.98	1.068	3.015	*
P*S	1	00.969	00.969	157.19	3.98	0.015	4.264	*
D	8	202.513	25.314	4107.40	2.07	2.266	6.397	*
P*D	8	68.469	08.559	1388.69	2.07	3.204	9.046	*
S*D	8	03.053	00.382	61.92	2.07	3.204	6.397	*
P*S*D	8	03.092	00.387	62.71	2.07	4.532	0.127	*
Error	72	0.443	6.163	C V % : 1.792				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

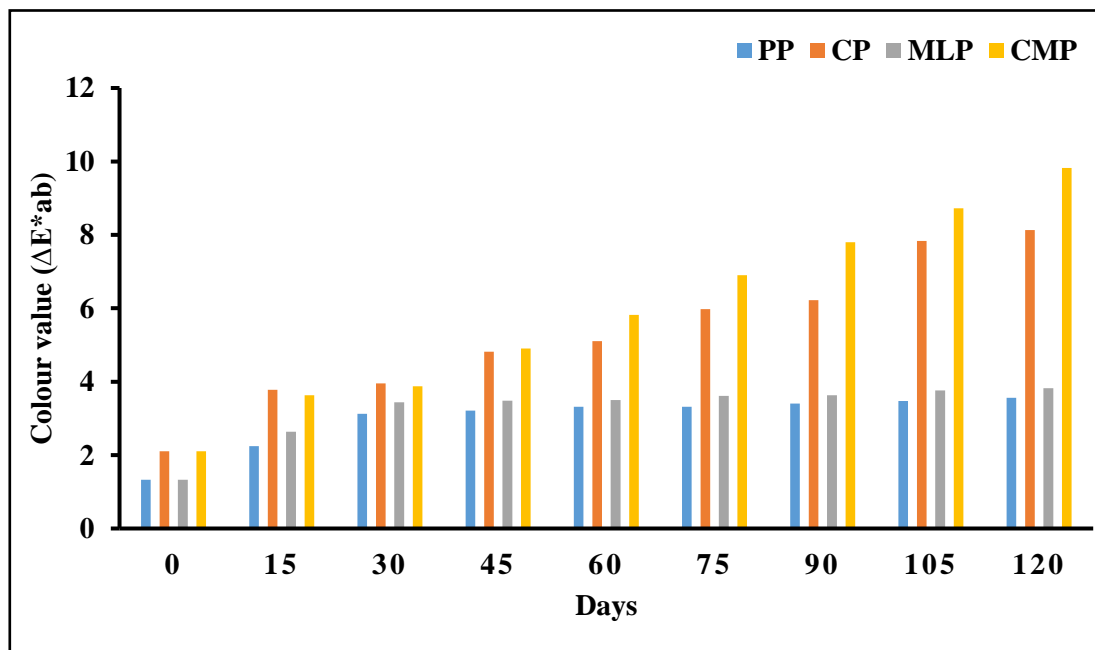


Fig. 4.10 Effect of storage on colour value (ΔE^*ab)

Fig 4.10 represent the data of ΔE^*ab value graphically. It could be seen that ΔE^*ab value increased for all product as the storage period increased. This indicates that difference between desired ΔE^*ab value and sample ΔE^*ab value was increased as storage period increased.

4.5.6 Effect of Storage on Moisture Content

Moisture is very important parameter for dehydrated products, because if moisture increases product become softer and there may be chances of microbial growth. Therefore, maintenance of moisture content in product is necessary to increase the shelf-life. The data obtained on moisture content is presented in Table 4.24. The moisture content for PP and MLP was same at very first day but it increased to 7.36% and 6.92% respectively after 120 days of storage. Moisture content for CP and CMP was more and which also increased after 120 days. But microbial growth was not occur in PP and MLP, thus these product was safe for consumption.

Table 4.24 Effect of storage on moisture content (%) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	6.50 ± 0.43	8.46 ± 0.05	6.50 ± 0.10	8.26 ± 0.30
15	6.98 ± 0.03	8.57 ± 0.02	6.29 ± 0.01	8.33 ± 0.04
30	7.00 ± 0.26	8.78 ± 0.03	6.58 ± 0.02	8.50 ± 0.26
45	6.44 ± 0.02	8.57 ± 0.03	6.59 ± 0.02	8.42 ± 0.03
60	7.08 ± 0.02	8.83 ± 0.04	6.62 ± 0.06	8.65 ± 0.02
75	7.12 ± 0.02	8.93 ± 0.04	6.80 ± 0.10	8.71 ± 0.04
90	7.17 ± 0.04	8.96 ± 0.05	6.83 ± 0.04	8.80 ± 0.07
105	7.33 ± 0.08	9.09 ± 0.16	6.87 ± 0.01	8.82 ± 0.01
120	7.36 ± 0.05	9.68 ± 0.03	6.92 ± 0.01	8.84 ± 0.02

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

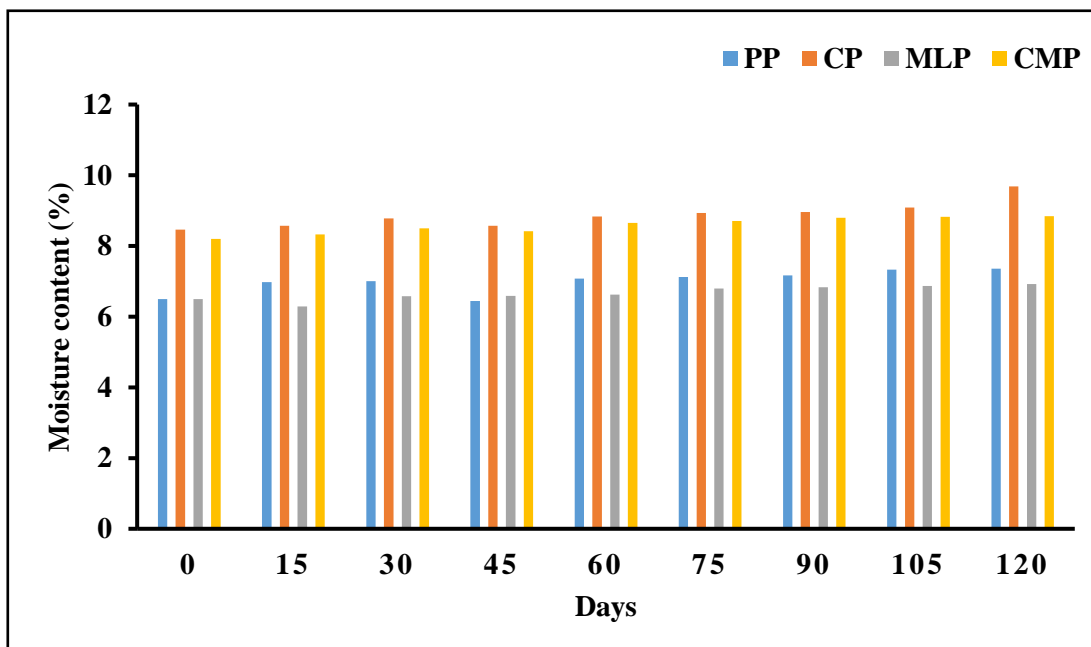
The statically analysed data for effect of storage on moisture content is written in Table 4.25. It was observed that interaction between sample (P) and packaging material (S) (P*S) was non-significance and interaction of sample (P) and days of storage (D) (P*D) was also non-significance as the calculated F values (F_c) were less than the tabulated F values (F_{tab}) for these factors. But interaction of packaging material (S) and days of storage (D) (S*D); interaction of all three factors (P*S*D) were significant at 5% level of significance because calculated F values (F_c) were higher than the tabulated F values. These three factors were also significant individually at 5% level of significance.

Table 4.25 ANOVA for effect of storage on moisture content (%) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	97.470	97.470	6667.28	3.98	1.645	4.644	*
S	1	02.570	02.570	175.81	3.98	1.645	4.644	*
P*S	1	00.014	00.014	00.94	3.98	2.326	NS	NS
D	8	06.335	00.792	54.17	2.07	0.034	0.098	*
P*D	8	00.215	00.027	01.83	2.07	4.936	NS	NS
S*D	8	00.856	00.107	07.32	2.07	4.936	0.098	*
P*S*D	8	00.479	0.060	04.10	2.07	6.980	0.197	*
Error	72	1.052	1.461	CV % : 3.711				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

**Fig. 4.11 Effect of storage on moisture content**

The data presented in Fig. 4.11 revealed that as the storage period increases from 0 to 120 days, moisture content was increased for all samples. It shows that in all sample, moisture content was increased as storage period increased.

4.5.7 Effect of Storage on Ascorbic Acid Content

Ascorbic acid is water soluble and heat sensitive vitamin, thus it decreases after dehydration. The data obtained on effect of storage on ascorbic acid content is shown in Table 4.26. The ascorbic acid content was more in CP and CMP because these samples were dehydrated at low temperature than the PP and MLP. But it was observed that ascorbic acid content decreased faster in CP and CMP products than the PP and CMP during storage period. Ascorbic acid content for PP was 5.67 mg/100g which

Table 4.26 Effect of storage on ascorbic acid content (mg/100g) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	5.67 ± 0.02	6.50 ± 0.09	5.68 ± 0.02	6.54 ± 0.02
15	5.60 ± 0.17	6.04 ± 0.04	5.63 ± 0.07	6.10 ± 0.30
30	5.60 ± 0.17	5.90 ± 0.11	5.61 ± 0.18	5.80 ± 0.10
45	5.56 ± 0.02	5.61 ± 0.03	5.58 ± 0.05	5.63 ± 0.03
60	5.51 ± 0.01	5.51 ± 0.08	5.55 ± 0.03	5.54 ± 0.01
75	5.50 ± 0.26	5.53 ± 0.03	5.55 ± 0.11	5.51 ± 0.03
90	5.43 ± 0.01	5.45 ± 0.15	5.48 ± 0.03	5.40 ± 0.45
105	5.38 ± 0.02	5.39 ± 0.09	5.42 ± 0.03	5.31 ± 0.05
120	5.38 ± 0.02	5.15 ± 0.02	5.39 ± 0.08	5.24 ± 0.01

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

decreased to 5.38 mg/100g and in MLP it was 5.68 mg/100g which also decreased to 5.39 mg/100g. The ascorbic acid content for CP was 6.5 mg/100g which decreased to 5.15 and for CMP it was 6.54 mg/100g which decreased to 5.24 mg/100g. Therefore, PP and MLP had better result than the CP and CLP during shelf-life study from the ascorbic acid point of view.

Table 4.27 ANOVA for effect of storage on ascorbic acid (mg/100g) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	0.577	0.577	35.65	3.98	1.731	4.886	*
S	1	0.005	0.005	0.33	3.98	1.731	NS	NS
P*S	1	0.005	0.005	0.34	3.98	2.448	NS	NS
D	8	6.074	0.759	46.92	2.07	3.672	0.103	*
P*D	8	2.493	0.312	19.25	2.07	5.193	0.146	*
S*D	8	0.023	0.003	00.18	2.07	5.193	NS	NS
P*S*D	8	0.032	0.004	00.25	2.07	7.344	NS	NS
Error	72	1.165	1.618	C V % : 2.270				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

The statically analysed data obtained on effect of ascorbic acid content is written in Table 4.27. As it could be seen that interaction between sample (P) and packaging material (S) (P*S) was non- significant; interaction of packaging material and days of storage (S*D); interaction of all three factors (P*S*D) were also non-significant. It was found that influence of packaging material (S) on ascorbic acid was also non-significant

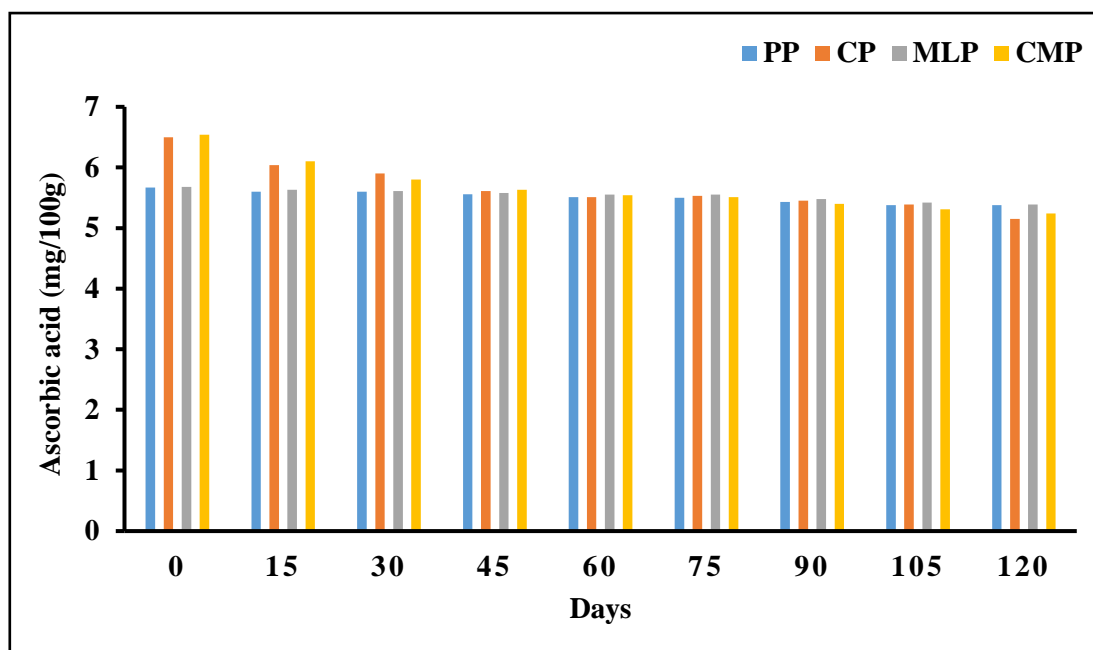


Fig. 4.12 Effect of storage on ascorbic acid content

because calculated F values (F_c) were less than the tabulated F values (F_{tab}). The individual influence of sample (P) and days of storage (D) on ascorbic acid content was significant at 5% level of significance as the calculated F values (F_c) were more than the tabulated F values (F_{tab}). The data obtained on effect of storage on ascorbic acid were graphically represented in Fig. 4.12. It could be seen that there is no vast difference in the data of ascorbic acid content between all four samples.

4.5.8 Effect of Storage on Ash Content

The data obtained on effect of storage on ash content is presented in Table 4.28. Ash content was 3.60% in dehydrated sample which comprised of minerals such as calcium, potassium, iron, phosphorous or many others. Ash content in optimized sample was slightly less than the control sample. On first day of analysis of ash content was slightly decreased during storage period. It was found that calcium content was more in CP and CMP samples than the PP and MLP samples.

ANOVA table for effect of storage on ash content of dehydrated bottle gourd shreds is shown in Table 4.29. The calculated F values (F_c) were more than the tabulated F values (F_{tab}) for individual factors sample and packaging material, thus these two factors had significant effect on ash content at the 5% level of significance. Other than these two factors, all factors had non-significant effect on ash content as the calculated F values (F_c) were less than the tabulated F values (F_{tab}).

Table 4.28 Effect of storage on ash content (%) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	3.60 ± 0.30	3.70 ± 0.10	3.50 ± 0.36	3.76 ± 0.15
15	3.39 ± 0.05	3.59 ± 0.06	3.40 ± 0.13	3.76 ± 0.43
30	3.35 ± 0.12	3.61 ± 0.24	3.34 ± 0.06	3.75 ± 0.14
45	3.30 ± 0.05	3.59 ± 0.03	3.30 ± 0.03	3.74 ± 0.24
60	3.29 ± 0.17	3.57 ± 0.23	3.31 ± 0.08	3.73 ± 0.03
75	3.28 ± 0.35	3.55 ± 0.05	3.29 ± 0.08	3.72 ± 0.06
90	3.27 ± 0.04	3.56 ± 0.07	3.29 ± 0.55	3.72 ± 0.01
105	3.26 ± 0.05	3.54 ± 0.01	3.28 ± 0.03	3.70 ± 0.03
120	3.26 ± 0.04	3.53 ± 0.03	3.27 ± 0.04	3.69 ± 0.06

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

Table 4.29 ANOVA for effect of storage on ash content (%) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	2.361	2.361	71.05	3.98	2.480	0.070	*
S	1	0.287	0.287	08.64	3.98	2.480	0.070	*
P*S	1	0.062	0.062	01.87	3.98	3.508	NS	NS
D	8	0.292	0.037	01.10	2.07	5.262	NS	NS
P*D	8	0.122	0.015	00.46	2.07	7.442	NS	NS
S*D	8	0.132	0.017	00.50	2.07	7.442	NS	NS
P*S*D	8	0.084	0.010	00.32	2.07	0.105	NS	NS
Error	72	2.393	3.323	C V % : 5.193				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

Fig. 4.13 illustrates the effect of storage on ash content of dehydrated bottle gourd shreds, which graphically represent the data of Table 4.28.

4.5.9 Effect of Storage on Calcium Content

After dehydration, mineral content of product, is increases because water is removed which cause increase in mineral content. The result obtained on calcium content is presented in Table 4.30. It was observed that calcium content was more in optimized sample (59.34 mg/100g in PP and 59.33 mg/100g in MLP samples) over the control sample (38.26 mg/100g in CP and 39.33 mg/100g in CMP samples). There was higher difference between control samples and optimized samples. It was found that there was slight decrease in calcium content of samples during storage.

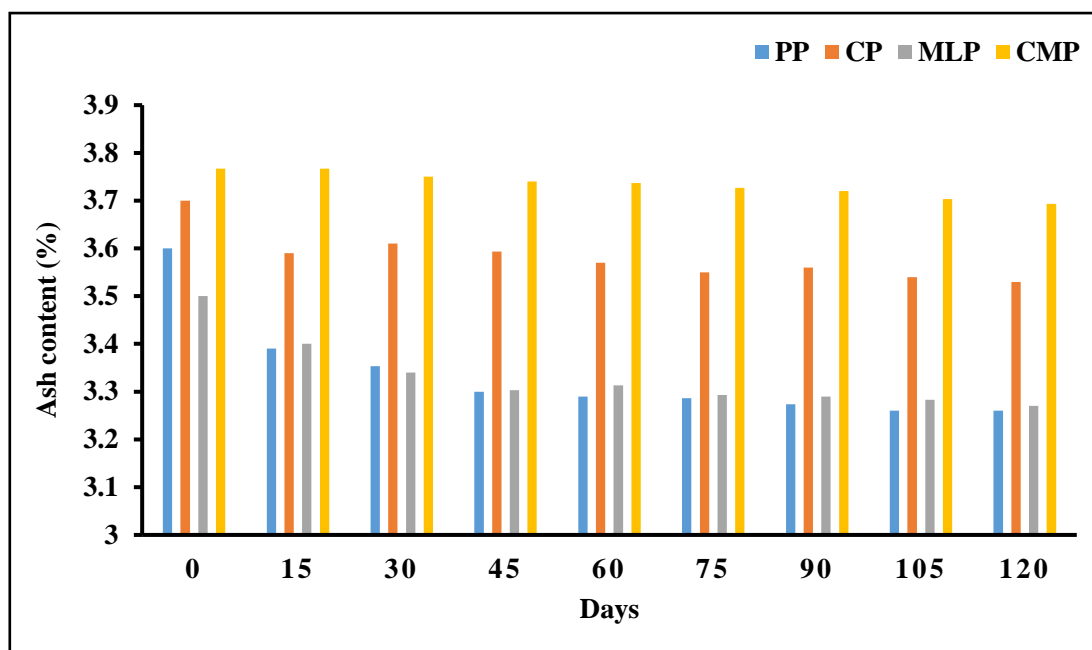


Fig. 4.13 Effect of storage on ash content

The statistically analysed data for effect of storage on calcium content is presented in Table 4.31. Here, sample (P), packaging material (S) and days of storage (D) had significant effect on calcium content at 5% level of significance due to higher

Table 4.30 Effect of storage on calcium content (mg/100g) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	59.34 ± 0.05	38.26 ± 0.04	59.33 ± 0.07	39.93 ± 0.02
15	58.89 ± 0.13	38.66 ± 0.01	58.92 ± 0.03	39.92 ± 0.02
30	58.80 ± 0.09	38.66 ± 0.04	58.90 ± 0.04	39.88 ± 0.02
45	58.73 ± 0.01	38.43 ± 0.01	58.92 ± 0.02	39.85 ± 0.01
60	58.72 ± 0.01	38.52 ± 0.02	58.89 ± 0.04	39.80 ± 0.01
75	58.71 ± 0.00	38.51 ± 0.04	58.87 ± 0.01	39.60 ± 0.03
90	58.69 ± 0.01	38.50 ± 0.06	58.86 ± 0.03	39.52 ± 0.01
105	58.65 ± 0.02	38.38 ± 0.01	58.83 ± 0.05	39.36 ± 0.03
120	58.62 ± 0.05	38.29 ± 0.06	58.81 ± 0.03	39.26 ± 0.05

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

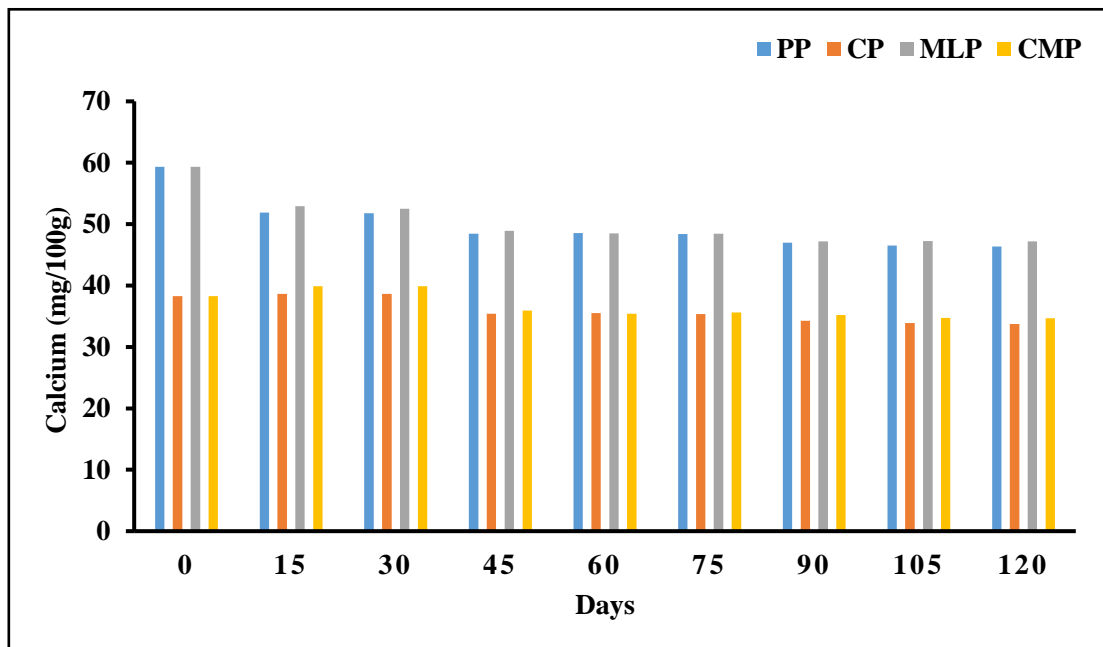
calculated F values (F_c) than the tabulated F values (F_{tab}). Similarly, all interaction had also significant effect at 5% level of significance on calcium content of dehydrated bottle gourd shreds during storage period.

Table 4.31 ANOVA for effect of storage on calcium content (mg/100g) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	10731.12	10731.12	5736682	3.98	5.885	1.661	*
S	1	07.364	07.364	3936.75	3.98	5.885	1.661	*
P*S	1	04.096	04.096	2189.49	3.98	8.323	2.349	*
D	8	03.915	0.489	261.60	2.07	0.012	3.524	*
P*D	8	02.183	0.273	145.84	2.07	1.765	4.984	*
S*D	8	01.570	0.196	104.93	2.07	1.765	3.524	*
P*S*D	8	02.291	0.286	153.06	2.07	2.497	7.048	*
Error	72	0.134	1.870	CV % : 8.845				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated samples, S = Packaging materials, D = Days of storage

**Fig. 4.14 Effect of storage on calcium content**

Effect of storage on calcium content is graphically represented in Fig. 4.14. There was decrease in calcium content in all samples of dehydrated bottle gourd shreds during storage period.

4.5.10 Effect of Storage on Potassium Content

Table 4.32 shown the data obtained on effect of potassium content of dehydrated bottle gourd shreds. It was found that potassium content was higher in optimized sample over the control sample. Potassium content for PP was 396.24 mg/100g which decreased to 357.92 mg/100g and for MLP it was maximum i.e 397.25 mg/100g which decreased to 367.93 mg/100g after 120 days. Potassium content in CP was 263.45

mg/100g which decreased to 229.84 and for CMP it was 263.97 mg/100g which decreased to 235.13 mg/100g.

Table 4.32 Effect of storage on potassium content (mg/100g) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	396.24 ± 0.30	263.45 ± 1.80	397.25 ± 0.37	263.97 ± 0.86
15	388.54 ± 0.75	251.66 ± 1.41	391.21 ± 0.22	252.00 ± 0.15
30	379.38 ± 0.61	273.05 ± 1.91	385.82 ± 0.22	248.66 ± 0.05
45	375.54 ± 0.06	242.57 ± 0.14	385.46 ± 0.57	245.53 ± 0.53
60	368.24 ± 0.26	242.41 ± 0.07	382.78 ± 0.28	241.56 ± 0.62
75	365.21 ± 0.02	235.88 ± 0.08	376.56 ± 0.06	241.00 ± 1.04
90	363.79 ± 0.03	233.45 ± 0.04	373.96 ± 0.24	237.33 ± 0.75
105	361.99 ± 0.08	234.01 ± 0.05	369.59 ± 0.03	235.13 ± 0.04
120	357.92 ± 0.12	229.84 ± 0.03	367.93 ± 0.06	234.05 ± 0.09

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

Table 4.33 ANOVA for effect of storage on potassium content (mg/100g) of dehydrated bottle gourd shreds

Factor	DF	SS	MS	F Cal	F Tab	SEm	CD	Test
P	1	487202.128	487202.128	1273534	3.98	8.416	0.237	*
S	1	879.062	879.062	2297.85	3.98	8.416	0.237	*
P*S	1	168.500	168.500	440.45	3.98	0.119	0.335	*
D	8	10627.308	1328.413	3472.44	2.07	0.178	0.503	*
P*D	8	225.740	28.218	73.76	2.07	0.252	0.712	*
S*D	8	200.472	25.059	65.50	2.07	0.252	0.503	*
P*S*D	8	188.184	23.523	61.49	2.07	0.357	1.007	*
Error	72	27.544	0.382	C V % : 0.199				

* Significant at 5% level of significance; NS: non-significant

P = Dehydrated sample, S = Packaging material, D = Days of storage

The statistical data obtained on effect of storage on potassium was shown in Table 4.33. Sample (P), packaging material (S) and days of storage (D) had significant effect on potassium content at 5% level of significance due to higher calculated F values (F_c) than the tabulated F values (F_{tab}). Similarly, all interaction had also significant effect at 5% level of significance on potassium content of dehydrated bottle gourd shreds during storage period.

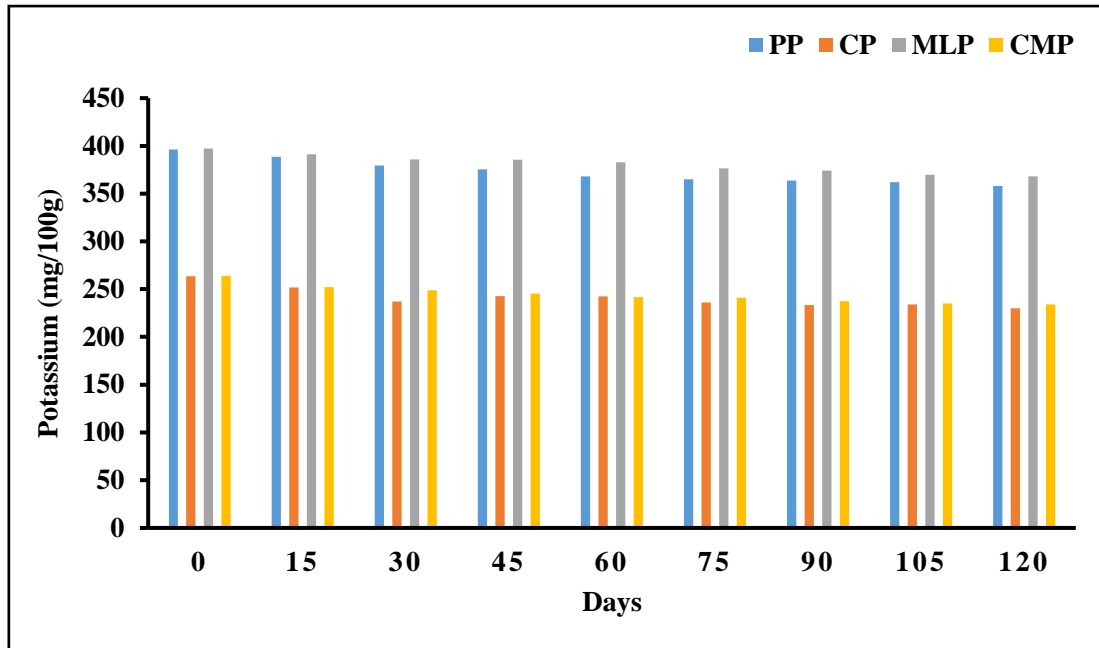


Fig. 4.15 Effect of storage on potassium content

There is vast difference between the potassium content of optimized sample and control sample which is graphically represented in Fig. 4.15. The potassium content showed a decreasing trend during the entire period of storage for both control and dehydrated sample.

4.5.11 Effect of Storage on Total Plate Count (TPC)

The result obtained on effect of storage on total plate count is depicted in Table 4.34. It was observed that there is absence of TPC in optimized sample, where as in

Table 4.34 Effect of storage on total plate count (log cfu/g) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	Absent	6.38 ± 0.01	Absent	6.36 ± 0.03
15	Absent	7.48 ± 0.02	Absent	7.65 ± 0.03
30	Absent	7.58 ± 0.01	Absent	7.68 ± 0.10
45	Absent	7.60 ± 0.02	Absent	7.65 ± 0.01
60	Absent	7.91 ± 0.01	Absent	7.73 ± 0.01
75	Absent	7.90 ± 0.10	Absent	7.83 ± 0.01
90	Absent	8.12 ± 0.02	Absent	8.83 ± 0.04
105	Absent	8.55 ± 0.02	Absent	8.83 ± 0.08
120	Absent	8.60 ± 0.02	Absent	8.92 ± 0.03

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

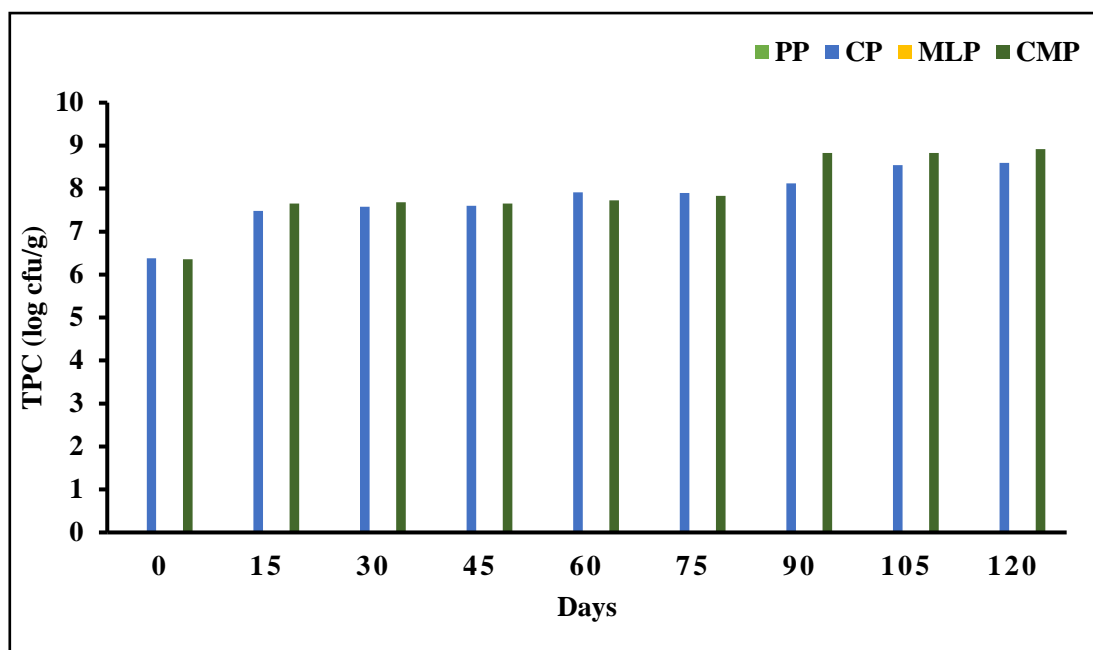


Fig. 4.16 Effect of storage on total plate count

control sample there was growth of TPC from the beginning of storage period, and was increased with increase in storage period.

The TPC was found 6.38 log cfu/g at the first day of storage in CP sample and were increased to 8.60 log cfu/g after the end of storage i.e 120 days. TPC initially in CMP was 6.36 log cfu/g, and was increased to 8.92 log cfu/g after 120 days of storage. According to FSSAI standards TPC is acceptable up to 4 log cfu/g in dehydrated products. In CP and CMP it was more than the acceptable limit, thus these products could not meet the required standard. Fig. 4.16 represent the data graphically on TPC of dehydrated bottle gourd shreds.

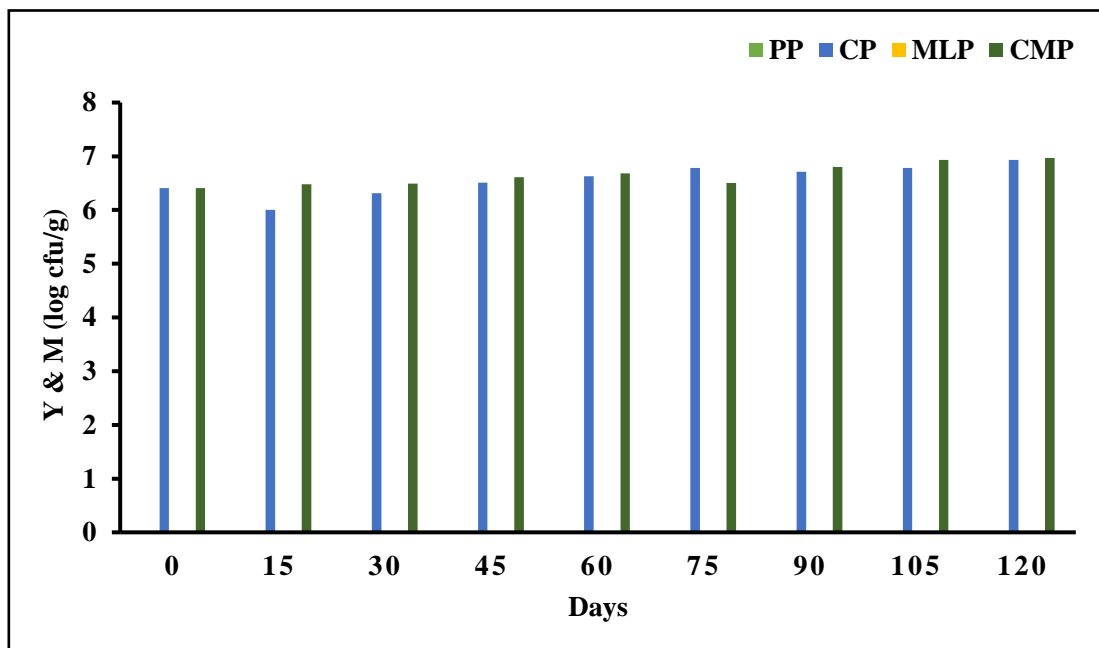
4.5.12 Effect of Storage on Yeast and Mold Count

The changes in yeast and mold count in dehydrated shreds during storage are shown in Table 4.35 and graphically represented in Fig. 4.17. In PP and MLP products yeast and mold count was absent during whole storage period, but in control sample i.e. in CP and CMP yeast and mold count was increased as storage period increases. According to FSSAI standards yeast and mold count acceptable limit is 3 log cfu/g in dehydrated products. In samples CP and CMP, it was more than the acceptable limit, thus these products could not follow the required standards.

Table 4.35 Effect of storage condition on yeast and mold count (log cfu/g) of dehydrated bottle gourd shreds

Storage period (Days)	PP	CP	MLP	CMP
0	Absent	6.41 ± 0.06	Absent	6.41 ± 0.08
15	Absent	6.00 ± 0.20	Absent	6.48 ± 0.03
30	Absent	6.31 ± 0.02	Absent	6.49 ± 0.02
45	Absent	6.51 ± 0.05	Absent	6.61 ± 0.05
60	Absent	6.63 ± 0.01	Absent	6.68 ± 0.01
75	Absent	6.78 ± 0.04	Absent	6.50 ± 0.36
90	Absent	6.71 ± 0.03	Absent	6.80 ± 0.17
105	Absent	6.78 ± 0.06	Absent	6.93 ± 0.02
120	Absent	6.93 ± 0.02	Absent	6.97 ± 0.01

PP – Dehydrated sample in polypropylene pouch, CP – Control sample in polypropylene pouch, MLP - Dehydrated sample in metalized laminated pouch, CMP – Control sample in metalized laminated pouch

**Fig. 4.17 Effect of storage on yeast and mold count**

The variations in yeast and mold count of dehydrated bottle gourd shreds during storage are depicted in Fig. 4.17. The yeast and mold count of dehydrated bottle gourd shreds showed a decreasing trend during entire course of storage in both control and dehydrated samples.

4.5.13 Effect of Storage on Coliform Count

During storage period of dehydrated bottle gourd shreds in different packaging materials, it was found that the coliform count were absent initially and remained absent

throughout the period of storage in all samples. Absence of coliform during entire storage period, indicates that hygienic conditions were maintained during preparations and further no toxins are produced in the dehydrated bottle gourd shreds during storage.

Storage study was important to check quality and shelf-life of optimized dehydrated bottle gourd shreds. During storage, sensory score for dehydrated sample was decreased as storage period increased. The optimized sample had better score for sensory than the control sample. There was no significant difference between ash content, calcium and potassium content of different sample during shelf-life study. In colour value (ΔE^*ab), moisture content and microbial load of optimized and control samples was increased as storage period increased. Based on presented data, sample MLP was found better than the other samples at the end of storage period of 120 days.

CHAPTER V

SUMMARY AND CONCLUSIONS

Bottle gourd belongs to Cucurbitaceae family and scientific name is *Lagenaria siceraria*. Bottle gourd is considered as a wonder fruit as it contains glucose, pentose, lignin, shikimic acid. It contains appreciable amount of minerals such as calcium, potassium, iron and phosphorous. Bottle gourd fruit has high medicinal value such as it gives cooling effect on human body and helps in digestion. Bottle gourd is immunomodulatory, anti-stress, anti-inflammatory, cardio-protective and has anti-oxidant properties according to ayurveda and unani.

Bottle gourd is a cheap fruit and mostly available throughout the year. There are many chances of post-harvest losses due to improper handling and lack of processing. Hence, necessary steps should be taken to preserve them by extending the shelf-life in the processed form. To preserve the fruit by evaporating water to stop water activity is an important process. The study was attempted with the aim of developing and optimizing the processing parameters for production of dehydrated bottle gourd shreds. The specific objectives of the investigation were:

- 1) Physico-chemical characterization of bottle gourd fruits
- 2) Optimization of steam blanching technique for bottle gourd shreds
- 3) Standardization of dehydration parameters for bottle gourd shreds using microwave assisted fluidized bed dryer and evaluation of quality characteristics
- 4) Shelf life studies of dehydrated bottle gourd shreds

Based on the results obtained, following conclusions were drawn from present investigation;

1. The bottle gourd fruit had seed/pulp/peel ratio 20.61:70.23:9.16. Bottle gourd had moisture content 94.36%, ash content 0.55%, protein content 1.23%, total fibre content 0.63%, total fat content 0.23%, total carbohydrate content 2.98%, TSS 4.03 °Brix, ascorbic acid content 9.24 mg/100g, calcium content 13.60 mg/100g and potassium content 87.41 mg/100g.
2. Blanching is a very important parameter prior to canning, drying or freezing. POD is considered as the most heat stable enzyme in bottle gourd. If POD is inactivated, remaining all other enzymes are mostly inactivated.

3. To inactivate POD enzyme in bottle gourd shreds, steam blanching was performed. The inactivation time of POD was increased as shreds thickness increased.
4. Blanching time required to inactivate POD enzyme for 3 mm shreds was 6 min, for 5 mm shreds 7.5 min and for 7 mm shreds it was 8.3 min. Minimum time required for inactivation of POD was 6 min for 3 mm shreds.
5. Higher ascorbic acid and TSS could be obtained from blanched shreds of bottle gourds during short blanches as compared with long blanches. But, juice yield was increased as shred thickness increased.
6. Ascorbic acid and TSS were higher in 3 mm thick bottle gourd shreds i.e. 7.08 mg/100g and 2.83 °Brix respectively. However, juice yield was less in 3 mm thick shreds i.e. 62.93% after steam blanching.
7. Ascorbic acid found in 5 and 7 mm thick shreds was 6.77 and 6.26 mg/100g respectively. TSS of 5 and 7 mm thick shreds was 2.70 and 2.63 °Brix. Juice yield was higher in 7 mm thick bottle gourd shreds i.e. 65.39% than the 5 mm bottle gourd shreds i.e. 64.25%.
8. Optimization was carried out based on minimum time required for POD inactivation time, maximum ascorbic acid content, maximum TSS and minimum juice yield. Based on above factors 3 mm shreds was optimized for further dehydration process.
9. Pre-drying was done in MCD at 0.3 cm/s belt speed with pulsation time of 25 sec on and 15 sec off for magnetron of dryer. After that, dehydration of bottle gourd shreds was carried out in FBD at temperature of 55°, 60° and 65 °C and air velocity of 6, 8, and 10 m/s.
10. Drying parameters were optimized based on minimum dehydration time, minimum colour value (ΔE^*ab), maximum ascorbic acid and maximum rehydration ratio.
11. Increase in drying temperature significantly affected the dehydration time, as it is minimum at 65 °C drying temperature and 10 m/s air velocity. It had taken 58.56 min total time (MCD and FBD) for dehydration of optimized bottle gourd shreds.

12. Most effective dehydrated bottle gourd shred was obtained with 5.67 mg/100g ascorbic content, 1.33 ΔE^*ab value and 12.93% rehydration ratio at 65 °C drying temperature and 10 m/s air velocity.
13. Higher temperature and air velocity for dehydration process decreased dehydration time and ΔE^*ab value; increased ascorbic acid and rehydration ratio of bottle gourd shreds. Thus, 65 °C drying temperature and 10 m/s air velocity of fluidized bed dryer was optimized for shelf-life study of dehydrated bottle gourd shreds.
14. Optimized dehydrated shreds were packed in metalized laminated pouches and polypropylene pouches. Shade dried bottle gourd shreds were taken as control sample and also packed in metalized laminated pouches and polypropylene pouches.
15. The shelf-life study was evaluated on sensory characteristics (colour and appearance, aroma, texture and overall acceptability), physico-chemical characteristics (colour value, moisture content, ascorbic acid content, ash content, calcium and potassium content) and microbial characteristics (total plate count, yeast and mold count and coliform count) of stored samples.
16. Sensory evaluation of dehydrated bottle gourd shreds shows significant difference in colour and appearance, aroma, texture and overall acceptability of the stored sample during 120 days of storage.
17. The initial mean value for colour value of PP sample was 1.33 which increased up to 3.56, for CP sample from 2.10 to 8.13, for MLP sample from 1.33 to 3.82 and for CMP sample it was 2.10 which was increased up to 9.82.
18. Moisture content found in PP, CP, MPL and CMP was 6.5%, 8.46%, 6.5% and 8.26% respectively which increased significantly as storage period increased.
19. Ascorbic acid decreased after drying as it is water soluble vitamin as well as heat sensitive. A decrease in Ascorbic acid content was seen in all the packaging material. In the samples stored PP pouches it was decreased from 5.67 mg/100g to 5.38 mg/100g, for CP sample from 6.50 mg/100g to 5.15 mg/100g, for MLP sample from 5.68 mg/100g to 5.39 mg/100g and for CMP samples from 6.54 mg/100g to 5.24 mg/100g after 120 days.

20. Ash content of bottle gourd was increased after drying, but there was no significant effect of storage on ash content of dehydrated bottle gourd shreds during storage period.
21. Similarly, there no significant difference in calcium and potassium content of dehydrated bottle gourd shreds. But, calcium and potassium content was found higher in optimized sample over the control sample.
22. Total plate count and yeast and mold count were found absent during storage period in both PP and MLP but was present in control sample, whereas, coliform count was absent initially and remain absent after 120 days of storage in all samples.

REFERENCES

- Abbasi, S., & Azari, S. (2009). Novel microwave–freeze drying of onion slices. *International Journal of Food Science and Technology*, 44, 974–979.
- Ahmad, I., Irshad, M., & Rizvi, M. M. A. (2011). Nutritional and medicinal potential of *Lagenaria siceraria*. *International Journal of Vegetable Science*, 17(2), 157–170.
- Ambrose, D. P., & Naik, R. (2014). Studies on the mechanical drying of curry leaf. *International Journal of Processing and Post-Harvest Technology*, 5(1), 8–11.
- Anonymous. (2018). Bottle gourd (Calabash) nutrition facts (n.d). Retrieved from (<https://www.nutrition-and-you.com/bottle-gourd.html>).
- Baysal, T., Icier, F., Ersus, S., & Yildiz, H. (2003). Effects of microwave and infrared drying on the quality of carrot and garlic. *European Food Research Technology*, 218, 68–73. DOI: 10.1007/s00217-003-0791-3.
- Beaudry, C., Raghavan, G. S. V., Ratti, C., & Rennie, T. J. (2004). Effect of four drying methods on the quality of osmotically dehydrated cranberries. *Drying Technology: An International Journal*, 22(3), 521–539. DOI: 10.1081/DRT-120029999.
- Bhat, S., Saini, C., & Sharma, K. (2017). Changes in total phenolic content and colour of bottle gourd (*Lagenaria siceraria*) juice upon conventional and ohmic blanching. *Food Science and Biotechnology*, 26(1), 29–36. DOI: 10.1007/s10068-017-0004-7.
- Bhatt, S., & Sharma, H. K. (2016). Combined effect of blanching and sonication on quality parameters of bottle gourd (*Lagenaria siceraria*) juice. *Ultrasonics Sonochemistry*, doi: <http://dx.doi.org/10.1016/j.ultsonch.2016.04.014>.
- Bisnoi, N., Kumari, P., & Yadav, Y. K. (2008). Study of dehydration characteristics of garlic. *Journal of Dairying, Foods and Home Science*, 27 (3/4), 238 – 240.
- Bobic, Z., Bauman, I., & Curic, D. (2002). Rehydration ratio of fluid bed dried vegetables. *Sadhana*, 27(3), 365–374.
- Bouraoui, M., Richard P., & Durance T., (1994). Microwave and convective drying of potato slices. *Journal of Food Process Engineering*, 17(3), 353 – 363.

- Chen, X. D., & Mujumdar, A. S. (2008). *Drying technologies in food processing*. Wiley Blackwell Publishing, United Kingdom.
- Colucci, D., Fissore, D., Rossello, C., & Carcel, J. A. (2018). On effect of ultrasound assisted atmospheric freeze drying in the antioxidant properties of eggplant. *Food Research International*, 106, 580–588.
- DaSilva, F. R. G.B., DeSouza, M. DeSouza Da Costa, A. M., Dematos Jorge, L. M., & Paraiso, P. R. (2012). Experimental and numerical analysis of soybean meal drying in fluidized bed. *Powder Technology*, 229, 61–70.
- Dhaliwal, M. S. (2017). *Handbook of vegetable crops*. Kalyani Publishers. pp: 115-119.
- Dhiman, K., Gupta, A., Sharma, D. K., Gill, N. S., & Goyal, A. (2012). A review on the medicinally important plants of the family Cucurbitaceae. *Asian Journal of Clinical Nutrition*, 4(1), 16-26. DOI: 10.3923/ajcn.2012.16.26.
- Doymaz, I. (2006). Thin-layer drying behaviour of mint leaves, *Journal of Food Engineering*, 74, 370–375. DOI:10.1016/j.jfoodeng.2005.03.009.
- Gajera, R. R. (2014). Development of production technology for bottle gourd based blended juice. (unpublished master's thesis). College of Food Processing Technology and Bio-Energy, AAU, Anand, Gujarat, India. Pp: 1-124.
- Ghule, B. V., Ghante, M. H., Yeole, P. G., & Saoji, A. N. (2007). Diuretic activity of *Lagenaria siceraria* fruit extract in rats. *Indian journal of Pharmaceutical Sciences*, 69(6), 817-819.
- Giner, S. A., & Calvelo, A. (1987). Modelling of wheat drying in fluidized beds. *Journal of food science*, 52(5), 1358-1363.
- Gopalan, C., Sastri, R. B.V., & Balasubramanian, S. C. (1989). *Nutritive value of Indian Foods*. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad.
- Gowen, A., Abu-Ghannam, N., Frias, J., & Oliveira, J. (2006). Optimisation of dehydration and rehydration properties of cooked chickpeas (*Cicer arietinum* L.) undergoing microwave– hot air combination drying. *Trends in Food Science & Technology*, 17, 177–183. DOI: 10.1016/j.tifs.2005.11.013.

- Guine, R. P. F., & Castro, J. (2002). Pear drying process analysis: drying rates and evolution of water and sugar concentrations in space and time. *Drying Technology*, 20(7), 1515-1526. DOI: 10.1081/DRT-120005865.
- Han, J. S., Mok, I. G., Park, H. G., & Kim, C. K. (2004). Efficient plant regeneration from the cotyledon explants of bottle gourd (*Lagenaria siceraria* Standl.). *Plant Cell Reports*, 23, 291-296. DOI: 10.1007/s00299-004-0846-3.
- Hanif, R., Iqbal, Z., Iqbal, M., Hanif, S., & Rasheed, M. (2006). Use of vegetable as nutritional food: Role in human health. *Journal of Agriculture and Biological Science*, 1(1), 18-22.
- Hema (2006). Studies on osmotic dehydration of bottle gourd (*Lagenaria siceraria*) (unpublished master's thesis). Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India. pp: 1-111.
- Herwig, T. (2004). Notes on *Lagenaria* and *Cucurbita*: Review and new contributions-Phyton (Horn, Austria), 44(2), 245-308.
- Kapoor, S. (2015, December 18). 16 reasons why lauki is healthy. Retrieved from <https://www.practo.com/healthfeed/16-reasons-why-lauki-is-healthy-3556/post>.
- Kirtikar, K. R., & Basu, B. D. (1991). *Indian medicinal plants Vol. II*. Lalit Mohan Basu Publication Allahabad, India P. 116-118.
- Kotecha, A. V. (2015). Preparation of dehydrated flakes from onion (unpublished master's thesis). Department of Food Science and Technology, Mahatma Phule Krishi Vidhyapeeth, Rahuri, Maharashtra, India. pp: 1-103.
- Krokida, M. K., & Maroulis, Z. B. (1999). Effect of microwave drying on some quality properties of dehydrated products. *Drying Technology*, 17(3), 449-466.
- Kulkarni, S. J., & Goswami, A. K. (2015). Application, advancements and research on drying – A review. *International Journal for Research in Applied Science and Engineering Technology*, 3(8), 404 – 406.
- Kumar, Y., & Belorkar, S. A. (2015). Fluidized bed drying of fruits and vegetables: An overview. *International Journal of Engineering Studies and Technical Approach*, 1(9), 1-8.

- Kumar, Y., Khan, M., & Patel, K. (2014). Effect of microwave on fluidized bed drying of beetroot (*Beta Vulgaris* L.). *American Journal of Engineering Research (Ajer)*, 3(3), 267-273.
- Kumar, Y., Tiwari, S., & Belorkar, S. A. (2015). Drying: An excellent method for food preservation. *International Journal of Engineering Studies and Technical Approach*, 1(8), 1-17.
- Liman, M. G., Abdullahi, A. S., Maigoro, A. L., & Umar, K. J. (2014). Effects of three drying techniques on mineral composition of some leafy garden vegetables, *Journal of Applied Chemistry (IOSR-JAC)*, 7(1), 38-42.
- Loukou, A. L., Lognay, G., Barthelemy, J. P., Maesen, P., Baudoin, J. P., & Zoro, B. I. (2011). Effect of harvest time on seed oil and protein contents and compositions in the oleaginous gourd *Lagenaria siceraria* (Molina) Standl. *Journal of Science Food and Agriculture*. 91, 2073- 2080. DOI: 10.1002/jsfa.4422.
- Maskan, M. (2001). Drying, shrinkage and rehydration characteristics of kiwi fruits during hot air and microwave drying. *Journal of Food Engineering*, 48(1), 177-182.
- Mattu, P. S. (2014). Studies on drying characteristics of Bottle Gourd. (unpublished master's thesis). Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India. pp:1-108
- Maxwell, M. (2011). Effect of different packaging materials on the quality and shelf life of Moringa (*Moringa oleifera*) leaf powder during storage (unpublished master's thesis). The school of research and graduate studies, Kwamenkrumah University of science and technology, Kumasi, Ghana. pp: 1-122.
- Mehta, D., Prasad, P., Bansal, V., Siddiqui, W., & Sharma, A. (2017). Effect of drying techniques and treatment with blanching on the physicochemical analysis of bitter gourd and capsicum, *LWT-Food Science and Technology*, doi:10.1016/j.lwt.2017.06.005.
- Milind, P., & Satbir, K. (2011). Is bottle gourd a natural gourd? *International Research journal of Pharmacy*, 2(6), 13-17.

- Mishra, S., Rana, A., Tripathy, A., & Meda, V. (2006). Drying characteristics of carrot under microwave vacuum condition. ASABE/CSBE North Central Intersectional Meeting. DOI: 10.13031/2013.22375.
- Momenzadeh, L., Zomorodian, A., & Mowla, D. (2011). Experimental and theoretical investigation of shelled corn drying in a microwave-assisted fluidized bed dryer using artificial neural network. *Food and Bioproducts Processing*, 89(1), 15-21
- Moursy, F. I., Soliman, A., Sorour, M. A., & Rohiem, S. R. (2014). Effect of drying temperature on vitamin C of lemon fruit. *International Journal of Advance Research in Science and Engineering*, 3(9), 467-469.
- Mujumdar, A. S. (2004). *Dehydration of products of biological origin 1st edition*. CRC Press, UK. 1-553.
- Mujumdar, A.S., & Devahastin, S. (2008). *Fundamental principles of drying*. Three S Colours Publications, Mumbai, India. 1-22.
- Murthy, Z.V.P., & Joshi, D. (2007). Fluidized bed drying of aonla. *Journal of Drying Technology*, 25, 883-889. DOI: 10.1080/07373930701370290.
- Negi, P. S., & Roy, S. K. (2001). Effect of drying conditions on quality of green leaves during long term storage. *Food Research International*, 34 (4), 283-287.
- Nindo, C. I., Sun, T., Wang, S. W., Tang, J., & Powers, J. R. (2003). Evaluation of drying technologies for retention of physical quality and antioxidants in asparagus (*Asparagus officinalis* L.). *Lebensmittel-Wissenschaft and Technologies*, 36, 507-516.
- Njoroge, E. W., Matofari, J. W., Mulwa, R. M. S., & Anyango, J. O. (2015). Effects of blanching time/temperature combination coupled with solar-drying on the nutritional and microbial quality of indigenous leafy vegetables in Kenya. *International research journals*, 6(7), 209-219. DOI: 10.14303/ajfst.2015.068.
- Parikh, N. R. (2014). Preservation of eggplant (*Solanum melongena*) applying osmotic and microwave-vacuum drying (unpublished master's thesis). College of Food Processing Technology and Bio-Energy, AAU, Anand, Gujarat, India. pp: 1-102.
- Patel, J. H. (2013). Hybrid drying (osmotic and microwave vacuum) of elephant foot yam (*Amorphophallus paeoniifolius*) (unpublished master's thesis).

- College of Food Processing Technology and Bio-Energy, AAU, Anand, Gujarat, India. pp: 1-72.
- Pereira, N. R., Marsaioli Jr., A., & Ahrne, L. M. (2007). Effect of microwave power, air velocity and temperature on the final drying of osmotically dehydrated bananas. *Journal of Food Engineering*, 81, 79–87.
- Pervin, S., Islam, M. S., & Islam, M. N. (2008). Study on rehydration characteristics of dried lablab bean (*Lablab Purpures*) seeds. *Journal of Agriculture and Rural Development*, 6 (1 & 2), 157-163.
- Pragati, Dahiya, S., & Dhawan, S. S. (2000). Effect of different drying methods on the nutritional composition of aonla fruit (*Emblica officinalis* Garten). Department of Foods and Nutrition, 85-89.
- Quenzer, N. M., & Burns, E. E. (1981). Effects of microwave, steam and water blanching on freeze dried spinach. *Journal of Food Science*, 46, 410-413.
- Rahman, A. S. H. (2003). Bottle gourd (*Lagenaria siceraria*) a vegetable for good health. *Natural Product Radiance*, 2(5), 249-256.
- Ralls, J. W., Maagdenberg, H. J., Yacoub, N. L., Homnick, D. A., Zinnecker, M., & Mercer, W. A. (1973), In-plant continuous hot-gas blanching of spinach. *Journal of Food Science*, 38, 192-194.
- Ranganna, S. (1986). Hand Book of analysis and quality control for fruit and vegetable products. New Delhi: Tata McGraw-Hill publication. pp-1-976.
- Reyes De Corcuera, J. I., Cavalieri, R. P., & Powers, J. R. (2004). Blanching of foods. *Encyclopedia of Agricultural, Food and Biological Engineering*. DOI: 10.1081/E-EAFE-120030417.
- Rossi, M., Giussani, E., Morelli, R., Scalzo, R. L., Nani, R. C., & Torreggiani, D. (2003). Effect of fruit blanching on phenolics and radical scavenging activity of high bush blueberry juice. *Food Research International*, 36, 999-1005.
- Sahoo, N. R. (2011). Studies on different drying methods for onion (*Allium cepa* L.) (unpublished doctoral dissertation). Orissa University of Agriculture and Technology, Bhubaneshwar, Odisha, India.

- Salunkhe, D. K., & Kadam, S. S. (1998). Pumpkin, squashes and gourds, In: Handbook of Vegetable Science and Technology, Chap. 11”, Marcel Dekker Inc., New York, pp: 279-282.
- Sharma, G. P., & Prasad, S. (2004). Effective moisture diffusivity of garlic cloves undergoing microwave-convective drying. *Journal of Food Engineering*, 65, 609–617.
- Shinde, K. A., Pawar, S. G., & Khodke, S. U. (2016). Study on drying characteristics of bottle gourd in tray dryer. *International Journal of Research Studies in Agricultural Science*, 2(2), 1-7.
- Shoba, (2009). Studies on drying of methi leaves (*Trigonella foenum-graecum* L.) (unpublished master’s thesis). University of Agricultural Sciences, Bangalore, Karnataka, India. 1-112.
- Sivarajan, S. S., & Balchandra, A. (1994). *Ayurvedic drugs and their plant sources*, Oxford and IBH Publication Company Pvt. Ltd., New Delhi, 176-177.
- Sivaraj, N., & Pandravada, S. R. (2005). Morphological diversity for fruit characters in bottle gourd germplasm from tribal pockets of Telangana region of Andhra Pradesh, *Asian Agri History*, 9(4), 305-310.
- Swasdisevi, T., Soponronnarit, S., Prachayawarakorn, S., & Phetdasada, W. (1999). Drying of chopped spring onion using fluidization technique. *Drying Tehnology*, 17(6), 1191–1199.
- Sowjanya, P. (2004). Studies on quality of solar and tray dried figs (unpublished master’s thesis). Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, India. pp:1-102.
- Sukhlencha, A. (2012). Bitter bottle gourd (*Lagenaria siceraria*): Healer or killer? *International Journal of Nutrition, Pharmacology, Neurological Diseases*, 2(3), 276-277.
- Thomas, S. C. (2006). *Taiwanese native medicinal plants*. CRC Press, London, New York. pp: 71-80.
- Thomas, S. C. (2008). *Vegetables and fruits: nutritional and therapeutic values, 1st edition*, CRC Press, London, United Kingdom. pp-1-304.

- USDA (2018). National nutrient database for standard reference legacy release. Retrieved from <https://ndb.nal.usda.gov/ndb/foods/show?ndbno=11218&fg=11&man=&lfacet=&format=Abridged&count=&max=25&offset=0&sort=cqookp&rptfrm=nl&nutrient1=255&nutrient2=203&nutrient3=207&subset=&tCount=767&measureby=g>.
- Vadivambal, R., & Jayas, D. S. (2007). Changes in quality of microwave treated agricultural products- a review. *Bio-systems Engineering*, 98, 1-16. DOI: 10.1016/j.biosystemseng.2007.06.006.
- Wang, J., Xiong, Y., & Yu, Y. (2004). Microwave drying characteristics of potato and the effect of different microwave powers on the dried quality of potato. *European Food Research and Technology*, 219, 500–506. DOI: 10.1007/s00217-004-0979-1.
- Wang, J., & Xi, Y. S. (2005). Drying characteristics and drying quality of carrot using a two stage microwave process. *Journal of Food Engineering*, 68, 505-511. DOI: 10.1016/j.jfoodeng.2004.06.027.
- Yadav, S., & Sehgal, S. P. (1997). Effect of home processing and storage on ascorbic acid and β carotene content of bathua (*Chenopodium album*) and fenugreek (*Trigonella foenum-graecum*) leaves. *Plant foods for human nutrition*, 50(3), 239-247.
- Yarrakula, S. (2017). Development of microwave assisted fluidized bed dryer for nutmeg mace (unpublished master's thesis). Department of Food and Agricultural Process Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Kerala, India. pp: 1-120.
- Yetisir, H., Sakar, M., & Serce, S. (2008). Collection morphological characterization of *Lagenaria siceraria* germplasm from the Mediterranean region of Turkey. *Genetic Resources and Crop Evolution*, 55, 1257–1266. DOI: 10.1007/s10722-008-9325-y.
- Yongsawatdigul, J., & Gunasekaran, S. (1996). Microwave-vacuum drying of cranberries: part 11. quality evaluation. *Journal of Food Processing and Preservation*, 20, 145-156.

APPENDICES

Appendix-I

Physico-chemical characterization of bottle gourd fruits

Replication 1

Constituent	Value
Seed/pulp/peel ratio (%)	20.59:70.30:09.11
Moisture content (%)	94.32
Ash content (%)	00.54
Protein content (%)	01.31
Total fibre content (%)	00.60
Total fat content (%)	00.30
Total carbohydrate content (%)	02.93
Total soluble solids (°Brix)	04.00
Ascorbic acid content (mg/100g)	09.30
Calcium (mg/100g)	13.42
Potassium (mg/100g)	88.13

Replication 2

Constituent	Value
Seed/pulp/peel ratio (%)	19.74:70.80:08.89
Moisture content (%)	94.13
Ash content (%)	00.54
Protein content (%)	01.18
Total fibre content (%)	00.70
Total fat content (%)	00.20
Total carbohydrate content (%)	03.25
Total soluble solids (°Brix)	04.10
Ascorbic acid content (mg/100g)	09.27
Calcium (mg/100g)	13.93
Potassium (mg/100g)	87.02

Replication 3

Constituent	Value
Seed/pulp/peel ratio (%)	21.50:69.59:09.48
Moisture content (%)	94.63
Ash content (%)	00.59
Protein content (%)	01.20
Total fibre content (%)	00.60
Total fat content (%)	00.20
Total carbohydrate content (%)	02.78
Total soluble solids (°Brix)	04.00
Ascorbic acid content (mg/100g)	09.15
Calcium (mg/100g)	13.46
Potassium (mg/100g)	87.08

Appendix-II

Effect of steam blanching on quality of bottle gourd shreds

Replication 1

Shreds thickness (mm)	POD inactivation time (min)	Total soluble solids (°Brix)	Ascorbic acid (mg/100g)	Juice yield (%)
3	05.50	02.90	07.08	62.90
5	08.00	02.80	06.77	63.81
7	07.50	02.60	06.26	65.58

Replication 2

Shreds thickness (mm)	POD inactivation time (min)	Total soluble solids (°Brix)	Ascorbic acid (mg/100g)	Juice yield (%)
3	06.00	02.80	07.09	63.21
5	07.00	02.70	06.86	64.17
7	08.50	02.60	06.36	65.20

Replication 3

Shreds thickness (mm)	POD inactivation time (min)	Total soluble solids (°Brix)	Ascorbic acid (mg/100g)	Juice yield (%)
3	06.50	02.80	07.08	62.68
5	07.50	02.60	06.70	64.49
7	08.00	02.70	06.18	65.38

Appendix-III

Effect of drying parameters on quality of bottle gourd shreds

Replication 1

Air velocity (m/s)	Total Time required for dehydration (min)	Ascorbic acid content (mg/100g)	Colour value (ΔE^*ab)	Rehydration ratio (%)
At 55 °C temperature				
6	75.00	05.31	02.24	09.33
8	73.50	05.37	02.24	09.44
10	73.00	05.47	02.24	12.21
At 60 °C temperature				
6	65.70	05.50	01.63	09.95
8	64.50	05.59	01.26	10.68
10	63.00	05.60	01.71	12.92
At 65 °C temperature				
6	60.20	05.65	01.53	10.91
8	60.00	05.67	01.90	11.08
10	58.30	05.66	01.50	12.96

Replication 2

Air velocity (m/s)	Total Time required for dehydration (min)	Ascorbic acid content (mg/100g)	Colour value (ΔE^*ab)	Rehydration ratio (%)
At 55 °C temperature				
6	75.50	05.45	01.64	09.87
8	74.00	05.47	01.64	10.57
10	73.50	05.45	01.64	11.64
At 60 °C temperature				
6	65.50	05.55	01.26	09.22
8	64.30	05.50	01.53	10.36
10	63.10	05.59	01.80	12.77
At 65 °C temperature				
6	60.80	05.58	01.44	11.32
8	60.30	05.65	01.71	11.39
10	59.20	05.68	01.47	12.93

Replication 3

Air velocity (m/s)	Total Time required for dehydration (min)	Ascorbic acid content (mg/100g)	Colour value (ΔE^*ab)	Rehydration ratio (%)
At 55 °C temperature				
6	75.30	05.42	01.71	09.23
8	74.50	05.43	01.63	09.50
10	73.40	05.49	02.20	11.99
At 60 °C temperature				
6	65.20	05.56	01.52	09.65
8	64.20	05.51	01.40	10.43
10	63.20	05.62	01.92	12.59
At 65 °C temperature				
6	60.50	05.60	01.90	10.99
8	60.00	05.64	00.76	10.93
10	58.20	05.68	01.04	12.91

Appendix - IV

Effect of drying on chemical analysis of dehydrated bottle gourd shreds

Replication 1

Parameters	Values
Moisture content (%)	06.00
Ash content (%)	03.60
Protein content (%)	12.87
Total fibre content (%)	04.34
Total fat content (%)	03.38
Total carbohydrate content (%)	69.81
Ascorbic acid content (mg/100g)	05.65
Calcium (mg/100g)	59.40
Potassium (mg/100g)	396.42

Replication 2

Parameters	Values
Moisture content (%)	06.50
Ash content (%)	03.30
Protein content (%)	12.73
Total fibre content (%)	04.45
Total fat content (%)	03.37
Total carbohydrate content (%)	69.65
Ascorbic acid content (mg/100g)	05.67
Calcium (mg/100g)	59.32
Potassium (mg/100g)	395.89

Replication 3

Parameters	Values
Moisture content (%)	06.40
Ash content (%)	03.90
Protein content (%)	12.73
Total fibre content (%)	04.42
Total fat content (%)	03.38
Total carbohydrate content (%)	69.17
Ascorbic acid content (mg/100g)	05.69
Calcium (mg/100g)	59.30
Potassium (mg/100g)	396.24

Appendix - V

Effect of storage on sensory characteristic of dehydrated bottle gourd shreds

Replication 1

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour and appearance	07.55	07.50	07.21	07.20	07.14	06.84	06.90	06.50	05.16
Aroma	07.61	07.14	07.03	07.04	06.98	06.80	06.89	06.88	05.78
Texture	07.26	06.71	06.93	06.80	06.64	06.58	06.42	06.34	05.81
Overall acceptability	07.62	07.41	07.32	07.18	07.14	07.08	06.98	06.81	06.91
CP – Control sample in polypropylene pouch									
Colour and appearance	05.00	04.23	05.08	04.67	04.45	04.59	04.58	04.28	04.15
Aroma	05.28	05.38	05.16	05.04	04.99	04.52	04.51	04.09	04.19
Texture	05.10	05.61	06.18	06.06	06.15	06.07	05.00	05.10	05.38
Overall acceptability	05.03	05.80	05.40	05.50	05.09	04.98	04.96	04.50	04.49
MLP – Dehydrated sample in metalized laminated pouch									
Colour and appearance	07.60	07.25	07.38	07.10	07.16	06.96	06.92	06.73	06.74
Aroma	07.63	06.68	06.87	06.47	06.60	06.08	06.09	06.25	06.21
Texture	07.37	07.08	07.29	07.38	07.30	07.14	07.23	06.83	06.64
Overall acceptability	07.53	07.29	07.60	07.51	07.44	07.37	06.95	07.48	06.48
CMP - Control sample in metalized laminated pouch									
Colour and appearance	04.80	04.22	04.87	05.02	05.05	04.98	05.41	05.08	05.01
Aroma	05.28	05.69	04.93	04.99	05.00	04.97	04.90	04.71	04.17
Texture	05.60	04.80	06.30	06.27	06.28	06.89	05.60	05.20	04.75
Overall acceptability	05.04	05.56	05.37	05.38	05.26	05.06	04.93	04.37	04.35

Replication 2

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour and appearance	07.60	07.20	07.18	07.40	07.16	06.91	06.87	06.54	05.21
Aroma	07.64	07.18	07.05	07.00	07.05	06.91	06.96	06.92	05.73
Texture	07.48	07.13	05.99	06.70	06.58	06.47	06.44	06.33	05.98
Overall acceptability	07.56	07.39	07.24	07.16	07.18	07.10	06.92	06.89	06.90
CP – Control sample in polypropylene pouch									
Colour and appearance	05.04	04.22	05.08	04.63	04.58	04.62	04.70	04.40	04.09
Aroma	05.30	05.38	05.16	05.03	05.01	04.60	04.51	04.51	04.16
Texture	05.10	05.61	06.18	06.07	06.18	05.98	04.90	04.90	05.24
Overall acceptability	05.03	05.80	05.40	05.30	05.18	05.06	04.84	04.60	04.53
MLP – Dehydrated sample in metalized laminated pouch									
Colour and appearance	07.50	07.19	07.30	07.40	07.09	06.92	06.89	06.91	06.71
Aroma	07.62	06.65	06.79	06.54	06.49	06.13	06.00	06.18	06.18
Texture	07.33	07.10	07.30	07.30	07.36	07.13	06.98	06.70	06.65
Overall acceptability	07.60	07.25	07.48	07.44	07.37	07.40	07.80	07.28	06.43
CMP - Control sample in metalized laminated pouch									
Colour and appearance	05.10	04.28	04.83	05.03	04.97	05.12	04.98	04.97	04.96
Aroma	05.24	05.66	04.95	05.03	05.02	04.96	04.89	04.75	04.45
Texture	05.60	05.12	06.10	06.26	06.22	06.89	05.30	04.99	04.76
Overall acceptability	05.00	05.60	05.47	05.28	05.30	05.10	04.96	04.38	04.39

Replication 3

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour and appearance	07.50	07.29	07.12	06.70	07.03	06.92	06.63	06.16	05.23
Aroma	07.61	07.07	06.98	06.96	07.03	06.99	06.88	06.81	05.77
Texture	07.28	07.49	07.78	06.60	06.76	06.51	06.37	06.38	06.21
Overall acceptability	07.59	07.52	07.28	07.17	07.25	07.09	07.10	06.79	06.86
CP – Control sample in polypropylene pouch									
Colour and appearance	04.90	04.21	05.00	04.62	04.77	04.62	04.52	04.22	04.09
Aroma	05.23	05.39	05.11	04.96	04.94	04.41	04.48	04.30	04.19
Texture	05.70	05.56	06.07	06.11	06.06	06.04	05.10	05.60	05.31
Overall acceptability	04.99	05.00	05.50	04.80	05.09	05.08	04.93	04.61	04.48
MLP – Dehydrated sample in metalized laminated pouch									
Colour and appearance	07.58	07.22	07.40	07.10	07.29	06.97	06.92	06.82	06.74
Aroma	07.61	06.68	06.74	06.49	06.41	06.15	06.21	06.17	06.12
Texture	07.29	07.06	07.25	07.40	07.39	07.06	06.79	06.87	06.60
Overall acceptability	07.58	07.30	07.42	07.49	07.48	07.34	07.80	07.14	06.50
CMP - Control sample in metalized laminated pouch									
Colour and appearance	04.98	04.31	04.94	04.98	05.07	04.99	04.61	04.95	05.03
Aroma	05.26	05.66	04.94	05.07	05.01	04.98	04.91	04.94	04.34
Texture	05.90	05.08	06.50	06.16	06.13	06.92	05.60	05.11	04.71
Overall acceptability	05.05	05.55	05.39	05.30	05.28	05.08	04.96	04.42	04.40

Effect of storage on physico-chemical characteristics of dehydrated bottle gourds

Replication 1

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour value (ΔE^*ab)	01.31	02.24	03.10	03.22	03.30	03.33	03.40	03.46	03.56
Moisture content (%)	06.00	06.95	07.20	06.46	07.10	07.14	07.18	07.34	07.31
Ascorbic acid content (mg/100g)	05.65	05.59	05.50	05.58	05.50	05.30	05.42	05.36	05.36
Ash content (%)	03.60	03.41	03.48	03.35	03.12	03.21	03.24	03.30	03.22
Calcium content (mg/100g)	59.40	58.79	58.90	58.75	58.71	58.72	58.70	58.65	58.58
Potassium content (mg/100g)	396.42	389.12	378.94	375.47	368.50	365.23	363.75	362.07	357.79
CP – Control sample in polypropylene pouch									
Colour value (ΔE^*ab)	02.20	03.75	03.96	04.83	05.00	05.98	06.23	07.80	08.12
Moisture content (%)	08.51	08.54	08.75	08.54	08.84	08.94	09.01	09.01	09.72
Ascorbic acid content (mg/100g)	06.60	06.01	05.89	05.61	05.60	05.56	05.62	05.40	05.12
Ash content (%)	03.60	03.65	03.33	03.58	03.33	03.54	03.48	03.54	03.54
Calcium content (mg/100g)	38.25	38.65	38.65	38.44	38.55	38.51	38.56	38.39	38.36
Potassium content (mg/100g)	265.47	251.68	235.18	242.72	242.41	235.93	233.41	233.99	229.84
MLP – Dehydrated sample in metalized laminated pouch									
Colour value (ΔE^*ab)	01.31	02.68	03.45	03.49	03.40	03.62	03.65	03.75	03.82
Moisture content (%)	06.60	06.30	06.57	06.62	06.63	06.80	06.79	06.88	06.91
Ascorbic acid content (mg/100g)	05.67	05.60	05.80	05.63	05.51	05.51	05.49	05.41	05.29
Ash content (%)	03.60	03.25	03.35	03.34	03.24	03.34	02.65	03.25	03.23
Calcium content (mg/100g)	59.32	58.95	58.86	58.95	58.86	58.88	58.83	58.89	58.85
Potassium content (mg/100g)	397.12	391.09	386.02	386.02	382.84	376.58	374.07	369.57	368.00
CMP - Control sample in metalized laminated pouch									
Colour value (ΔE^*ab)	02.20	03.63	03.86	04.90	05.81	06.80	07.90	08.75	09.83
Moisture content (%)	08.00	08.36	08.80	08.43	08.64	08.74	08.71	08.81	08.86
Ascorbic acid content (mg/100g)	06.52	06.40	05.80	05.62	05.55	05.50	05.50	05.36	05.26
Ash content (%)	03.80	04.01	03.60	03.89	03.71	03.78	03.72	03.68	03.63
Calcium content (mg/100g)	39.95	39.95	39.85	39.86	39.81	39.56	39.54	39.38	39.31
Potassium content (mg/100g)	263.37	251.87	248.72	246.05	241.82	239.95	236.53	235.14	234.02

Replication 2

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour value (ΔE^*ab)	01.33	02.26	03.13	03.20	03.34	03.31	03.50	03.48	03.58
Moisture content (%)	06.80	06.97	07.10	06.45	07.08	07.13	07.21	07.41	07.42
Ascorbic acid content (mg/100g)	05.67	05.43	05.80	05.56	05.53	05.80	05.45	05.40	05.38
Ash content (%)	03.30	03.33	03.35	03.25	03.47	03.67	03.32	03.28	03.31
Calcium content (mg/100g)	59.32	58.84	58.79	58.72	58.73	58.71	58.68	58.63	58.60
Potassium content (mg/100g)	395.89	388.82	379.12	375.60	368.25	365.21	363.82	362.00	357.93
CP – Control sample in polypropylene pouch									
Colour value (ΔE^*ab)	01.88	03.80	03.92	04.81	05.30	06.00	06.23	07.85	08.12
Moisture content (%)	08.49	08.59	08.82	08.61	08.78	08.94	08.96	08.98	09.67
Ascorbic acid content (mg/100g)	06.41	06.02	06.02	05.58	05.49	05.56	05.41	05.29	05.16
Ash content (%)	03.80	03.59	03.70	03.57	03.80	03.54	03.59	03.55	03.49
Calcium content (mg/100g)	38.31	38.68	38.71	38.41	38.51	38.51	38.44	38.39	38.28
Potassium content (mg/100g)	262.88	253.06	239.00	242.43	242.48	235.93	233.50	233.97	229.81
MLP – Dehydrated sample in metalized laminated pouch									
Colour value (ΔE^*ab)	01.33	02.61	03.43	03.46	03.53	03.62	03.62	03.78	03.84
Moisture content (%)	06.50	06.28	06.61	06.58	06.68	06.70	06.88	06.85	06.93
Ascorbic acid content (mg/100g)	05.71	05.58	05.60	05.58	05.56	05.68	05.51	05.39	05.42
Ash content (%)	03.80	03.50	03.40	03.27	03.41	03.35	03.62	03.29	03.31
Calcium content (mg/100g)	59.32	58.93	58.94	58.91	58.94	58.86	58.90	58.81	58.78
Potassium content (mg/100g)	397.12	391.07	385.58	385.48	383.03	376.49	373.68	369.63	367.91
CMP - Control sample in metalized laminated pouch									
Colour value (ΔE^*ab)	01.88	03.61	03.89	04.80	05.84	06.90	08.00	08.73	09.81
Moisture content (%)	08.20	08.35	08.30	08.38	08.68	08.73	08.83	08.84	08.82
Ascorbic acid content (mg/100g)	06.54	06.10	05.70	05.67	05.54	05.55	05.80	05.26	05.23
Ash content (%)	03.60	03.26	03.89	03.46	03.78	03.65	03.71	03.74	03.70
Calcium content (mg/100g)	39.91	39.90	39.89	39.84	39.78	39.62	39.52	39.32	39.28
Potassium content (mg/100g)	263.58	252.17	248.65	245.56	240.85	242.03	237.42	235.08	233.97

Replication 3

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Colour value (ΔE^*ab)	01.35	02.24	03.13	03.21	03.32	03.22	03.30	03.47	03.54
Moisture content (%)	06.70	07.02	06.70	06.41	07.06	07.09	07.12	07.24	07.35
Ascorbic acid content (mg/100g)	05.69	05.78	05.50	05.54	05.50	05.40	05.42	05.38	05.40
Ash content (%)	03.90	03.43	03.23	03.30	03.28	02.98	03.26	03.20	03.25
Calcium content (mg/100g)	59.30	59.04	58.71	58.72	58.73	58.72	58.69	58.68	58.68
Potassium content (mg/100g)	396.41	387.68	380.08	375.55	367.97	365.19	363.80	361.9	358.04
CP – Control sample in polypropylene pouch									
Colour value (ΔE^*ab)	02.22	03.79	03.97	04.82	05.00	05.96	06.20	07.84	08.15
Moisture content (%)	08.40	08.58	08.77	08.56	08.87	08.97	08.91	09.28	09.65
Ascorbic acid content (mg/100g)	06.49	06.09	05.79	05.64	05.44	05.50	05.32	05.48	05.17
Ash content (%)	03.70	03.53	03.80	03.63	03.58	03.50	03.61	03.53	03.56
Calcium content (mg/100g)	38.22	38.65	38.62	38.44	38.50	38.56	38.52	38.87	38.23
Potassium content (mg/100g)	262.00	250.24	236.97	242.56	242.34	235.78	233.44	234.07	229.87
MLP – Dehydrated sample in metalized laminated pouch									
Colour value (ΔE^*ab)	01.35	02.63	03.44	03.49	03.57	03.59	03.62	03.75	03.80
Moisture content (%)	06.40	06.29	06.56	06.57	06.55	06.90	06.82	06.88	06.92
Ascorbic acid content (mg/100g)	05.66	05.71	05.43	05.53	05.58	05.46	05.44	05.46	05.46
Ash content (%)	03.10	03.45	03.27	03.30	03.29	03.19	03.60	03.31	03.27
Calcium content (mg/100g)	59.26	58.88	58.91	58.90	58.89	58.89	58.90	58.79	58.82
Potassium content (mg/100g)	397.67	391.47	385.86	384.88	382.47	376.61	374.13	369.57	367.88
CMP - Control sample in metalized laminated pouch									
Colour value (ΔE^*ab)	02.22	03.65	03.86	05.00	05.81	07.00	07.50	08.68	09.82
Moisture content (%)	08.60	08.28	08.40	08.45	08.63	08.66	08.86	08.81	08.84
Ascorbic acid content (mg/100g)	06.56	05.80	05.90	05.60	05.53	05.48	04.90	05.31	05.23
Ash content (%)	03.90	04.03	03.76	03.87	03.72	03.75	03.73	03.69	03.75
Calcium content (mg/100g)	39.94	39.91	39.90	39.85	39.81	39.62	39.52	39.39	39.21
Potassium content (mg/100g)	264.96	251.96	248.61	244.98	242.01	241.02	238.04	235.17	234.16

Effect of storage on microbial characteristics of dehydrated bottle gourds

Replication 1

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CP – Control sample in polypropylene pouch									
Total plate count	06.36	07.50	07.59	07.57	07.92	07.80	08.11	08.56	08.58
Yeast and mold count	06.41	06.23	06.30	06.52	06.62	06.75	06.74	06.83	06.91
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
MLP – Dehydrated sample in metalized laminated pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CMP - Control sample in metalized laminated pouch									
Total plate count	06.33	07.68	07.68	07.64	07.72	07.85	08.85	08.81	08.91
Yeast and mold count	06.48	06.45	06.46	06.65	06.68	06.60	06.87	06.95	06.95
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Replication 2

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CP – Control sample in polypropylene pouch									
Total plate count	06.39	07.49	07.58	07.62	07.89	07.89	08.15	08.56	08.58
Yeast and mold count	06.47	05.94	06.34	06.50	06.64	06.83	06.68	06.71	06.92
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
MLP – Dehydrated sample in metalized laminated pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CMP - Control sample in metalized laminated pouch									
Total plate count	06.35	07.62	07.58	07.65	07.75	07.82	08.86	08.92	08.89
Yeast and mold count	06.31	06.51	06.51	06.63	06.67	06.80	06.93	06.91	06.98
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Replication 3

Parameters	Storage period (Days)								
	0	15	30	45	60	75	90	105	120
PP – Dehydrated sample in polypropylene pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CP – Control sample in polypropylene pouch									
Total plate count	06.39	07.45	07.57	07.61	07.92	08.01	08.10	08.57	08.60
Yeast and mold count	06.35	05.83	06.29	06.51	06.63	06.76	06.71	06.80	06.96
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
MLP – Dehydrated sample in metalized laminated pouch									
Total plate count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Yeast and mold count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
CMP - Control sample in metalized laminated pouch									
Total plate count	06.40	07.65	07.78	07.66	07.72	07.82	08.78	08.76	08.96
Yeast and mold count	06.44	06.48	06.50	06.55	06.69	06.10	06.60	06.93	06.98
Coliform count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Appendix-VI

Score Card for Sensory Evaluation of Dehydrated Bottle Gourd Shreds

Kindly evaluate the product using 9 point hedonic scale.

Sample code	Colour and Appearance	Aroma	Texture	Overall acceptability

Evaluation guidance:

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

Comments:

Name:

Signature:

Date:

Time: