EFFECT OF PRETREATMENTS AND DRYING TEMPERATURE ON QUALITY CHARACTERISTICS OF DEHYDRATED *AMLA* *(Phyllanthus emblica)*

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Effect of Pretreatments and Drying Temperature on Quality Characteristics of Dehydrated *Amla (Phyllanthus emblica)*

A dissertation submitted to the Department of Food Technology, Central Campus of Technology, Tribhuvan University, in partial fulfillment for the degree of B.Tech. in Food Technology

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Approval Letter

This *dissertation* entitled *Effect of Pretreatments and Drying Temperature on Quality Characteristics of Dehydrated Amla (Phyllanthus emblica)* presented by Aayush Sharma Ghimire has been accepted as the partial fulfillment of the requirement for the B. Tech. degree in Food Technology

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Abstract

Amla, a richest source of vitamin C were subjected to different pretreatments and drying temperature to investigate the effect of pretreatments and drying temperature on quality characteristics of dehydrated *amla*. *Amla* were subjected to following pretreatments *viz.* cut blanching, cut sulphiting, cut (blanching + sulphiting), whole blanching, whole sulphiting, whole (blanching + sulphiting) and dried at 60±2ºC at cabinet drier to a final moisture content 6±1%. Further, the best pretreatment was then subjected to 3 different drying temperature range *viz*, 55±2ºC, 60±2ºC and 65±2ºC to a final moisture content 6±1%.

Among the different pretreatments, samples pretreated by pretreatment whole (blanching + sulphiting) showed higher retention of vitamin C (411.3 mg/100 g, db) (71.18%) along with improved rehydration ratio (2.227:1), coefficient of rehydration (0.422) and best organoleptic properties. *Amla* pretreated by pretreatment whole (blanching + sulphiting) and dried at 55±2ºC showed maximum retention of Vitamin C, best rehydration characteristics and better organoleptic property compared to other temperature range. Vitamin C retention was maximum at temperature 55±2ºC (429.67 mg/100 g, db) (74.36%) which was significantly different ($p \leq 0.05$) with the samples dried at other temperature range. Temperature showed significant effect on rehydration ratio. *Amla* dried at 55±2ºC showed maximum rehydration ratio (2.507:1) and coefficient of rehydration (0.4747). Sensory quality of the product dried at 55±2ºC was found superior to that obtained from 60±2ºC and 65±2ºC. The sensory attributes of all three products; dried at 55±2ºC, 60±2ºC and 65±2ºC were found significantly different ($p \leq 0.05$) to each other. The final optimized dried *amla* composition was found 6%, 3.3, 5.2%, 4.6%, 2.4% and 429.67 mg/100 g in terms of moisture content, pH, total sugar, reducing sugar, acidity and vitamin C respectively.

Table Of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Full form
AA	Ascorbic Acid
db	dry basis
HMFP	High Moisture Food Products
HMP	High Methoxyl Pectin
KMS	Potassium Meta bi-Sulphite
OA	Overall Acceptance
ppm	Parts per million
RDI	Required Daily Intake
SSP	Self Stable Product
TA	Titratable Acidity
TSS	Total Soluble Solids
wb	wet basis

Part I

Introduction

1.1 General introduction

Amla (*Phyllanthus emblica*) is highly nutritious fruit that grows abundantly in Nepal. It is grown in almost all parts of the country. It is also termed as Indian gooseberry which is a low cost important fruit valued for its nutritional and medicinal properties. It is one of the richest sources of ascorbic acid (600 mg/100 g) used as a strong rejuvenator in Indian pharmacopoea (Pathak and Ram, 2007) and is very popular for its medicinal properties as mentioned both in Ayurvedic and Unani system of medicine (Sharma *et al.*, 2011). It has high medicinal as well as nutritional value due to its high vitamin C content. It is valued as an anti-ascorbic, acidic, cooling laxative and diuretic (Naik *et al.*, 2005).

Fresh *amla* is rich in vitamin C and very few people are aware of its therapeutic value in Nepal. As such *amla* fruits are not consumed much in fresh form because of its acidic and bitter taste. It is, therefore, not popular as a table fruit. It is sometimes used for making pickles and dry-candy in the homes (Kalra, 1988). Dried *amla* is a delicious product which is liked by many people. Open-sun drying of *amla* is the most common preservation practice followed by people in Nepal. Open sun drying however is not recommended for drying as it results in huge loss of vitamin C (Sajith and Muraleedharan, 2013).

Dried fruits are fruit from which the majority of the original water content has been removed either naturally, through sun drying, or through the use of specialized dryers or dehydrators. Fruits are dried to increase the shelf life for long-term storage (Prakash *et al.*, 2004). The preparation of dried fruits today often involves pretreatment, recipe addition followed by conventional or commercial drying (Verma and Gupta, 2004).

Dried fruits have low moisture content and can be preserved for long period of time by using normal packaging materials. As shelf life of dried *amla* is high hence they are available in the off season also. Dried fruits prepared following pretreatments are generally superior in color and flavor to those dried without any pretreatments (Prajapati *et al.*, 2010).

1.2 Statement of the problem

Due to the bitter, astringent, sour taste and being perishable, the consumption of *amla* as fresh fruit is limited (Kumar and Nath, 1993). During processing, the ascorbic acid being unstable and oxidisable (Mottram, 1974), drastic losses result and retention of such essential nutrient is advantageous. The rate of loss of Ascorbic acid is greatly influenced by different factors like oxidation, pH, temperature, time, light and many more (Priestly, 1979).

Since *amla* is a perishable fruit its shelf-life can be increased by drying so that we can consume it throughout the year. Since ascorbic acid is an essential nutrient in *amla*, some works have been done to study the losses of ascorbic acid during drying. But till date no work has been done on effect of pretreatments on quality of cabinet dried *amla*.

Thus, the present work is concerned with the study of effect of pretreatments on quality of cabinet dried *amla* at various temperature. An effort is made to retain the Vitamin C by the process of various pretreatment at different temperature. It is expected that the pretreatment process at different temperature helps in retaining the Vitamin C, improves the rehydration properties and sensory attributes of cabinet dried *amla*.

1.3 Objectives

1.3.1 General objective

The general objective is to study the effect of pretreatments and drying temperature on quality characteristics of dehydrated *amla* (*Phyllanthus emblica*).

1.3.2 Specific objectives

The specific objectives are as follows:

1. To study the optimum blanching time for *amla* on the basis of enzyme inactivation.
2. To study the effect of pretreatment on quality by determining the changes in vitamin C content, rehydration characteristics and sensory attributes of cabinet dried *amla*.
3. To study the effect of drying temperature on quality by determining the changes in vitamin C content, rehydration characteristics and sensory attributes of cabinet dried *amla*.

4. To study the chemical composition of cabinet dried *amla*.

5. To estimate the cost of production of cabinet dried *amla*.

1.4 Significance of the study

Many fruits and vegetables are season oriented. Likewise, *amla* is also one of the winter season fruit. It contains higher percentage of ascorbic acid as compared to other fruits and vegetables (Dewan, 1994). *Amla* fruit is highly nutritive with great medicinal values and rich source of Vitamin C. As *amla* fruit is highly perishable in nature, its storage is very limited. Also it is a seasonal fruit. Drying of *amla* makes it available throughout the year. As dried *amla* has long shelf life, it can be stored for a long period of time. With the addition of water or other fluids, dried fruits quickly assume the flavor and texture of their fresh or frozen counterparts. Without any preparation or rehydration, dried fruits can also be eaten and is healthful replacement for other crispy snacks. Drying is also a suitable alternative for postharvest management. It facilitates in considerable saving in packaging, storage, etc. The fact that dried foods are lightweight and compact makes them desirable for hiking and camping trips. Also vitamin C is an essential nutrient and is recommended in our daily diet, dried *amla* is the best source for required vitamin C (Gautam, 1991). Moreover due to its astringent nature, acidic and bitter taste consumers are hesitant to eat it in raw form. Fresh *amla* is so sour that most people find it intolerable (Prajapati *et al.*, 2010). It is therefore not popular as a table fruit. However, excellent nutritive and therapeutic values of the fruit have great potentiality for processing into several quality products. The method of preparation of dried *amla* is hygienic, consume lesser time and provide maximum retention of nutrient. Nowadays, the craze towards processed food has been greatly increased which is very low or either deficit in Vitamin C content and people go through many problems related to deficiency in Vitamin C. The deficiency of ascorbic acid results in the defective formation of the intercellular cement substances. Fleeting joints pains, irritability, retardation of growth in the child, anaemia, shortness of breath, poor wound healing, and increased susceptibility to infection are among the signs of deficiency. Scurvy is the deficiency disease resulting from the lack of ascorbic acid in the diet (Scartezzini *et al.*, 2006). Hence present study was an effort to optimize suitable pretreatment method and drying temperature of cabinet dried *amla* to get higher amount of vitamin C, good rehydration properties and sensory attributes. Thus, the present work is concerned with the study of effect of pretreatments and drying

temperature on the retention of Vitamin C, rehydration properties and sensory attributes of cabinet dried *amla*.

1.5 Limitations of the study

Due to time constraints and limited laboratory facilities, following could not be done in this study:

1. Microbiological analysis.
2. Analysis of specific nutrients.

PART II

Literature review

2.1 *Amla*

2.1.1 Historological background

Amla commonly known as Indian gooseberry, is a wonder herb and one of the precious gift of nature to human health. It belongs to family Euphorbiaciae. It is an integral constituent of various Unani and Ayurvedic medicine with amazing remedial qualities (Ranote, 2006).

Amla is a gift of nature mankind. In Sanskrit, it is called Amalaki or Dhartiphala. Amla is perhaps the single most often mentioned herb in "Charak Samhita", the Ayurvedic medicine literature (500 BC). *Amla* is a wonder herb and one of the precious gifts of nature to humans. *Amla* is known as "Divya" and "Amrut" or Amrit Phala in Sanskrit, which literally means fruit of heaven or nectar fruit. The Sanskrit name, Amlaki, translates as the Sustainer or The Fruit where the Goddess of Prosperity Resides. In Hindu religious mythology the tree is worshipped as the Earth Mother as its fruit is considered to be so nourishing as to be the nurse of mankind (Udupa, 2003).

Amla is native to Srilanka, India, Malaysia, China (Zhang *et al.*, 2003) and distributed in terai and subtropical valleys in Nepal. The fruit is acrid, cooling, refrigerant, diuretic and laxative, hence used for treating chronic dysentery, bronchitis, diabetes, fever, diarrhea, jaundice, & coughs etc. It is highly nutritive and one of the richest source of ascorbic acid. It contains 500-1500 mg of ascorbic acid per 100 g of pulp (Gopalan *et al.*, 1993).

2.2 Botanical profile

Amla belongs to family Euphorbiaciae. The plant is an annual herb attending a height of 8 to 18 m prominent groove of glands and white hairs are present on the stem and branches. Bluish purple flowers bloom from March to May and fruits on August to February and it is reported that one tree gives three muri fruits. It is a potential crop which grows in marginal soils and various kinds of degraded lands such as salt-affected soils, dry and semi-dry regions. Several authors have reported that the distribution of this fruit tree is in terai, inner terai and central terai low hills throughout the country from 400-1800 m altitude. It is a small medium sized deciduous tree with smooth, greenish grey, exfoliating bark. Leaves are

feathery with small narrowly oblong, pinnately arranged leaflets. Fruits are depressed globose ½ - 1 inch in diameter, fleshy and obscurely 6-lobed, containing 6 small seeds. The tree is 30-40 ft in height and circumference of stem usually extends up to 3-6 ft and rarely up to 9 ft. Stem is usually curved, branches are strong and extended. Bark is thin and brownish in color. Leaves resemble to tamarind leaves. Fruits are fleshy and round in shape. Raw fruits are green in color and become greenish yellow on ripening. Fruit contain a three celled nut each cell of which contain two triangular seeds. Seeds are round, edges of which are sharp (Singh and Kumar, 2000)

2.3 Biochemical and nutritional composition of *amla*

2.3.1 Chemical composition

The fruit juice is reported to contain nearly 20 times as much Vitamin C as orange juice. Every 100 g edible fruit provides 470-680 mg of Vitamin C. Fruit contains moisture, protein, fat, minerals, fibers and carbohydrate. Its mineral and vitamin contents include calcium, phosphorous, iron carotene, carbohydrate, thiamine, riboflavin besides Vitamin C. A recent study on *amla* attributes its strong antioxidant properties to its small molecular weight tannoid complexes (Desouky *et al.*, 2000).

Detailed chemical composition of edible parts of *amla* is given in the Table 2.1, 2.2 and 2.3.

Table 2.1 Chemical composition of *amla*

Parameters	(Gopalan *et al.*, 1993)	(Shah, 1978)	(Bajpai and Shukla, 1998)	(Bhartakur and Arnold, 1990)
Moisture (%)	81.8	79.76	81.2	79.8
Protein (%)	0.5	0.46	0.5	0.69
Fat (%)	0.1	0.15	0.1	0.62
Ash (%)	0.5	0.63	0.7	-
Fiber (%)	3.4	19	3.4	-
Carbohydrates (%)	13.7	-	14	-
Ascorbic acid (mg)	600	-	600	588.9

All the values are per 100 g edible portion.

Table 2.2 Minerals and trace elements of *amla*.

Parameters	(Gopalan *et al.*, 1993)	(Bhartakur and Arnold, 1990)
Calcium (mg)	50	27.6
Phosphorus (mg)	20	28.2
Iron (mg)	1.2	3.3
Sodium (mg)	5.0	4.2
Potassium (mg)	225	282
Magnesium (mg)	-	11.8
Sulphur (mg)	-	16.6
Manganese (mg)	-	1.1

All values are per 100 g edible portion.

Table 2.3 Vitamin content of *amla*.

Vitamins	Amount (Gopalan *et al.*, 1993)
Carotene (µg)	9
Thiamin (mg)	0.03
Riboflavin (mg)	0.01
Niacin (mg)	0.2
Vitamin C (mg)	600

All the values are per 100 g edible portion.

2.3.2 *Amla* as a rich source of ascorbic acid

Many authors have reported the content of ascorbic acid in *amla* which indicates *amla* as a rich source of ascorbic acid compared to other fruits and vegetables. The ascorbic acid content of *amla* is reported to be the highest among fruits and vegetables. Compared to edible portions, it has 20 times vitamin C of grape fruit and 15 times that of lemon (Nisha *et al.*, 2004). More importantly, the vitamin C contained in the *amla* fruit is stabilized by the presence of tannins, which help *amla* to maintain its vitamin content even through processing. Consumption of only 10 g (one average size fruit) will meet the recommended daily allowances (RDA) of vitamin C. The ascorbic acid contents of small and large size fruits of *amla* found to be 412 and 900 mg per 100 g edible portion, respectively (Bhartakur and Arnold, 1990). Vitamin C is a water soluble vitamin and it is not stored in the body. It is important to consume it on everyday basis in diet. Vitamin C is part of the cellular chemistry that provides energy, it is essential for sperm production and for making the collagen protein involved in the building and health of cartilage, joints, skin and blood vessels. Vitamin C helps in maintaining a heathy immune system, it aids in neutralizing pollutants, is needed for antibody production, acts to increase the absorption of nutrients (including iron) in the gut and thins the blood. These are the most important functions of Vitamin C. The ascorbic acid contents of some of fruits and vegetables are given in Table 2.4.

Table 2.4 Ascorbic acid contents of some fruits and vegetables.

Fruits	Ascorbic acid	Vegetables	Ascorbic acid
Rich source		Amaranath leaves	173
Amla	700	Brussels sprouts	72
Guava	300	Cabbage	124
Good source		Coriander leaves	135
Orange	68	Drumstick leaves	220
Pineapple	63	Ipomoea leaves	137
Mango(ripe)	24	Spinach leaves	48
Tomato (ripe)	32	Radish leaves	65
Fair source			
Apple	2-8		
Banana	2-6		
Grapes	2-6		

All values are mg per 100 g of edible portion Source: Swaminathan (1997)

2.4 Varieties of *amla*

The different varieties of *amla* which are categorized on the basis of color are given as (Singh, 2003):

1. ***Green tinged:*** fairly large, nearly green in color, best for pickles and *murabba*.
2. ***Red tinged:*** medium size fruit having white streaks.
3. ***Hathiful:*** commercial variety found in Uttar Pradesh, India fairly large tree, fruit size good, with shining, conspicuous glands.
4. ***Chakaiya:*** fruits are small, fibrous and flattened in appearance.

5. ***Banarasi:*** fairly large in size, shining, thin skinned, and transparent and of yellowish color, best used for preserves.

2.5 Uses of *amla*

2.5.1 Food use

Amla is used for making different products such as pickles and dry candy (salt and spiced titaura) in Nepal as well as preserve which is popular in Nepal and India. *Murabba* is preserved by boiling the fresh fruit and keeping it in concentrated boiled sugar solution. Also different *amla* jam, sauces can be prepared from *amla*. It is useful during summer and provides cool to the consumer (Bhattacharya *et al.*, 2003).

2.5.2 Therapeutic use

It has been traditionally used in the Ayurvedic system of medicine since the time immemorial. Dried *amla* is one of the constituents of "*trifala*", a renowned Ayurvedic medicine. The tender shoots with butter and milk are equally useful for indigestion and diarrhea. Green fresh leaves with curd or sour milk are equally useful for indigestion and diarrhea. Milky juice of the plant is used as a dressing for fresh ark mixed with honey and turmeric is a remedy for gonorrhea. The bark of stem is also useful in diarrhea. Fermented preparation from the root is prescribed in jaundice, dyspepsia and cough (Dasaroju and Gottumukkala, 2014)

The fresh fruit is refrigerant, tonic, antiscorbutic, diuretic and laxative. A Sherbet or sweet juice prepared from the juice is regarded to be antibilious, diuretic and cooling, fevers, hiccups, vomiting, indigestion, chronic, constipation and other complaints of indigestion. The juice of fruit with clarified butter is prescribed as a restorative tonic. A mixture of fresh fruit juice and sugar is useful for relieving itching or burning sensation of trachea. Infusion prepared by keeping dried fruit overnight in water in an earthen vessel is effective as an Eye wash in ophthalmia (Krishnaveni and Mirunalini, 2011). *Amla* preserve has a beneficial effect in reducing cholesterol content of blood (Kapoor, 2008).

2.5.3 Uses of seed

The seed of *amla* too has some benefits. Infusion of seed is recommended as a drink in fever and diabetes; seeds are also used as a remedy for bilious infections and nausea. An ointment

prepared by burning seeds with oil is prescribed for scabies and itch. The root leafs; bark and fruit are also for the cure of snake bite (Khan, 2009).

2.5.4 Pharmacological use

The pharmacological properties of the *amla* are numerous. Not only is it a wonderful antioxidant, but it has proven anti-fungal, anti-bacterial, anti-viral, anti-mutagenic, yeast inhibiting, anti-inflammatory, hypolipidemic, and hypotensive relieving properties, it also acts as an antacid and anti-tumorganic agent. In addition, it increases protein synthesis and is thus useful in cases of hypoglycemia. Vitamin C in *amla* is powerful as it is a complex of ascorbate, tannins and polyphenols (Kapoor, 2008).

The antioxidant properties of *amla* extracts and their effects on the oxidative stress in streptozoticin-induced diabetes were examined in rats. *Amla* also showed strong inhibition of the production of advance glysosylated end products. The oral administration of *amla* extracts to the diabetic rats slightly improved body weight gain and also significantly alleviated various oxidative stress indices of the serum of the diabetic rats (Ghosal *et al.*, 2002). The elevated serum levels of 5-hydroxymehtylfurfural, which is a glycosylated protein that is an indicator of oxidative stress, were significantly reduced dose-dependently in the diabetic rats fed *amla* (Ghosal *et al.*, 2002).

2.5.5 Medicinal use

Amla or *Emblica Officinalis* is a natural, efficacious, an antioxidant with the richest natural source of Vitamin C. The fruit contains the highest amount of Vitamin C in natural form and cytokine like substances identified as zeatin, z. riboside, and z. nucleotide. Its fruit is acrid, cooling, refrigerant, diuretic and laxative. The dried fruit is useful in hemorrhage, diarrhea and dysentery. It is anti-bacterial and its astringent properties prevent infection and help in the healing of ulcers. It is used as a laxative to relieve constipation in piles. In general, *amla* is a powerful ally for many systems of the body. It is known to promote energy, reproductive health, and healthy cholesterol levels. *Amla* is also a tonic for the heart, the arterial system, the respiratory system, the sense organs, and the mind.

Amla protects cells against free radical damage and provides antioxidant protection (Krishnaveni and Mirunalini, 2010).Other novel functions are as follows:

(a) ***Amla*** **balances stomach acids:** Because it improves digestion but does not heat the

body. *Amla*-Berry is ideal for calming mild to moderate hyperacidity and other gull bladder related digestive problems. It should always be taken with food in such case (Grover *et al.*, 2010).

(b) Nourishes the brain and mental functioning: *Amla*-Berry is good for the brain. It is nutritious- nurturing for the mind and enhancing coordination among memory, recall and retention. It helps sharpen the intellect and mental functioning. It supports the nervous system and strengthens the senses (Grover *et al.*, 2010).

(c) Strengthens the lungs: *Amla*-Berry is a wonderful tonic for strengthening and nourishing the lungs and the entire respiratory tract. It also helps to maintain moisture balance in the lungs (Nadkarni, 2007).

(d) Supports the heart: It is *hridya*, which means it nurtures the heart, blood and circulation. It supports the cardiovascular system. On the other hand, it sometimes acts as a cardiac stimulant. For this reason, if you have a heart problem, you should check with a medical doctor before using *amla*-berry tablets (Thakur *et al.*, 2002).

(e) Helps the urinary system: Since, it enhances all the digestive fibers, *amla*-berry is especially supportive to the urinary system and can be helpful in a mild burning sensation while urinating. It supports natural diuretic action, but does not force water from the body like diuretic pills. In other words, it helps eliminate waste form the body but does not over–stimulate the urinary system (Grover *et al.*, 2010).

(f) Good for the skin: Because *Amla*-Berry strengthens digestion, helps the live detoxify and is rich in Vitamin C and other minerals, it is very good for the complexion. *Amla* Berry moisturizes the skin, cleanses the tissues of toxins, and supports immunity of the skin against bacterial infection (Thakur *et al.*, 2002).

(g) Enhances immunity: All of the benefits already mentioned make *amla*-berry a strong immunity booster. Polyphenols have been shown to have numerous health protective benefits, including lowering blood lipids and blood sugar, enhancing blood circulation, and blocking the actions of carcinogens, which together contribute to the anti-ageing effect (Suman, 2009).

(h) Acts as an antioxidant: *Amla*-berry tablets and other chemicals that contain *amla* are effective broad-spectrum antioxidants and free radical scavengers, helping to reduce disease and slow the aging process (Ghosal *et al.*, 2002).

(i) Regulates elimination: *Amla*-Berry tablets helps with the downward flow of energy in the body. They keep the function of elimination regular and ease constipation

(Ghosal *et al.*, 2002).

(j) Fortifies the liver: *Amla* helps purify the *Rasa Dhatu* (nutrient fluid) and *Rakta Dhatu* (blood), thus supporting the functions of liver, helping it in eliminating toxins from the body. Research shows that *amla* helps lower cholesterol**.**

(k) Promotes healthier hair: *Amla*-Berry boosts absorption of calcium, thus creating healthier bones, teeth, nails and hair. It also helps maintain youthful hair color and retards premature graying, and supports the strength of the hair follicles, so there is less thinning with age (Thakur *et al.*, 2002).

(l) Flushes out toxins: Individual who has been eating "junk" food for a while tends to have accumulated deposits of preservatives and additive in the liver. *Amla*-Berry helps support the liver in flushing out chemical and additives from the physiology (Ghosal *et al.*, 2002).

(m) Increases vitality: Because it has five tastes, helps in many body functions and cleanses the blood and the micro-channels of the body, *amla*-berry increases energy and removes fatigue. It supports regeneration of cells-the process by which tired old cells are replaced by vital, new ones (Ghosal *et al.*, 2002).

(n) Improves muscle tone: *Amla*-Berry enhances protein synthesis, which is why it is good for strengthening muscles and building lean muscle mass. Its unique *Ayurvedic* action offers athletes and body-builders a natural way to tone muscles and build lean mass (Ghosal *et al.*, 2002).

(o) Reduces unwanted fat: *Amla* reduces unwanted fat because it increases total protein levels; this is due to its ability to create a positive nitrogen balance and it also significantly reduces the level of free fatty acids.

(p) Fights against obesity: *Amla* reduces cholesterol and cholesterol induced atherosclerosis, making it a useful natural product to fight obesity.

(q) Fights against viruses: *Amla* intake helps body system to fight against all kind of viruses like those of hepatitis, AIDS, influenza and many others as it is rich in natural vitamin C.

2.6 *Amla* products

Different products can be made from *amla* in earlier time it was consumed as suds and lately following the development it was started being consumed as *amla* pickle, *amla* candy, indigenous *titaura* and *amla* sauce, *amla* squash. Recipe of some *amla* products developed

by some experts have been given in the following paragraph

(a) Jam: *Amla* fruit pulp (50%) is taken and 67% sugar is added. Herbs like 5% asparagus and 2% ashwagandha extract will increase its medicinal properties. The mixture is cooked and citric acid is added (acidity 1.2%). After judging the end point (68° Brix), it is filled into clean sterilized glass jars, upon setting of jam, lids and jars are closed ensuring an air tight seal. Highly acceptable even after the storage period of more than 9 months (Ranote, 2006). The best example of *amla* jam is chyavanprash. Chyavanprash is a delicious nutritive jam made with a base of fresh *amla* fruits and also includes a number of other herbs, ghee, sesame oil, sugar, and/or honey.

(b) Sauce: Five kg of sauce containing 50% *amla* pulp and 50% tomato pulp with 75 g sugar, 10 g salt, 60 g onion, 6 g garlic, 12 g ginger, 5 red chilies, and 12 g hot spices was prepared. Acetic acid and sodium benzoate as preservatives were added at the rate of 1ml and 0.3 g/kg of final product, respectively. Finally the sauce was filled in glass bottles and crown corked followed by processing in boiling water for 30 minutes and air-cooled. The product was highly acceptable (Ranote, 2006).

(c) Pickle: *Amla* pickles are also widely consumed and prepared with the intention of commercialization and household purposes. Pakistanis *amla* pickles are known to have good quality and acceptance in the international trade. *Amla* pickles are prepared. *Amla* is pretreated first in water to soften its tissues and it is worked with spices which is ultimately sun dried to obtain good quality of product (Ranote, 2006).

(d) *Amla* candy: *Amla* candy is prepared by the process given by (Siddappa *et al.*, 1986). The fruits were dipped on 30° Bx sugar syrup. The Bx was then raised by 10° Bx per day up to 60° Bx and then by 5° Bx per 2days up to 75° Bx. 0.15% of citric acid was added on the basis of sugar syrup initially and then on sugar (which added in each step) to add inversion process. At 75° Bx it was left for 1 week to be equilibrium. The fruit is drained from the syrup and then dried placing at trays using electric cabinet drying 66°C for 9 hrs.

(e) *Amla* juice: *Amla* fruits are preserved either in water or salt solution for a couple of weeks for the commercial preparation of products. Ina the quality of *amla* juice prepared from fruits steep preserved in water for 30 days was assessed during storage up to 9 months under ambient conditions. The juice was prepared from fruits withdrawn of steeping preservation in water, pasteurized at 90°C and preserved with 500 ppm SO_2 in glass bottles under ambient conditions (Jain and Khurdia, 2002).

(f) ***Amla*** **squash:** Srivastava and Kumar (2007) Standardized the recipe for preparation of herbal squash. Five different recipes with or without asparagus juice and ginger juice were developed. Asparagus and ginger juice were mixed with *amla* pulp and the remaining procedure is as such followed for simple squash. A recipe containing 25% *amla* pulp, 5% asparagus extract and 2% ginger juice with 50% TSS and 1.2% acidity is found most ideal for preparation of herbal squash.

(g) ***Amla*** **sukuti:** Amla fruits are highly perishable in nature as its storage in atmospheric conditions after harvesting is very limited (Kumar and Nath, 1993). Storage facilities such as cold storage, controlled/modified atmosphere storage, being very expensive, are not in the direct reach of poor farmers. Preservation of foodstuffs through dehydration is an ancient practice. Among the various drying methods available, open-sun drying is the most common preservation practice followed where solar radiation is high. The climatic adversities, contamination by insects and dust which constitutes a loss of quality of the dried product and need of a lot of man power are the important reasons for shifting from open sun drying to controlled drier. Bhatia *et al.* (1959) Recommended a drying temperature of 60-63°C after blanching of *amla* for 7 min in 2% sodium chloride solution. Minor ingredients and various spices are used as taste.

2.7 Vitamin C

Vitamin-C is a white crystalline compound, relatively simple structure and closely related to the monosaccharide sugars, with sour taste but no smell its empirical formula is $C_6H_5O_6$ and molecular weight is 176. Vitamin C was given the name ascorbic acid by its discoverer (Mottram, 1974).

2.7.1 Chemistry of vitamin C

Ascorbic acid is highly soluble compound that has both acidic and strong reducing properties. It is the most unstable of all known vitamins. In solution it easily gets oxidized, especially on exposure to heat. Oxidation is accelerated in the presence of copper and alkaline pH. On mild oxidation ascorbic acid is converted into dehydroascorbic acid. The oxidized form may be reduced back to ascorbic acid. Both ascorbic acid and dehydroascorbic acid have the vitamin C activity. When dehydroascorbic acid is treated with weak acid it is converted into diketogulonic acid (DKG) with no vitamin C activity, it cannot be reduced to dehydroascorbic acid again (Manaya and Shadaksharaswamy, 2008).

2.7.1.1 Physicochemical properties of ascorbic acid

1. Ascorbic acid is very stable when dry, moderately stable in acid solution but unstable in alkali (Levine and Welch, 2009).

2. Vitamin C is a comparatively strong acid, a half percent solution of ascorbic acid in water has a pH of about 3 and its acidic property is caused by the presence of enediol group. It behaves as a monobasic acid and give salt when reacted upon with alkalis (Ginter *et al.*, 2003).

3. Ascorbic acid is precipitated by lead ion at pH 7.6 (Levine and Welch, 2009).

4. Ascorbic acid is rapidly lost due to oxidation by exposure to air at relative humidity. The oxidation is speeded up by heat and prevented during cold storage (Rajlakshmi, 2000).

5. The oxidation of Ascorbic acid is accelerated by heat, light alkalis, oxidative enaymes and traces of Cu and Fe (Sebrell and Harris, 2001).

6. Vitamin C is the least stable among other Vitamins and is most easily oxidized to form dehydroascorbic acid (Sebrell and Harris, 2001).

2.7.2 Function of ascorbic acid on the body

2.7.2.1 Biochemical function

- The principal function of ascorbic acid is the formation of collagenous intercellular substances. Ascorbic acid is essential for hydroxylation of two amino acids, proline and lysine to hydroxyproline and hydroxylysine which are important constituents of collagen. This helps in wound healing and increases the ability to withstand the stress of injury or infection (Ashwell *et al.*, 2001).

- For other hydroxylation reaction to the formation of corticosterone and 17 hydroxy-corticosterone from deoxy-corticosterone, and for the conversion of tryptophan to 5 hydroxytryptophan (Buettner, 2003). For cell respiration and function of enzymes; it includes oxidation of phenylalanine to tyrosine, reduction of ferric iron to ferrous iron in the gastrointestinal track so that iron is more readily absorbed (Ashwell *et al.*, 2001).

- For synthesis of steroid hormones and decrease the cholesterol level (Haworth and Hirst, 2002).

2.7.2.2 Physiological function

For tissue oxidation as ascorbic acid identified as a reducing agent in living tissue, its function is in tissue oxidation though without much success, the oxidized form of vitamin i.e. dehydroascorbic acid can act as a hydrogen acceptor in the oxidation of phenolic amino acids, phenylalanine and tyrosine. Probably the ascorbic acid plays in the metabolism of active tissues which maintain the vitamin in the reduced state in living cells (Levin, 2008). Adrenal cortex function: Firstly Ginter *et al.* (2003) observed that ascorbic acid has a particular association with adrenal cortical hormones is of interest because both are concerned with the integrity of connective tissue (Levin, 2008). Blood formation: It is suggested that ascorbic acid is concerned with the formation of red blood corpuscles hemolytic state develop in scurvy and is responsible for the anemia (Levin, 2008).

2.7.3 Effect of deficiency

The deficiency of ascorbic acid results in the defective formation of the intercellular cement substances. Fleeting joints pains, irritability, retardation of growth in the child, anemia, shortness of breath, poor wound healing, and increased susceptibility to infection are among the signs of deficiency. Scurvy is the deficiency disease resulting from the lack of ascorbic acid in the diet (Levine *et al.*, 2002).

2.7.4 Side effect from over dosage

The reported side effects based on biochemical theory are gastro-intestinal disturbance, increase peristalsis, abdominal colic, gastro-enteritis and anal irritation, looseness of bowels, occasional diarrhea, abnormal uric acid metabolism, production of gout, oxaluria, and stone formation, bone demineralization and increased collagen catabolism, calcium resorption, allergic symptoms, occasional urticaria and erythema, transient urticaria, haemolytic crisis, human infertility. These effects were observed taking daily dose in the range between 200 mg to 300 mg (Harper, 2000).

2.7.5 Recommended daily allowances of ascorbic acid

The recommended human dietary intake of vitamin C varies from 30 mg in the UK to 125

mg in the USSR (Harper, 2000).The recommended daily allowances purposed by food and nutrition board national academy of science, the nutrition expert group of the ICMR, India, FAO and DHSS report are given Table 2.5.

Table 2.5 Recommended daily allowances of ascorbic acid.

Subject	Dose / person
Infants	20 mg
Children	20 mg
Males	30 mg
Females	50 mg
Pregnancy	50 mg
Lactation	50 mg

Source: FAO (1970)

2.7.6 Occurrence of ascorbic acid on body

The normal human body when fully saturated contains about 5 g of vitamin of which perhaps 30 mg are in the adrenal glands, 200 mg in the extra cellular fluids and rest distributed in varying concentration throughout the cells of the body. Blood contains about 1 mg/100 ml ascorbic acid (Levin, 2008).

2.7.7 Metabolism of ascorbic acid on body

In normal circumstances, the vitamin C is absorbed from the alimentary canal and passes into the plasma. It is absorbed by the leucocytes by active and passive mechanism where it is stored provided that tissues demands have been satisfied and vitamin utilization is stable. Absorption is impaired during the latter stages of vitamin C, deficiency possibly in consequence of damage to the lining membrane of the alimentary canal or as a result of pituitary disfunction (Ashwell *et al.*, 2001).

2.7.8 Synthesis and biosynthesis of ascorbic acid

Ascorbic acid is synthesized from glucose and other simple sugars by plants and by most animals species (Haworth and Hirst, 2002). But man, monkeys, guinea pigs, Indian fruit bat,

the red vented bulbul bird and fish are unable to synthesize this vitamin (Seib and Tolbert, 2005). Ascorbic acid is not present in microorganisms nor does it seem to be required (Ginter *et al.*, 2003). Glucose and galactose are involved in the biosynthesis of ascorbic acid (Levine and Welch, 2009).

2.7.9 Therapeutic use of ascorbic acid

Ascorbic acid has specific effect in the treatment of scurvy. Even small doses (e.g. 10 mg/day) not only prevent scurvy but cure the clinical features of ascorbic acid deficiency by Sheffield experiment. Ascorbic acid corrects the hyper tyrosinaemia that sometimes occurs in new infants, especially the premature and acts as a reducing agent in correction the rare condition methaemoglobinaemia (Levin, 2008).

2.7.10 Industrial applications

Due to its multifunctional ability, ascorbic acid has been used by food processors in the following ways (Woods, 2001) as:

a. A vitamin

b. An acid

c. An curing aid

d. An antioxidant

e. Oxygen scavenger

f. A color stabilizer

g. A bread improver

h. A clarity improver in beer

The main fields of applications are as now follows (Klaui *et al.*, 2000)

a) Soft drinks: Especially beverages based on citrus fruits, where vitamin C functions as an antioxidant for the flavors as well as a nutrient.

b) Meat and meat containing products: In meat curing and pickling.

c) Flour/Bread: For improving the baking quality.

d) Beer: As a stabilizer.

e) Frozen fruits: As an antioxidant.

2.7.11 Losses of vitamin C

(a) Pre harvest factor: Variations in the vitamin content of raw material can affect the content of vitamins in the final food products to a considerable extent. Raw food may vary widely in the vitamin content because of climatic and soil condition, genetic variation and maturity at the time of harvest (Harris, 2008).

(b) Oxidation of ascorbic acid: Vitamin C may be oxidized both by air and by enzymes (Wills *et al.*, 2003). Enzymes containing copper or iron in their prosthetic groups are most efficient catalysts of ascorbic acid decomposition. The most important enzymes of this group are ascorbic acid oxidase, phenolase, cytochrome oxidase and peroxidase. Among them only ascorbic acid oxidase involves a direct reaction between enzymes, substrate and molecular oxygen. The other enzymes oxidize the vitamin indirectly. Phenolases catalyses the oxidation of mono and dihydroxy phenols to quinines and this reacts directly with ascorbic acid (Welch *et al.*, 2007). Cytochrome oxidase oxidizes cytochromes to the oxidized form and this react with L-ascorbic acid. Peroxidase in combination with phenolic compounds utilizes H_2O_2, to bring out oxidation (Wills *et al.*, 2003). The enzymes do not act in intact fruits because of the physical separation of enzymes from the substrates. When the fruit is damaged or cellular fragments occurred, reductase is more liable and therefore oxidases are free to react with ascorbic acid. The route and rate of oxidation is influenced by several factors, including pH, trace metals, enzymes, oxidation reduction potential, presence of oxygen as well as time and temperature (Stevens, 2008).

(c) Leaching of ascorbic acid: When fruits and vegetables are cooked, a large part of vitamin C can be washed out into the cooking water. Leaching in the prime cause of vitamin C loss when undamaged peels are blanched at 97°C (Ponne *et al.*, 2005).

(d) Drying or dehydration: Ascorbic acid is the most difficult of the vitamins to preserve during the dehydration of food; it is generally considered that the presence of vitamin

C in processed food is highly correlated with overall quality of food products (Nagy, 2007).

(e) Anaerobic destruction: Anaerobic destruction of ascorbic acid following oxidative changes is also significance. The rate of this reaction is virtually independent of pH except in the range 3-4 where it is slightly increased. Accelerators of this reaction are fructose, Fructose 6-phosphate, fructose, 1,6diphosphate, sucrose and caramelized fructose. Furfural and carbon dioxide are appeared to be the major end products of decomposition (Welch *et al.*, 2007).

(f) Non enzymatic changes: Non enzymatic changes which are of the catalytic effects of Cu. which are enhanced by iron, resulting in the formation of dehydro ascorbic acid and hydrogen peroxide. The H_2O_2 produced in this reaction further changes and gives O2 and water (Welch *et al.*, 2007).

(g) Loss during storage: The destruction rate of ascorbic acid during storage is affected by moisture content, enzyme, temperature and time. Significant losses begin to occur during storage and rate of loss is time and temperature dependent (Welch *et al.*, 2007).

2.7.12 Retention of vitamin C

Vitamin C from fruits can be retained by optimum harvest condition, shortest possible processed time, blanching, construction and maintenance of equipment, removing oxygen, acidic condition, uses of sulphites, best storage condition, packaging practices, powder form of product, quick freezing.

2.8 Blanching

Heat treatment of food for a short period prior to canning, freezing and dehydration followed by cooling is called blanching. It is generally applied to fruit and vegetables, and primarily carried out to inactivate enzymes. Un-blanched frozen or dried foods undergo relatively rapid changes during storage, in food quality such as color, flavor, texture and nutritive value due to continuous enzymatic activity (Kharel, 2004). In plant tissues, enzymes such as lipoxygenase, chlorophyllase, polyphenoloxidase and polygalacturanase cause loss of nutrition, flavor and texture. In addition, peroxidase and catalase are the two most heat resistant although they are not implicated as a cause of deterioration during storage, their

activity is used to evaluate the effectiveness of blanching. If both of these enzymes are inactivated, then it can be safely assumed that other significant enzymes are also inactivated. Peroxidase is the more heat resistant of the two and the absence of residual peroxidase activity indicates that other less heat resistant enzymes are also destroyed (Kharel, 2004).

2.8.1 Effect on foods by blanching

The heat received by the food during blanching inevitably causes some changes to sensory and nutritional qualities. In, general, the time- temperature combination used for blanching is a compromise which ensures adequate inactivation but prevents excessive softening and loss of flavor in the food (Fellows, 2009). Foods are processed in various ways to lengthen the time they can be stored, e.g. by canning, freezing, drying, sterilization and irradiation, and ascorbic acid losses vary depending on the method used. Before canning or freezing, vegetables are exposed to boiling water or steam to inactivate enzymes that have a detrimental effect during storage. This is known as blanching. Blanching softens the tissues, pectic substances in cell wall and middle lamella. Loss of ascorbic acid due to blanching is between 13–60%. Short exposure to high temperatures is less harmful than longer heating at lower temperatures. Blanching process involves heat and water, which are the key factors in loss of water-soluble nutrients and vitamins in foods and affect nutrient content in blanched foods as water-soluble vitamins and nutrients leach out and degrade in blanching water, and small pieces of vegetable lose more ascorbic acid than do large pieces (Rahman and Perera, 2000).

2.8.1.1 Effect on nutrients by blanching

Some minerals, water- soluble vitamins and other water-soluble components are lost during blanching. Losses of vitamins are mostly due to leaching, thermal destruction and, to a lesser extent, oxidation (Fellows, 2009). The extent of vitamin loss depends upon on a number of factors including:

- The maturity of food and variety
- Methods used in preparation of the food, particularly the extent of cutting, slicing or dicing
- The surface-area-to volume ratio of the pieces of food

- Method of blanching
- Time and temperature of blanching (lower vitamin losses at higher temperature for shorter times)
- Method of cooling

Blanching as a unit operation is a short time heating in water at temperatures of 100°C or below. In order to reduce losses of hydro soluble substances (mineral salts, vitamins, sugars, etc.) during water blanching, several methods have been developed (Heldman and Hartel, 1999):

1. Setting temperature at 85-95°C instead of 100° C.
2. Adjusting blanching time, just sufficient to inactivate enzymes catalase and peroxidase.

2.8.1.2 Effect on color and flavor by blanching

Blanching brightens the color of some foods by removing air and dust on the surface and thus altering the wave length of reflected light. The green color of chlorophyll is protected by using alkaline blanching, although the increase in pH may increase losses of ascorbic acid. Blanching water is often added with sodium carbonate to neutralize the natural acidity of the products. When, correctly blanched, most foods have no significant changes to flavor or aroma, but under blanching can lead to the development of off- flavors during storage of dried or frozen foods (P. J. Fellows, 2009). Green tender peas when blanched with the use of blanching aids, 0.125% MgO and 0.1% NaHCO3 retained maximum percentage of Chlorophyll (Muftugil, 2001).

2.8.1.3 Effect on texture by blanching

One of the purposes of blanching is to soften the texture of vegetables to facilitate filling into containers prior to canning. Calcium chloride (1-2%) is added to the blanched water to form insoluble calcium pectate complexes and thus to maintain firmness in the tissue (Fellows, 2009).

Blanching is essential where fruits and vegetables are to be frozen or dried because drying or freezing operations only slow down enzymatic action but do not completely stop it. If

blanching is not done prior freezing or drying then the frozen or dried product, which is often held in frozen or dried state for many months, will slowly develop off flavors and off colors and also other kinds of enzymatic spoilage might result. Under blanching may cause more damage to food than the absence of blanching does. Heat, which is sufficient to disrupt tissue but not to inactivate enzymes, causes the mixing of enzymes and substrates. In addition, only some enzymes may be destroyed which causes increased activity of other enzymes and thus accelerates deterioration (Kharel, 2004).

Bhatia *et al.* (1959) recommended blanching of amla for 7 min in 2% NaCl solution prior drying at 60-63°C.

2.9 Sulphiting

The color and shelf-life of the dried products could be improved by using chemical preservatives. The browning reaction continues after drying and dried fruits will continue to darken during storage unless they have been treated with sulfur dioxide (SO_2). The presence of SO_2 in the dried fruits will also inhibit the microbial spoilage and will help to deter insect both during drying and later in storage (Bhalla, 1986). According to Potter (1987) sulfur dioxide may function in several ways. Sulfur dioxide is an enzyme poison against common oxidizing enzymes. It also has an antioxidising property that is an oxygen acceptor (as is ascorbic acid). Further, SO_2 minimizes nonenzymatic reaction Millard type browning by reacting with aldehyde groups of sugar, so that they would no longer be free to combine with amino acids. Sulfuring of fruits and vegetables also causes a great reduction in number of microorganisms and serves to inhibit growth in dried product.

Sulphitation was done to study the effect on colour by soaking the samples in 0.1% of potassium metabisulphite solution for five minutes (Chakroborty *et al.*, 1968). Alam *et al.* (2002) studied drying of *amla*, Chakaiya and Banarsi in mechanical dryer at 60°C after pre-treatment with blanching and sulphitation and compared with sun dried samples. They found the pre-treated and mechanically dried chakaiya variety of *amla* to the quality attributes after drying. Hendel (1960) reported that addition of sulphite to the blanched water helped in the retention of more ascorbic acid during blanching and dehydration. Blanching in sulphite solution helped in the retention of ascorbic acid in the dehydrated okra (Inyang and Ike, 1998). Blanching with hot water or with potassium metabisulphite (KMS) before drying checks the enzymatic spoilage and also improves the colour and texture of the *amla* shreds

(Prajapati *et al.*, 2010). Beneficial effect of blanching with KMS/sulphitation on retention of ascorbic acid content of dried product was also observed by many workers (Sethi, 1986; Tripathi *et al.*, 1988; Sagar and Kumar, 2006; R. Singh *et al.*, 2006; Prajapati *et al.*, 2010) in *amla*. It may be due to inactivation of oxidase enzyme.

2.10 Preservation by drying and dehydration

The essential feature of dehydration as a food preservation method is that the availability of water i.e. a_w, in the food is lowered to a level at which there is no danger from microbial growth and in doing so, the water content is reduced to minimize the rates of biological, chemical and physical processes which limit the storage life of food (Ekechukwu, 1999) .

The quality and stability of dehydrated foods are thus related to the reduction of a_w in these foods. The reduction of a_w results from the concentration of the internal aqueous environment, which is achieved by removing the water as in drying (Ekechukwu, 1999) .

According to Frazier and Westhoff (1978) solute and ions tie up water in solution. Therefore, an increase in the concentration of dissolved substances is in effect of drying of the material. Not only is water tied up by solutes but also water tends to leave the microbial cells by osmosis if there is higher concentration of solutes outside the cells than inside. Some fruits like apple, apricot, banana, citrus products, grape, mango, papaya and vegetables like carrot, onion, garlic are preserved in dehydrated form, Increase in TSS and decrease in water activity makes the products self stable. Cabinet drier is commonly used for laboratory studies in the dehydration of fruits and in small scale and seasonal commercial operations (Desrosier and Desrosier, 1978).

Preservation of fruits by drying them is perhaps the oldest method known. Large quantities of fruits are dried in the sun in different parts of the world such as Asia Minor, Greece, Spain and other Mediterranean countries, Arabia, Afghanistan, Australia, etc. The modern method of dehydration, i.e. drying fruits and vegetables under controlled conditions of temperature and humidity, is however, assuming importance as a major industry. The dehydration industry got an impetus during the World War II. On account of their concentrated form, low cost, convenience and easy transportability, dried fruit and vegetable products and also other dehydrated foods became highly popular among the armed forces (Giridhari *et al.*, 1986).

Dehydrated vegetables, however, lost some of their popularity owing to some undesirable changes in color, taste and flavor during storage and distribution. Dehydration techniques have since been greatly improved to get over most of these defects so that the modern dehydrated food is really a first class product in every way. It is sometimes said that the dehydration industry will one day be the most important one among the food preservation techniques employing various other well-known methods of preservation such as canning, freezing, addition of chemical preservatives, etc. There is scope for advanced scientific as well as development work in the field of food dehydration, especially of fruits and vegetables (Giridhari *et al.*, 1986).

Drying occurs from vaporization of the liquid by supplying heat to the wet material (Diamante *et al.*, 2014). According to Srivastava and Kumar (2007), both the terms 'drying' and 'dehydration' mean the removal of water. The former term is generally used for drying under the influence of non-conventional energy sources like sun and wind. In sun drying, there is no possibility of temperature and humidity control (Srivastava and Kumar, 2007).

Dehydration means the process of removal of moisture by the application of artificial heat under controlled conditions of temperature, humidity and air flow. In this process, single layer of fruits, whole or cut into pieces or slices are spread on trays which are placed inside the dehydrator. The initial temperature of the dehydrator is 43^{o}C which is gradually increased to 66-71^{o}C (Srivastava and Kumar, 2007).

Modern dryers, such as tunnel dryers and forced air circulation cabinet dryers have been used for drying fruits with a better color and flavor. Over 85% of industrial dryers are of the convective type with hot air or direct combustion gases used as the drying medium. The product changes during drying include shrinkage, puffing, and crystallization. Sometimes there are also desirable or undesirable chemical or biochemical reactions occurring that will cause changes in color, texture, odor, and other properties in the final product (Diamante *et al.*, 2014).

Various drying systems are used depending on what fruits are being dried and how the products are designed. Combined convective and far-infrared drying provides a shorter drying time due to its higher heat and mass transfer coefficients. Hot air drying, including oven drying, forced-air cabinet drying, and thin-layer drying, is widely used and the time taken depends on the drying temperatures and sample thicknesses. Microwave drying

reduces the sample mass rapidly and has a very short drying time. Solar drying is well suited for drying small quantities of fruits. Sun drying is simple but lengthy and unhygienic. Freeze drying is also one of the way to dry fruits without the loss of essential nutrients in it (Diamante *et al.*, 2014).

2.10.1 Cabinet drying

Cabinet dryers are usually small, insulated units with a heater, circulating fan, and shelves to hold the product to be dried. The small dehydration units sold for home use are small scale examples of this type of dryer. Different designs are used, but the general procedure is to force heated air over multiple trays. Small-scale cabinet dryers are typically single pass units. However, greater energy efficiencies can be obtained if some of the heated air is re-circulated. This is especially true in later stages of drying when the moisture removal rate is low and the exit air retains considerable moisture holding capacity. Fig. 2.1 shows the basic operation of a cabinet dryer with recirculation. Energy savings of 50% or more can be achieved with recirculation (Wilhelm *et al.*, 2004). Alam *et al.* (2002) studied drying of *amla*, Chakaiya and Banarsi in mechanical dryer at 60ºC after pre-treatment with blanching and sulphitation and compared with sun dried samples.

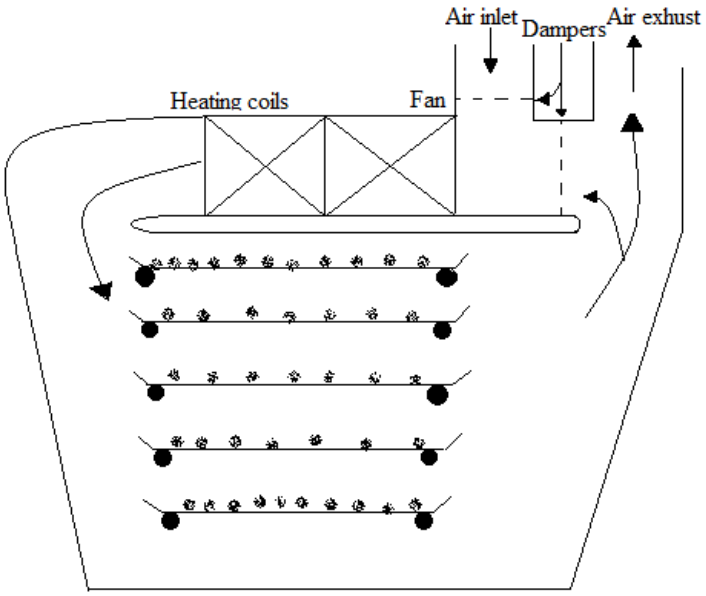

Fig. 2.1 Cabinet dryer with air re-circulation system

Source: Wilhem *et al.* (2004)

2.11 Drying kinetics

Drying occurs from vaporization of the liquid by supplying heat to the wet material. Conduction, like contact or indirect dryers, convection such as direct dryers, and radiation or volumetrically by placing the wet material in a microwave or radio frequency electromagnetic fields are various methods that are used in drying fruit . The methods chosen are dependent on what kind of fruit and the commercial conditions. In many processes, incorrect drying methods result in irreversible damage to the quality of the final product which makes the product non-saleable (Gujral and Brar, 2003). With modern dehydrators and well-designed drying methods, fruits can be dried at the peak season when the fruit is available to reach the requirements of customers throughout the year.

Drying kinetics is the description of the changes of moisture content of material during drying. It can be expressed as a drying curve or drying rate curve which is shown in Fig. 2.2 and 2.3 respectively.

Drying curve (Fig. 2.2) can be obtained experimentally by plotting the free moisture content versus drying time. This plot can be converted into a drying rate curve (Fig. 2.3) by calculating the derivative of the curve over time. From these two types of curve it is seen that drying is divided into two distinct portions. The first is the constant rate period, in which unbound water is removed (line BC). Water evaporates as if there is no solid present, and its rate of evaporation is not dependent on the material being dried. In this stage of drying the rate-controlling step is the diffusion of the water vapor across the air moisture interface. This period continues until water from the interior is no longer available at the surface of food material. Point C distinguishes the constant rate period from the subsequent falling rate period and is called the critical moisture content. The surface of the solid is no longer wet (Brennan *et al.*, 1990; Geankoplis, 1993; Rizvi, 1995).

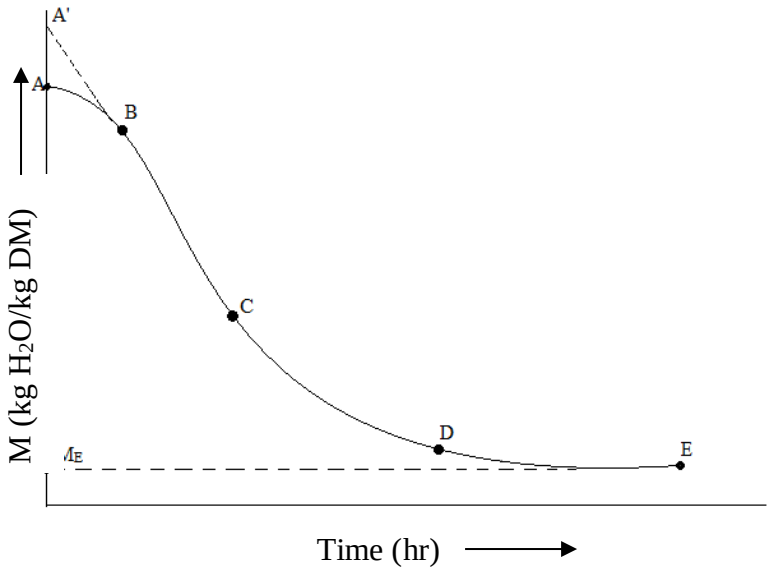

Fig. 2.2 Drying curve showing moisture content as a function of drying time

Source: Geankoplis (1993), Rizvi (1995)

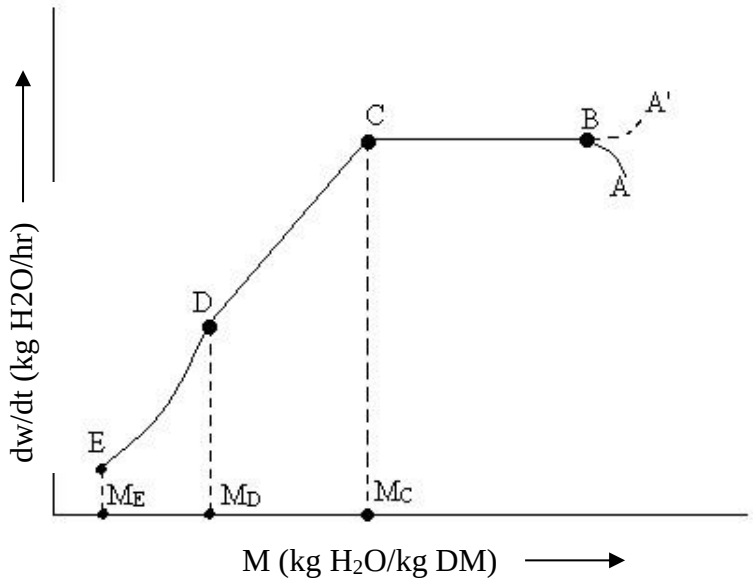

Fig. 2.3 Drying Rate as a function of moisture content

Source: Geankoplis (1993), Rizvi (1995)

The falling rate period has two sections as seen in Fig. 2.2. From C to D, the wet areas on the surface of the drying material become completely dry. When the surface is dry (point D, the evaporation front continues moving toward the center of the solid. This is shown by the curve from D to E. The water that is being removed from the center of the solid moves to the

surfaces as a vapor. Although the amount of water removed in the falling rate period is relatively small, it can take considerably longer time than in the constant rate period. The heat transmission now consists of heat transfer to the surface and heat conduction in the product. The drying rate in the falling rate period is controlled by diffusion of moisture from the inside to the surface and then mass transfer from the surface. During this stage some of the moisture bound by sorption is being removed. As the moisture concentration is lowered by drying, the rate of internal movement of moisture decreases. The rate of drying falls even more rapidly than before and continues to drop until the moisture content falls down to the equilibrium value for the prevailing air humidity and then drying stops (Geankoplis, 1993; Rizvi, 1995).

2.12 The drying process of food

In the drying process, three types of bound water could be seen in food materials.

1. Water molecules which were bound to ionic groups
2. Water molecules which were hydrogen bonded to hydroxyl and amide groups
3. Unbound free water found in interstitial pores in which capillary forces and soluble constituents could cause lowering of vapor pressure (Badger and Benchero, 1995).

Badger and Benchero (1995) studied the drying phenomenon and concluded that the drying rate includes different periods, first the moisture was removed by evaporation from the saturated surface, and next the area of saturated surface gradually decreases, followed by water evaporation in the interior parts of the sample. In the drying curve three periods could be identified as warming up, constant rate and falling rate. The exchange point which drying rate changes from constant rate to falling rate of drying curve was termed critical moisture content. The warming up period was of little consequence in most cases because of its short duration. Either the constant rate or falling rate period may constitute the major portion of the drying time. During the constant rate drying period, the rate of moisture removal from the product was limited only by the rate of evaporation on water surfaces on or within the product. In this constant-rate period, the water was being evaporated from what is effectively a free water surface. The illustrative figure for the phenomenon of drying and moisture removal is shown in Fig. 2.4.

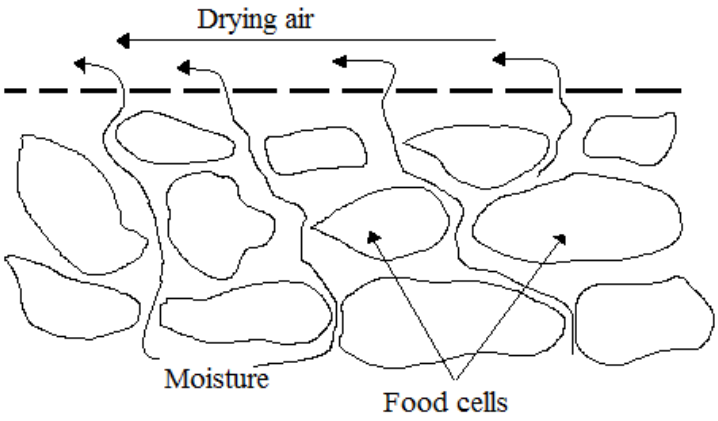

Fig. 2.4 Process of food dehydration

Source: Rahman (2007)

Brennan (2006) reported that the rate of removal of water could then be related to the rate of heat transfer, if there was no change in the temperature of the material and therefore all heat energy transferred to it may result in evaporation of water.

Some food materials do not show constant rate drying period. A constant rate drying period was not detected in drying curves of chilli (Akpinar, 2003), apricot (Togrul, 2003), carrot, corn, tomato, mushroom, garlic, onion, spinach, green pepper, red pepper, pumpkin, yellow pepper, green pea, leek and celery (Krokida *et al.*, 2003).

2.13 Changes during drying on nutritive and chemical components of fruits

Fruit firmness decreases either during ripening in the field or during storage regardless of the initial ripeness of the fruit (Nunes *et al.*, 1995). According to Koh and Melton (2004) softening of strawberry fruit, either during ripening in the field or during storage is mainly due to loss of cell wall material. Softening of strawberry is mainly due to the presence of polygalacturonase which solubilizes and degrades the cell wall polyuronides (Hubert, 1984). Weight loss of fruit was found to be negligible for 2 days at 0°C and 10°C but it increased at 10°C and increased rapidly from day 3 at 20°C (Youngjae *et al.*, 2007).

Cordenunsi *et al.* (2005) reported that no significant changes in pH were observed during storage of the fruits for 6 days at 6°C. Again, the exception was 'Toyonoka' cultivar, which showed a decrease of pH from 4.1 to 3.8. According to Olsson *et al.* (2004), there was decrease in the pH content of ripe dark red strawberries after 3 days at 4°C. Cordenunsi *et al.* (2005) reported an increase of up to 30% in the total soluble sugars of full-size, three-

quarters red strawberries during storage at 6°C for 6 days. Reyes *et al.* (1982) observed a decline in soluble solids in overripe strawberries. They reported that soluble solids of strawberries remain the same or increase during storage. After 8 days at 1°C, the soluble solids concentration of half mature strawberries was found to be lower than that of fruit at the time of harvest. Ruiz *et al.* (2011) found that losses of antioxidant activity are more dependent on drying temperature than on drying time.

Changes in nutrient composition during processing vary widely depending on the severity of the processing. The degree of cell disruption, fruits temperature and time involvement during processing are the main factors affecting loss of nutrients. The degree of cell wall disruption will govern the release and mixing of enzymes and substrate with resultant increase in browning caused by polyphenol oxidase and off flavor development by catalase and peroxidase during processing and storage unless the enzymes are heat inactivated. Thermal processing will cause losses in carotene and vitamin C, with the latter begins more heat liable. Vitamin C losses of from 44.3% to 71.5% were reported by Leon and Lima (1966) during the canning of mango juice from several varieties at selected storage maturity. Storage temperature of the processed product is important to the retention of nutrients texture, appearance and flavor (Falcone *et al.*, 1975). Adsule and Roy (1975) reported increase in acidity of storage mango pulp and also reported the rate of loss of ascorbic acid was directly proportional to temperature of storage and also showed that sulfur dioxide helped the retention of ascorbic acid. Feaster (1950) reported that the storage temperature significantly influences the ascorbic acid and non-enzymatic browning increased appreciably with storage temperature. These derivatives contribute to non-enzymatic browning which is higher at higher temperature. Jain (1961) showed that sulfur dioxide slowed down the process of non-enzymatic browning possibly by preventing the reaction leading to non-enzymatic browning. The losses of SO_2 were found to be more at higher temperature than at lower temperature. Adsule and Roy (1975) had reported similar trend in loss of SO_2 in canned orange juice and mango pulp respectively. Adsule and Roy (1975) reported 81.8-89.6% retention of carotenoids during nine months storage in preserved mango pulp from different varieties of mango.

2.13.1 Influence of dehydration on nutritive value

Proteins, fats and carbohydrate are present in larger amount per weight in dried foods than in their fresh counterpart. With dried food there is a loss in vitamin content. Ascorbic acid

and carotene are subject to damage by oxidative process. Riboflavin is light sensitive and thiamine is heat sensitive and destroyed by sulfuring (Adhikari, 2014).

2.13.2 Influence of dehydration on carbohydrate

The principle deterioration in fruits is in carbohydrates. Discoloration may be due to enzymatic browning or to caramelization types of reaction. In the latter instances, the reaction of organic acid and reducing sugars causes discoloration noticed as browning. The addition of sulfur dioxide to tissues is a means of enzyme poisoning and antioxidant power. The effectiveness of this treatment is dependent upon low moisture contents. The critical moisture levels in browning appear to be between 1 and 30%. Below 1% browning occurs, but at greatly reduced levels. Above 30% browning occurs at apparently equal rate (Adhikari, 2014).

2.13.3 Influence of dehydration on pigments

Drying foods change their physical and chemical properties and can be expected to alter their abilities to reflect, scatter, absorb and transmit light modifying the color of the foods. The carotenoids have been found altered during the drying process. The higher the temperature and longer the treatment, the more pigments are altered. Sulfur treatment tends to bleach anthocyanin pigments while at the same rate exerting a strong inhibitory action on oxidative browning. Continuous vacuum dehydration units have been developed which greatly improve the quality of the dried fruits, especially comminuted products such as purees and juices. This equipment has been used successfully in producing powder crystals (Adhikari, 2014).

2.13.4 Influence of dehydration on TSS, titratable acidity and ascorbic acid

Ashebir *et al.* (2009) observed significant changes in TSS, TA and AA after hot-air drying of different tomato cultivars due to variation in the level of temperature, but there was no significant difference among cultivars and no interaction between cultivar and temperature. The decrease in moisture content in the fruits is usually accompanied by an increased percentage of TSS, since TSS is the major component of dry matter. High TSS with reasonable amount of TA may contribute to the sweetness and flavor of dried product.

2.14 Rehydration

Rehydration capacity is one of the indices of water absorption of dried plant tissues expressed as the ratio of weight after rehydration to initial weight (Levi *et al.*, 1988) and it is a quality parameter that is associated with the level to which a dried product can regain its original structure. Dehydrated products can be used in many processed or ready-to-eat foods in place of fresh foods and have several advantages such as convenience in transportation, storage, preparation and use (Mazza and LeMague, 1980). Dehydrated products need to be rehydrated before consumption or further processing (Oliveira and Ilincanu, 1999). Solids eaten after rehydration should be characterized by color, size, shape and texture resembling the raw material. Hence, the rehydration rate and the rehydration degree are important parameters determining the quality of the product (Lewicki, 2006).

Rehydration is an important step in the utilization of dried fruits and vegetables. For rehydrated vegetables, the most pertinent properties are related to the texture and flavor. The rate and extent of rehydration may be used as an indicator of food quality; those foods that are dried under optimum conditions suffer less damage and rehydrate more rapidly and completely than poorly dried foods (Fellows, 2000). Rehydration is influenced by several factors, grouped as intrinsic factors (product chemical composition, pre-drying treatment, product formulation, drying techniques and conditions, postdrying procedure, etc.) and extrinsic factors such as composition of immersion media, temperature, hydrodynamic conditions. Some of these factors induce changes in the structure and composition of the plant tissue, which results in the impairment of the reconstitution properties (Akonor and Tortoe, 2014). Consumers usually tend to prefer processed rehydrated vegetables with a firmer texture than those typically produced by a conventional (well controlled) process. Therefore, textural improvement has become essential outcome of dehydration (Quintero-Ramos *et al.*, 1992).

The loss of texture in this product is caused by gelatinization of starch, crystallization of cellulose and localized variations in the moisture content during drying which set up internal stresses. These rupture cracks, compress and permanently distort the relatively rigid cells to give the food a shrunken shriveled appearance. On rehydration the product absorbs water more slowly and does not regain the firm texture of the fresh material. There are substantial variations in the degree of shrinkage and rehydration with different foods (Fellows, 2000). Dried dehydrated products are usually subjected to reconstitution test in which water is added

to the product to restore to a condition similar to that when the material was fresh. The rehydration ratio (RR) is given by the ratio of drained dehydrated weight to weight of sample before drying:

$$\text{Rehydration ratio} = \frac{\text{WR}}{\text{WD}} \qquad \text{Eq. 2.1}$$

Where: WR = Drained weight of rehydrated sample; WD = Weight of dried/dehydrated sample.

In the same light dehydration ratio (DR) can be expressed (Hiremath *et al.*, 2009) as:

$$\text{Dehydration ratio} = \frac{\text{WD}}{\text{WRm}} \qquad \text{Eq. 2.2}$$

Where: WRm = Weight of raw material (before drying).

It is obvious, for a host of reasons stated by Fellows (2000), dehydration ratio is always less than rehydration ratio, implying that reconstitution can never be 100%.

Dauthy (1995) and Ranganna (1986) have given an expression used for calculating rehydration coefficient to test rehydration property.

$$\text{Rehydration coefficient} = \frac{\text{WR}(100 - \text{MD})}{(\text{WD} - \text{WMd}) \times 100} \qquad \text{Eq. 2.3}$$

Where: MD = Moisture content of material before drying (i.e., of the fresh material), WMd = Amount of moisture present in the dried sample taken for rehydration

Data from [Eq. 2.3] can then be used to calculate the moisture content (MR) in the rehydrated sample by the following expression (Ranganna, 1986):

$$\text{Moisture Content} = \frac{\text{WR} - \text{DR}}{\text{WR}} \times 100 \qquad \text{Eq. 2.4}$$

Where: DR = Dry matter content in the sample taken for rehydration.

Part III

Materials and methods

3.1 Materials

3.1.1 Collection of *amla*

Fresh *amla* grown in Dhankuta district was purchased from Agriculture produce Market, Dharan. The fruit was brought from Hile, a hilly region north to Dharan. The collected samples were mature and fresh.

3.1.2 Iodized sodium chloride

Iodized sodium chloride was brought from the local market of Dharan.

3.2 Equipment

Electric balance (PHOENIX instrument, 620 g), thermometer, hand refractometer (0-30, ATAGO, made in Japan), hot air oven (VITCO), stainless steel knives, kettles, cabinet drier (Hot air convective Dryer, YLD-2000), cooking arrangement, glassware's, pH meter (LABTRONICS, made in India), blotting paper, etc. needed for the work were all obtained from the Central Campus of Technology, Dharan.

3.3 Methods

3.3.1 Preliminary operation of *amla*

Following preliminary operations were carried out:

3.3.1.1 Sorting/Grading

Damaged and bruised fruits were sorted out from undamaged fruits. *Amla* of 1.5 cm to 2 cm diameter were selected.

3.3.1.2 Washing

The selected fruits were washed with tap water to remove dusts, adhered impurities, mud etc.

3.3.2 Pretreatment process

Before going ahead with the actual preserving of *amla* a few works were done to optimize the pretreatment process of dried *amla*. The *amla* samples were divided into two part. One part

is whole and the next part is flaked. Then the both whole and flaked *amla* were subjected to blanching, sulphiting and both blanching and sulphiting. Blanching was done dipping the *amla* in 2% sodium chloride (NaCl) solution for 7 min after optimizing the time followed by cooling (Bhatia *et al.*, 1959). Sulphitation was done to study the effect on color by soaking the samples in 0.1% of potassium metabisulphite solution for five minutes (Chakroborty *et al.*, 1968). Whole *amla* samples after pretreatment were cut into similar shape and size as flaked samples prior to drying.

3.3.3 Drying

The pretreated *amla* were than dried. The completion of drying was confirmed by studying the final moisture content of 6%. The product was considered sufficiently dried when the moisture content reached about 6%.

3.3.3.1 Cabinet drying

Cabinet drying was carried out at 60°C (Bhatia *et al.*, 1959). After every one hour interval the weight of dried *amla* was taken to calculate the moisture content of the dried sample. Initial weight of *amla* prior to drying was taken and the moisture content was measured on the basis of reduction of weight of the dried sample.

3.3.4 Optimization of pretreated cabinet dried *amla*

Pretreatment was selected on the basis of retention of vitamin C, good rehydration properties and sensory attributes of cabinet dried *amla.* Pretreatment with both good retention of vitamin C, rehydration properties and sensory attributes was selected. Vitamin C, rehydration properties and sensory attributes were analyzed after drying pretreated *amla* at 60°C in the cabinet drier.

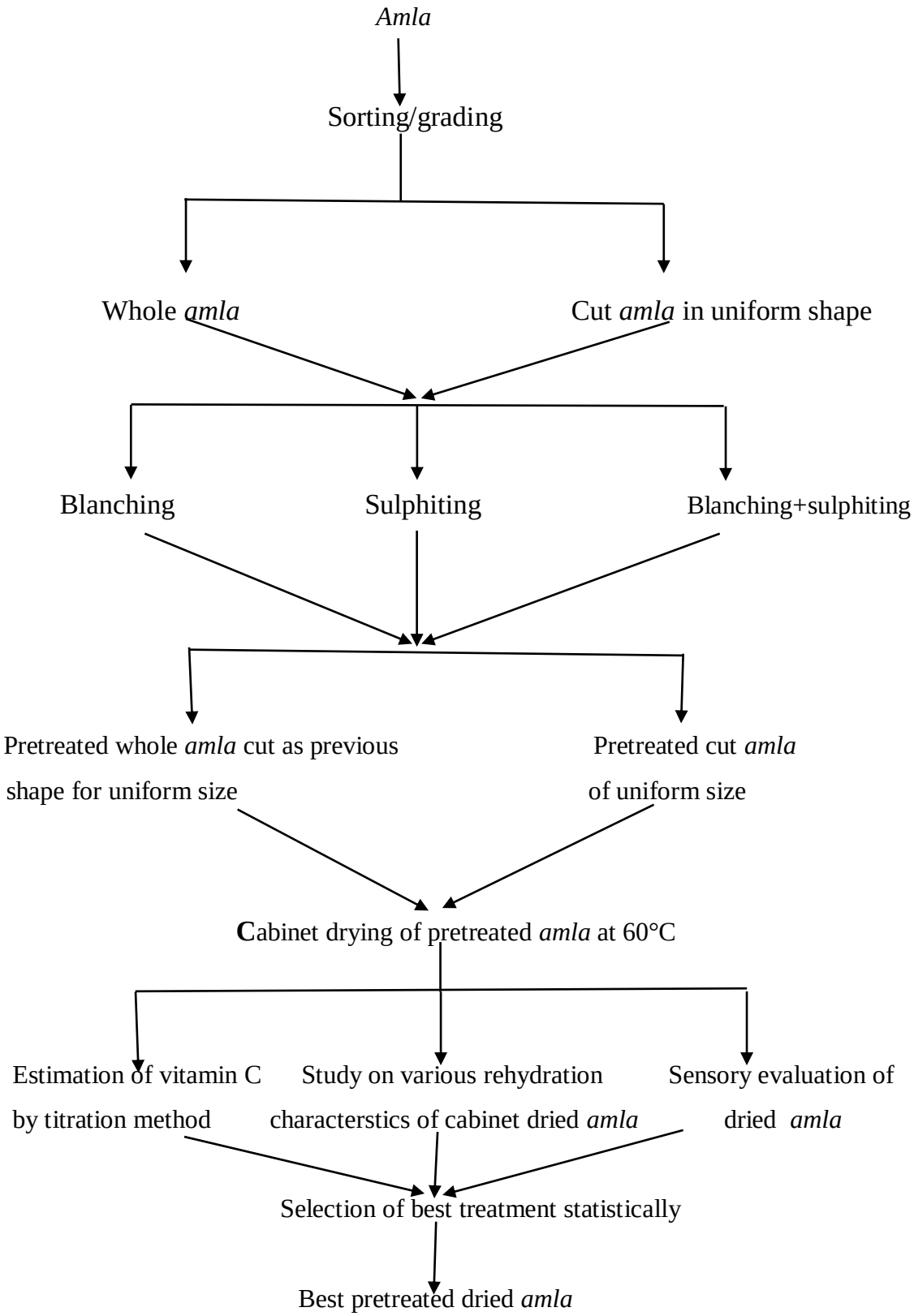

Fig. 3.1 Flowchart for optimization of pretreatment process in dried *amla*

3.3.5 Optimization of temperature during cabinet drying

The best pretreatment was done to the *amla* after optimizing the pretreatment process and cabinet dried at various temperature (55°C, 60°C, 65°C). Temperature was selected on the basis of retention of vitamin C, rehydration properties and sensory attributes of cabinet dried *amla.* Temperature with both good retention of vitamin C, rehydration properties and sensory attributes was selected. Vitamin C, rehydration properties and sensory attributes were analyzed after drying pretreated *amla* at 55°C, 60°C, 65°C in the cabinet drier.

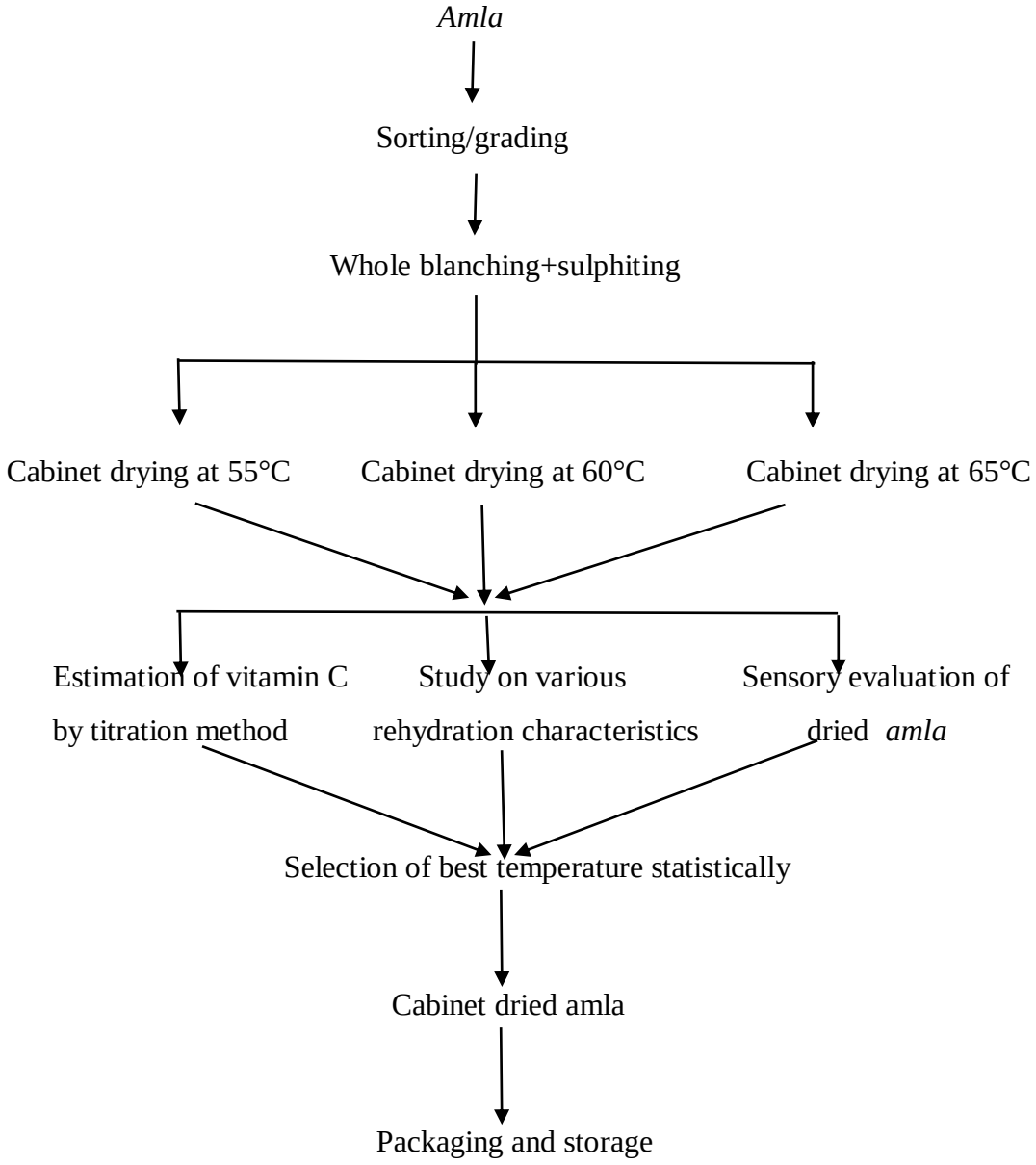

Fig. 3.2 Preparation of cabinet dried *amla*

3.3.6 Rehydration

Rehydration of dried *amla* was done in boiled water for 5 min per (Ranganna, 1986).

3.3.7 Analytical procedure

3.3.7.1 Determination of moisture

The moisture content was determined by hot air oven method as described in (Ranganna, 1986). Two gram sample was taken in the petridish of known weight. Then it was placed in the hot air oven maintained at 100°C and drying was done until constant weight was observed. The difference in weight of sample was taken as water present in that sample. The experiment was repeated three times.

3.3.7.2 Determination of acidity

Acidity was determined by titrimetric method described by (Ranganna, 1986). Ten gram of sample was taken and fine grinding was done by adding water making final volume of 100 ml. 10 ml of prepared sample was used for acidity determination was taken in conical flask and NaOH solution was taken as titre in burette. Phenolphthalein was taken as indicator. The volume consumed for neutralization was noted and acidity was calculated by using formula

$$\text{\% Total acid (as citric acid)} = \frac{\text{Titre} \times \text{Normality of NaOH} \times \text{Volume made up (ml)} \times 64}{\text{Aliquot (ml)} \times \text{weight of sample taken} \times 1000} \times 100$$

3.3.7.3 Determination of TSS

TSS of the fresh *amla* and prepared fruit leather was determined by using hand refractometer of range 0 to 32°Bx. The values are expressed in °Bx (Ranganna, 1986). Two gram of sample was taken and crushed. It was dissolved in 10 ml of water. The TSS was then observed in the refractometer after calibrating it to zero with water.

3.3.7.4 Determination of Total sugar and reducing sugar

Total sugar and reducing sugar was determined by Lane and Eynon's method from the process given by (Ranganna, 1986).

3.3.7.5 Determination of ascorbic acid

Ascorbic acid (Vitamin C) was determined by 2,6 - dichlorophenol indophenol visual dye method as described in (Ranganna, 1986). To measure vitamin C, the fresh and dried *amla* was ground and extracted by 3% meta-phosphoric acid (HPO_3). Dye factor was calculated by using the formula

$$\text{Dye factor} = \frac{\text{mg of ascorbic acid}}{\text{ml of dye}}$$

Vitamin C was determined by the formula

$$\text{Vitamin C } \left(\frac{\text{mg}}{100\text{ g}}\right) = \frac{\text{Titer} \times \text{dye factor} \times \text{volume made up (ml)} \times 100}{\text{ml of aliquot} \times \text{ml(g) of sample taken}}$$

3.3.7.6 Rehydration test

The rehydration test of dried *amla* were carried out as the process described in Ranganna (1986) with slight modification.

Dried *amla* 2-10 g was weighed and was immersed in 100 ml boiling water and covered with a watch glass to boil for 5 min. The surface water was absorbed with the help of coarsely porous Whatman No.4 filter paper. The drained sample was then weighed in order to calculate rehydration ratio.

The rehydration ratio was calculated as follows:

$$\text{Rehydration ratio} = \frac{\text{Rehydrated weight}}{\text{Dehydrated weight}}$$

3.3.7.7 Coefficient of rehydration

The coefficient of rehydration of rehydrated samples was calculated as per Ranganna (1986) as shown in Eq 2.3.

$$\text{Rehydration coefficient} = \frac{\text{WR} \times (100\text{-MD})}{(\text{WD-WMd}) \times 100}$$

3.3.8 Sensory evaluation and statistical analysis

Among the six samples of prepared dried *amla* of various pretreatment, the best one in terms of sensory quality was determined. Also among the three samples of prepared dried *amla* at various temperature, the best one in terms of sensory quality was determined. For sensory evaluation, 9 points hedonic rating method was used as described by (Ranganna, 1986). The panelist members consisted of research students and teachers of CCT who had some previous experience in the sensory evaluation. Sensory evaluation was carried out for the quality attributes *viz.*, color, flavor, texture, and overall acceptability to carry out comparative evaluation of the products prepared by cabinet drying at various temperature. Each panelist was provided with 3 samples and an evaluation card (Appendix B). They were provided with potable water for rinsing between the samples.

3.3.9 Statistical method

The experiment was conducted in triplicate. All calculations were performed in Microsoft Office Excel (2016). The data were subjected to statistical analysis and the scores given by panelist were analyzed by one-way and two-way analysis of variance (ANOVA), no blocking at 5% level of significance using statistical software GenStat Release 12.1 (2009). The calculated mean values of each sensory parameter were compared with value in the LSD at 5% level of significance to determine whether the samples were significantly different from each other and also to determine which one is superior between them.

Part IV

Results and discussion

4.1 Chemical constituents of fresh *amla*

The chemical composition of *amla* as obtained in the analysis is given below in Table 4.1

Table 4.1 Chemical composition of fresh *amla*

Constituents	Value
Acidity as citric acid % (db)	2.70±(0.10)
Vitamin C as ascorbic acid (mg/100 g) (db)	577.8±(2.58)
Moisture % (wb)	81.63± (1.10)
Total sugar % (db)	6.33±(0.11)
TSS (°Bx)	11.2±(0.10)
Reducing sugar % (db)	3.74±(0.04)
pH	3.4±(0.10)

*Values are means of triplicate. Figures in the parentheses are the standard deviations.

The result obtained from Table 4.1 showed positively with the result of (Jain *et al.*, 2001) and (Suman, 2009). The moisture content of *amla* was found to be 81.63% which was similar to the data given by (Suman, 2009) which is 83.08%. The total sugar, Vitamin C, TSS, pH, of *amla* was found to be 6.33%, 577.8 mg/100 g, 11.2°Bx, 3.4 respectively which was similar to that of (Jain *et al.*, 2001) i.e. 7.13%, 550 mg/100 g, 11.75°Bx, 3.6 for total sugar, vitamin C, TSS, pH respectively. The acidity of *amla* was 3.5% as (Suman, 2009) but the acidity was found to be 2.7% which was lower than the given data. The difference in result might be due to variation in species.

4.2 Optimization of blanching time based on enzyme inactivation

Mainly the blanching treatment is affected by the enzyme activity. The size, shape and heat conductivity also play role in blanching (Reyes De Corcuera *et al.*). Blanching should be maintained with in appropriate stage so that there may not the damage of fruits. Blanching is done to check out the catalase and peroxidase enzymes in order to reduce the losses of mineral

salts, vitamins, sugars (Kordylas, 1990). The blanching temperature can be set to 85-95°C instead of 100°C (Jones, 1996).

Bhatia *et al.* (1959) recommended blanching of *amla* for 7 min in 2% NaCl solution prior drying at 60-63°C, followed by cooling with cold water. The residual catalase and peroxidase activity after blanching were measured by catalase and peroxidase visual test methods and the result obtained are shown in Table 4.2.

Table 4.2 Blanching time optimization based on catalase and peroxidase enzyme inactivation of *amla* sample.

	Blanching time (min)				
	0	3	5	7	9
Catalase test for sample at 98±2°C	+	+	+	-	-
Peroxidase test for sample at 98±2°C	+	+	+	-	-

4.3 Optimization of pretreatments

Amla were whole pretreated and cut pretreated. Whole *amla* after pretreatment were cut to uniform shape and size as cut *amla*. Three pre-drying treatments namely blanching, sulphiting and combined blanching + sulphiting was done. So there were six samples altogether *viz.* cut blanching, cut sulphiting, cut (blanching + sulphiting), whole blanching, whole sulphiting, whole (blanching + sulphiting). Blanching was carried out by boiling the whole and cut *amla* samples for 7 min in 2.0% sodium chloride (NaCl) solution, followed by cooling with cold water (Bhatia *et al.*, 1959). Sulphitation was done by soaking the samples in 0.1% of potassium metabisulphite solution for five minutes (Chakroborty *et al.*, 1968). Also combined treatment (blanching + sulphiting) was done and dried at a temperature of 60±2ºC (Alam *et al.*, 2010) to a final moisture content of 6±1% at a cabinet drier. The dried sample were analyzed for Vitamin-C, rehydration ratio, coefficient of rehydration and sensory properties.

4.3.1 Effect of pretreatment on Vitamin-C, rehydration ratio and coefficient of rehydration of cabinet dried *amla.*

Table 4.3 Effect of pretreatment on quality of cabinet dried *amla.*

Pretreatment	Vitamin C(mg/100 g)db	RR	COR
Cut blanching	362.67^{a}±(2.51)	1.94^{a}±(0.02)	0.36^{a}±(0.003)
Cut sulphiting	404.67^{d}±(3.05)	2.21^{cd}±(0.02)	0.41^{bc}±(0.01)
Cut (blanching + sulphiting)	381.00^{b}± (4.00)	2.26^{d}± (0.15)	0.42^{c}±(0.02)
Whole blanching	396.33^{c}±(3.05)	1.84^{a}±(0.03)	0.34^{a}±(0.005)
Whole sulphiting	440.67^{f}±(3.05)	2.11^{bc}±(0.02)	0.39^{b}±(0.004)
Whole (blanching + sulphiting)	411.33^{e}±(2.51)	2.22^{d}±(0.06)	0.42^{c}±(0.01)

* Values are means of triplicate, figures in the parenthesis are the standard deviations

* Figures with same super script are not significantly different

* Figures with different super script are significantly different

The Vitamin-C retention in dried samples was determined and the average values are shown in Table 4.3. The Vitamin-C retention in dried samples pre-treated by cut blanching, cut sulphiting, cut (blanching + sulphiting), whole blanching, whole sulphiting, whole (blanching + sulphiting) were found to be 362.67(mg/100 g), 404.67(mg/100 g), 381(mg/100 g), 396.33(mg/100 g), 440.67(mg/100 g), and 411.33(mg/100 g) respectively. Statistical analysis showed that there was significant difference ($p \leq 0.05$) of the above treatments on retention of Vitamin-C of the samples. LSD indicated that there exists a significant difference between all the samples at 5% level of significance. Whole *amla* had better retention of vitamin C than the cut ones. From the above statistical analysis pre-treatment by whole sulphiting was the best treatment combination for maximum retention of vitamin C. This may be due to the reason that whole *amla* had less exposure to the pretreatment solution than the cut *amla* which lead higher retention of vitamin C as vitamin C was not oxidized due to the less exposure of whole *amla* to pretreatment solution. Similar findings were observed by (Prajapati *et al.*, 2010). He reported that pre-treatment of sulphiting followed by controlled drying was the best treatment combination. Beneficial effect of KMS/sulphitation on retention of ascorbic acid content of

dried product was also observed by many workers (Sethi, 1986; Tripathi *et al.*, 1988; Sagar and Kumar, 2006; Singh *et al.*, 2006) in *amla*. It may be due to inactivation of oxidase enzyme.

The dried *amla* were rehydrated and the rehydration ratio was calculated. The average results are shown in Table 4.4. Rehydration ratio of dehydrated *amla* were found to vary from 1.847 to 2.267, which was affected significantly ($p \leq 0.05$) by the pre-treatments. The rehydration ratio of dried samples pre-treated by pretreatments *viz.* cut blanching, cut sulphiting, cut (blanching + sulphiting), whole blanching, whole sulphiting, whole (blanching + sulphiting) were found to be 1.940, 2.210, 2.267, 1.847, 2.110, 2.227 respectively. LSD indicated the pretreatment cut (blanching + sulphiting) had significantly higher rehydration ratio than the other samples. Combined treatment of blanching and sulphiting had desirable effects, respectively, on rehydration properties of the dehydrated *amla* while whole blanching showed minimum rate of rehydration. KMS alone treated sample showed slight improvement in rehydration characteristic of the dried *amla*. Due to the effectiveness of KMS on textural quality of *amla*, combination of KMS with blanching resulted in best rehydration properties and showed a higher value. Also blanching was done with 2% NaCl. It is also believed that sodium and chloride ions permeate the fruit tissue during soaking and re-associate as NaCl crystals on drying inside the cellular compartments. During rehydration there will be increased attraction of water resulting in increased flow into the tissue and therefore improved rehydration. Similarly cut *amla* had desirable effects, respectively, on rehydration properties of the dehydrated *amla* than the whole *amla*. This may be due to the reason that cut *amla* surface was exposed more to the pretreatment solution than the whole *amla* which therefore lead cut *amla* to have higher rehydration ratio than whole *amla*. Ghavidel and Davoodi (2010) reported combination of $CaCl_2$ with KMS resulted in best rehydration properties and showed a higher value of rehydration for dehydrated tomato slices. NaCl also had improved rehydration properties of the dehydrated tomatoes compared to control sample. Similarly sulphiting pretreatment showed higher rehydration ratio than blanching pretreatment for dehydrated carrot dried on mechanical drier (Al-Amin *et al.*, 2015). Also combined pretreatment of (blanching + sulphiting) showed higher rehydration ratio than blanching pretreatment alone in solar dried *amla* (Verma and Gupta, 2004).

The dried *amla* were rehydrated and the coefficient of rehydration was calculated. The average results are shown in Table 4.4. Coefficient of rehydration of dehydrated *amla* were found to vary from 0.3497 to 0.4297, which was affected significantly ($p \leq 0.05$) by the pre-treatments. The coefficient of rehydration of dried samples pre-treated by pretreatments *viz.*

cut blanching, cut sulphiting, cut (blanching + sulphiting), whole blanching, whole sulphiting, whole (blanching + sulphiting) were found to be 0.3673, 0.4150, 0.4297, 0.3497, 0.3997, 0.4220 respectively. LSD indicated the pretreatment cut (blanching + sulphiting) had significantly higher coefficient of rehydration than the other samples. Combined treatment of blanching and sulphiting had desirable effects, respectively, on rehydration properties of the dehydrated *amla* while whole blanching showed minimum rate of rehydration. KMS alone treated sample showed slight improvement in rehydration characteristic of the dried *amla*. Due to the effectiveness of KMS on textural quality of *amla*, combination of KMS with blanching resulted in best rehydration properties and showed a higher value. Also blanching was done with 2% NaCl. It is also believed that sodium and chloride ions permeate the fruit tissue during soaking and re-associate as NaCl crystals on drying inside the cellular compartments. During rehydration there will be increased attraction of water resulting in increased flow into the tissue and therefore improved rehydration. Similarly cut *amla* had desirable effects, respectively, on rehydration properties of the dehydrated *amla* than the whole *amla*. This may be due to the reason that cut *amla* surface was exposed more to the pretreatment solution than the whole *amla* which therefore lead cut *amla* to have higher coefficient of rehydration than whole *amla*. (Ghavidel and Davoodi, 2010) reported combination of $CaCl_2$ with KMS resulted in best rehydration properties and showed a higher value of rehydration for dehydrated tomato slices. NaCl also had improved rehydration properties of the dehydrated tomatoes compared to control sample. Similarly sulphiting pretreatment showed higher coefficient of rehydration than blanching pretreatment for dehydrated carrot dried on mechanical drier (Al-Amin *et al.*, 2015). Also combined pretreatment of (blanching + sulphiting) showed higher coefficient of rehydration than blanching pretreatment alone in solar dried *amla* (Verma and Gupta, 2004).

4.3.2 Sensory evaluation

The different pretreated samples were coded as A (Cut blanching), B (Cut sulphiting), C (Cut (blanching + sulphiting)), D (Whole blanching), E (Whole sulphiting), F (Whole (blanching + sulphiting)). The coded samples were provided to 10 semi-trained panelists including students of Central Campus of Technology, Dharan. They were asked to score the dehydrated *amla* for color, texture, flavor and taste and overall acceptability as in the score sheet shown in the Appendix B.

The dried samples were evaluated for color, flavor, texture and overall acceptability and the panelist scores were noted (Appendix A). The average scores for color are shown in Fig.4.1.

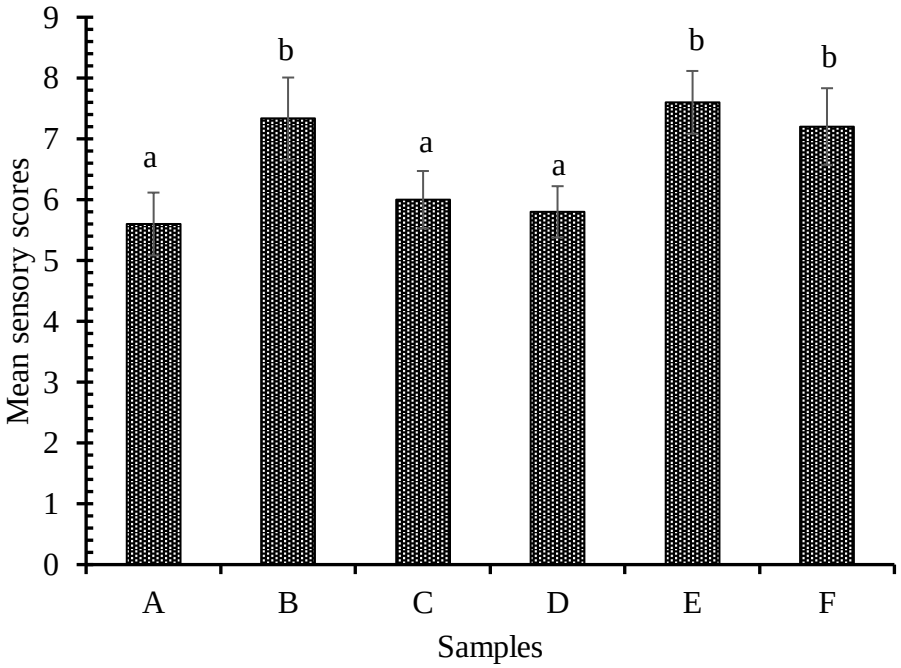

Fig. 4.1 Mean sensory score for color of dehydrated *amla*

From the Fig.4.1 it has been observed that in terms of color the sample coded E had highest mean score followed by samples B, F, C, D and sample A. Statistical test showed that there exist significant effect ($p \leq 0.05$) on color property due to various pretreatments. LSD indicated there exists significant difference between the samples A and F, A and B, A and E, B and C, B and D, E and D, E and C, F and D, F and C. However there was no significant difference between samples A and C, A and D, C and D and samples F and B, F and E, B and E at 5% level of significance.

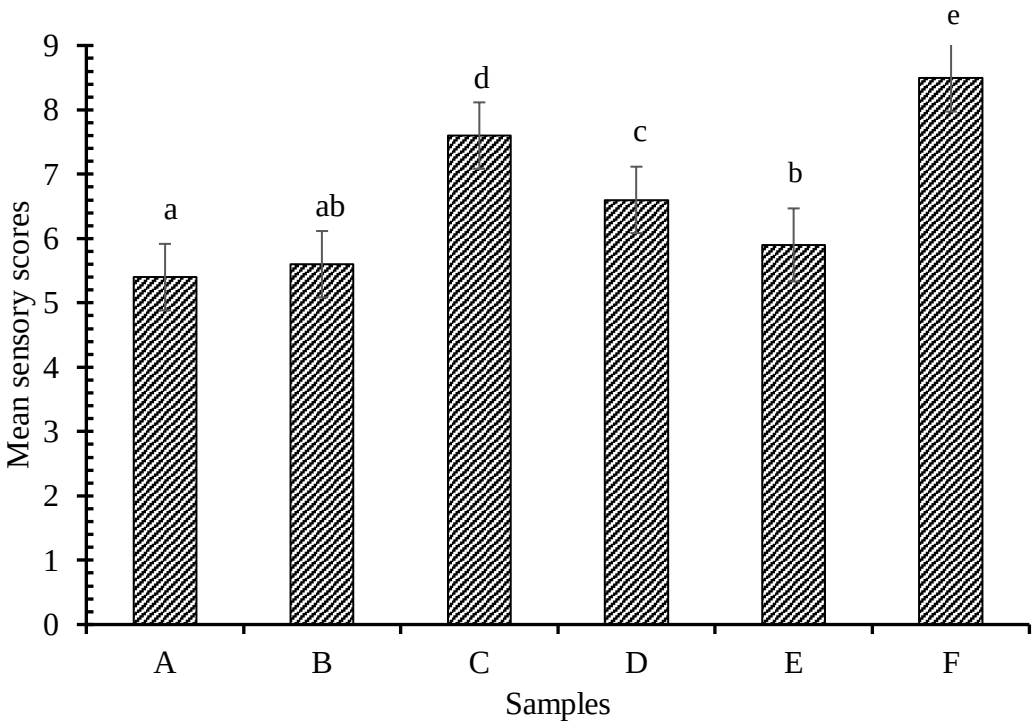

Fig. 4.2 Mean sensory score for flavor of dehydrated *amla*

Various pre-treatments had significant effect ($p \leq 0.05$) on flavor of the dehydrated *amla*. From Fig.4.2 the average mean score was highest for the sample F followed by samples C, D, E, B, A respectively. Sample A showed lowest mean scores. LSD indicated there exist significant difference between all the samples at 5% level of significance.

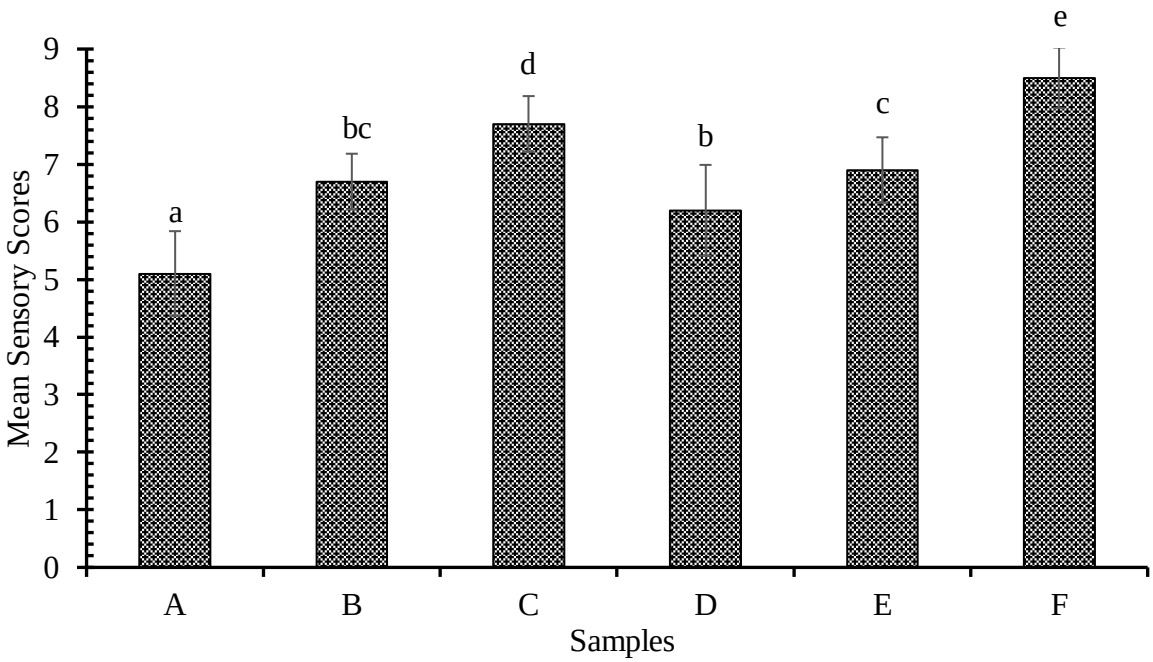

Fig. 4.3 Mean sensory score for texture of dehydrated *amla*

In terms of texture, the average mean score was highest for the sample F followed by samples C, E, B, D, A respectively as shown in Fig.4.3. Sample A showed lowest mean scores. LSD indicated there exist significant difference between all the samples at 5% level of significance.

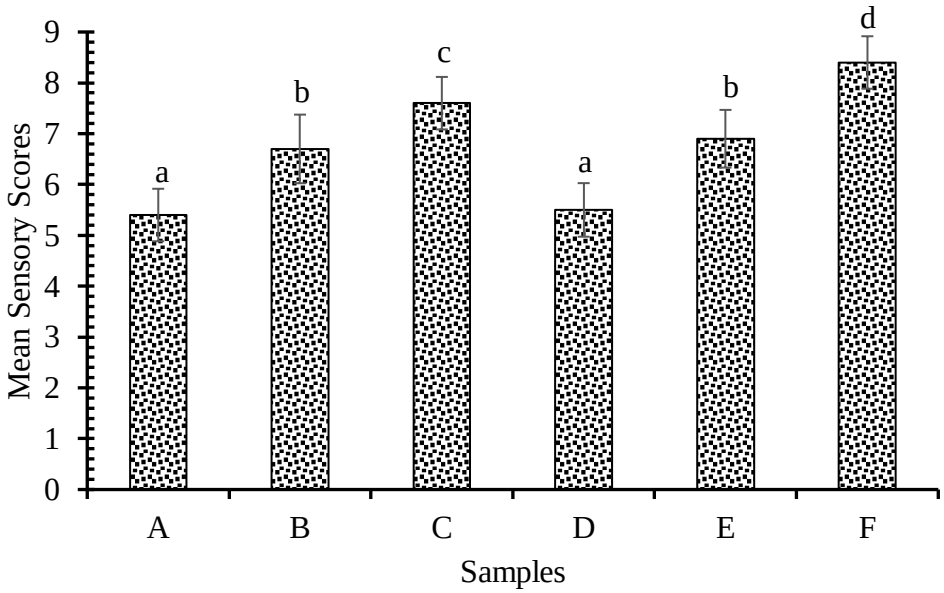

Fig. 4.4 Mean sensory score for overall acceptability of dehydrated *amla*

The overall acceptability judged by organoleptic evaluation also indicated that (Whole (blanching + sulphiting)) sample with controlled drying is the most suitable combination for *amla* dehydration. From Fig.4.4 sample F had highest mean score followed by C, E, B, D, A respectively. Statistical test showed that there exist significant effect ($p \leq 0.05$) on overall acceptability due to various pretreatments. LSD indicated there exists significant difference between samples A and B, E, C and F; samples D and B, E, C and F; samples B and C and F; samples E and C and F.

4.3.3 Final optimization of pretreatment

The vitamin C retention was highest in a sample with treatment whole sulphiting followed by combined treatment using whole (blanching + sulphiting) and so on. Rehydration ratio was significantly higher in a sample pre-treated with combined treatment using cut (blanching + sulphiting) followed by combined treatment using whole (blanching + sulphiting) and so on. Coefficient of rehydration was significantly higher in a sample pre-treated with combined treatment using cut (blanching + sulphiting) followed by combined treatment using whole (blanching + sulphiting) and so on. Sensory properties of samples with different pretreatment had significant effect on their organoleptic properties. Samples pretreated by whole (blanching + sulphiting) prior to drying obtained higher scores in terms of texture, flavor and overall acceptability. In the terms of color samples treated with KMS alone had a highest score. With

all these findings samples pretreated with whole (blanching + sulphiting) was considered as optimum considering all the properties in account.

4.4 Optimization of drying temperature

The best pretreatment Whole (blanching + sulphiting) was done and *amla* were dried at 55±2ºC, 60±2ºC, 65±2ºC (Alam *et al.*, 2002) and the effect of drying temperature on vitamin-C retention, rehydration ratio, coefficient of rehydration and sensory properties were studied.

4.4.1 Effect of drying temperature on Vitamin-C, rehydration ratio and coefficient of rehydration of dried *amla*

Table 4.4 Effect of different drying temperature on quality of dried *amla*

Drying temperature	Vitamin C (mg/100 g)db	RR	COR
55 ± 2^0C	$429.67^a\pm(1.52)$	$2.50^a\pm(0.03)$	$0.47^a\pm(0.005)$
60 ± 2^0C	$409.33^a\pm(2.20)$	$2.20^b\pm(0.03)$	$0.41^a\pm(0.005)$
65 ± 2^0C	$399.33^b\pm(2.08)$	$1.96^c\pm(0.01)$	$0.37^a\pm(0.003)$

* Values are means of triplicate, figures in the parenthesis are the standard deviations

* Figures with same super script are not significantly different

* Figures with different super script are significantly different

The Vitamin-C retention in dried samples was determined and the average values are shown in Table 4.5. The Vitamin-C retention in dried samples dried at temperature 55±2ºC, 60±2ºC, 65±2ºC were found to be 429.67(mg/100 g), 409.33(mg/100 g) and 399.33(mg/100 g) respectively. Statistical analysis showed that the temperature had a significant effect ($p\leq0.05$) on retention of Vitamin-C of the samples. The LSD indicated that there exists a significant difference between the samples dried at temperature 55±2ºC, 60±2ºC and 65±2ºC at 5% level of significance. From the above statistical analysis high temperature drying had a lower retention of Vitamin-C compared to low temperature. Ascorbic acid (vitamin C) is sensitive to heat and light. The vitamin C content was higher at lower drying temperatures. This may be due to comparatively less loss of vitamin-C at lower temperature. Similar findings were observed by (Singh and Singh, 2011). When *amla* were dried in solar-assisted heat pump dryer at different temperature, the lowest temperature showed the maximum retention of vitamin C.

The dried *amla* were rehydrated and the rehydration ratio was calculated. The average results are shown in Table 4.4. Rehydration ratio of dehydrated *amla* was found to vary from 1.963 to 2.507 which were significantly different ($p \leq 0.05$) by the different drying temperature. The rehydration ratio of samples dried at temperatures 55±2ºC, 60±2ºC and 65±2ºC were found to be 2.507, 2.207, and 1.963 respectively. From the average mean it was observed the samples dried at temperature 55±2ºC had higher rehydration ratio. The LSD also indicated that there exists a significant difference between the samples dried at temperature 55±2ºC, 60±2ºC and 65±2ºC at 5% level of significance. Similar findings were observed by (Nour *et al.*, 2011) . He reported that mushrooms dried at lower temperature were found to have greater rehydration ratio as compared with the sample dried at higher temperature. This is due to the reason at lower temperatures, less cellular destruction and dislocation occur thus, the material is capable of absorbing more water.

The dried *amla* were rehydrated and the coefficient of rehydration was calculated. The average results are shown in Table 4.5. Coefficient of rehydration of dehydrated *amla* was found to vary from 0.3717 to 0.4747 which were significantly different ($p \leq 0.05$) by the different drying temperature. The rehydration ratio of samples dried at temperatures 55±2ºC, 60±2ºC and 65±2ºC were found to be 0.4747, 0.4180, 0.3717respectively. From the average mean it was observed the samples dried at temperature 55±2ºC had higher coefficient of rehydration. The LSD also indicated that there exists a significant difference between the samples dried at temperature 55±2ºC, 60±2ºC and 65±2ºC at 5% level of significance. Similar findings were observed by (Nour *et al.*, 2011) . He reported that mushrooms dried at lower temperature were found to have greater coefficient of rehydration as compared with the sample dried at higher temperature. This is due to the reason at lower temperatures, less cellular destruction and dislocation occur thus, the material is capable of absorbing more water.

4.4.2 Sensory evaluation

The samples dried at different temperature were evaluated for color, flavor, texture and overall acceptability. The samples were coded as A(55±2ºC), B(60±2ºC) and C(65±2ºC).The coded samples were provided to 10 semi-trained panelists including students of Central Campus of Technology, Dharan. The average mean score is in the score sheet shown in the Appendix B. The dried samples were evaluated for color, flavor, texture and overall acceptability and the panelist scores were noted .The average scores are shown in Fig.4.5.

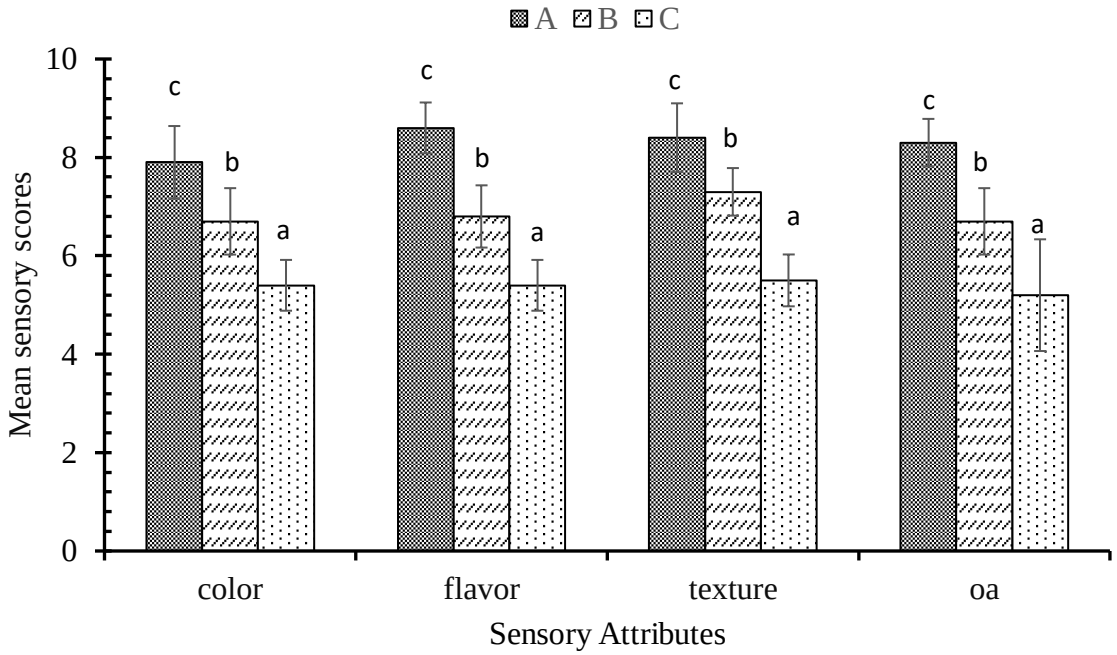

Fig. 4.5 Average sensory scores of dehydrated samples using different drying temperatures for sensory parameters

From the above figure it has been observed that in terms of color the sample coded A (55±2ºC) had highest mean score followed by sample B(60±2ºC) and sample, C(65±2ºC) respectively. Statistical test showed that there exists significant effect ($p \leq 0.05$) on color property due to different drying temperature. LSD indicated there exists significant difference between all three samples at 5% level of significance.

The mean scores obtained for the flavor attribute of the samples dried at different temperature showed that sample A (dried at 55±2ºC) obtained the highest score (i.e. 8.6), followed by sample B (6.8), C (5.4) respectively. Statistical analysis showed there was significant effect of drying temperature on flavor perception by the panelist. The LSD table for the flavor attribute shows that sample A (55±2ºC) is significantly different to sample B (60±2ºC) and sample C (65±2ºC) respectively. Also, sample B&C are significantly different in terms of flavor. Pezzutti and Crapiste (1997) reported higher temperature drying resulted in increase of flavor loss in the dehydrated product.

In terms of texture, sample dried at temperature (55±2ºC) was liked the most and (60±2ºC) was liked moderately but that of the sample dried at (65±2ºC) was liked slightly by

the panelist. Statistical tests indicated that the samples were significantly different ($p \leq 0.05$).LSD indicated there exist significant difference between all the samples.

The overall acceptability had highest scores for the sample A i.e. sample dried at temperature (55±2ºC) .It has the mean score of 8.3 followed by the sample B & C respectively. Statistical analysis indicated there exist a significant difference on overall acceptance of the various samples due to various drying temperature. LSD indicated there exist significant difference between all the samples at 5% level of significance.

4.4.3 Final optimization of drying temperature

The samples dried at 55±2ºC retained significantly ($p \leq 0.05$) higher vitamin-c than that dried at 60±2ºC and 65±2ºC. In terms of rehydration characteristics, samples dried at 55±2ºC had significantly higher rehydration ratio and coefficient of rehydration than that dried at 60±2ºC and 65±2ºC. Samples dried at 55±2ºC were significantly different and had obtained higher value in terms of color, flavor, texture and overall acceptability. So, drying temperature at 55±2ºC was considered to be optimum in terms of vitamin C, rehydration characteristics and sensory properties evaluated.

4.5 Chemical composition of final product.

The chemical composition of final products is shown in the Table 4.5

Table 4.5 Chemical composition of dried *amla*

Constituents	Value
Acidity as citric acid % (db)	2.40±(0.20)
Vitamin C as ascorbic acid (mg/100 g) (db)	429.67±(3.17)
Moisture % (wb)	6± (0.03)
Total sugar % (db)	5.3±(0.26)
Reducing sugar % (db)	4.63±(0.15)
pH	3.3±(0.1)

*Values are means of triplicate. Figures in the parentheses are the standard deviations.

The result obtained from Table 4.6 showed the moisture content of dried *amla* was found to be 6% after drying. The total sugar, Vitamin C, reducing sugar of dried *amla* was found to be 5.3%, 429.7 mg/1060 g, 4.63% respectively which was similar to that of (Sarangam and Chakraborty, 2015) i.e. 4.98%, 463 mg/100 g, 4.82% for total sugar, vitamin C, reducing sugar respectively. Slight variation might be due to the variety of *amla*, variation in the pretreatment used, variation of environment of the dryer though the temperature and type of dryer is same. The acidity of dried *amla* was 2.4% which was similar to that of (Prajapati *et al.*, 2010) i.e. 2.6%. The decrease in acidity of dried *amla* compared to that of fresh might be because that acids get converted into sugars or some other compounds or might have been utilized in process of respiration (Sagar and Kumar, 2006). Vijayanand *et al.* (2007) have reported acidity in *amla* powder more when whole fruit was blanched. It suggests that loss of acidity is more when blanching is done after making shreds. TSS and pH of dried *amla* was found to be 11.2 and 3.3 respectively.

4.6 Weight distribution of *amla* fruit

Each kg of *amla* contained 750 g pulp, 250 g seed. Pulp loss could be minimized by careful shredding of the fruit. Seed is useful byproduct used as a remedy for bilious infections and nausea (Khan, 2009).

4.7 Cost evaluation

The cost of 1 kg of dried *amla* was calculated as NRs. 1250, considering 25% overhead expenses. Cost can be reduced by mass production. The budget chart is shown in Appendix C.

Part V

Conclusions and recommendations

5.1 Conclusions

Amla is an under-utilized fruit. It is abundant in vitamin C and has many food uses. Also it has a short storage life as it is a seasonal fruit. This research work helps to value-add the *amla* fruit and make its products available throughout the year. The following conclusions were made from the research:

1. 7 min is optimum time for blanching *amla* in 2% Nacl solution followed by cooling on the basis of enzyme inactivation.
2. Higher retention of vitamin C, improved rehydration properties and better organoleptic property was found in dried *amla* pretreated with whole (blanching+sulphiting) prior to drying.
3. Higher retention of vitamin C, improved rehydration properties and better organoleptic property was found in dried *amla* dried at 55±2°C than 60±2°C and 65±2°C.
4. The acidity, vitamin C, moisture, total sugar, reducing sugar and pH of dried *amla* was found to be 2.4%, 430.13 mg/100 g, 6%, 5.3%, 4.63% and 11.2 respectively
5. The cost of dried *amla* was calculated as NRs. 1250 per kg.

5.2 Recommendations

Following suggestions are recommended for future work on dehydration of *amla*.

1. Effect of different storage condition on quality characteristics of dehydrated *amla* can be studied.
2. Varietal effect on dehydration characteristics of *amla* can be studied.
3. Storage stability and shelflife study of dried *amla* can be studied in different packaging materials.
4. Optimization of spices can be done for recipe addition in dehydrated *amla* and the product can be commercialized.

Part VI

Summary

Amla (*Phyllanthus emblica*) has been used in different *Ayurvedic* formulation since time immemorial. Though it has several nutritional, medicine and therapeutic values, it is not consumed much in raw state due to its astringency taste. Thus the preparation of dried *amla* leads to the higher consumption of *amla* throughout the year. *Amla* is a natural, efficacious, an antioxidant with the richest natural source of vitamin C. *Amla* has different food uses. Similarly, it has medicinal and therapeutic uses.

Fruits are dried to increase the shelf life for long-term storage. The preparation of dried fruits today often involves pretreatment, recipe addition followed by conventional or commercial drying. The work was carried out to study on the optimization of pretreatment and drying temperature of cabinet dried *amla* and product formation.

The main aim of this research was to study on the changes in parameters such as vitamin C content, rehydration properties and sensory attributes of the cabinet dried *amla* by different methods of pretreatments at different range of temperatures.

Amla were sorted and washed. Then the *amla* were divided into 6 lots for pretreatment *viz*. Cut blanching, Cut sulphiting, Cut (blanching + sulphiting), Whole blanching, Whole sulphiting, Whole (blanching + sulphiting). They were cabinet dried at 60±2ºC. Then the dried *amla* were analyzed to optimize the pretreatments by analyzing the retention of vitamin C, rehydration properties and sensory attributes of cabinet dried *amla*. With the findings samples pretreated with Whole (blanching + sulphiting) was considered as optimum considering all the properties in account. The prepared *amla* by using pre-optimized conditions were subjected to different range of temperature to study the effect of drying temperature (55±2ºC, 60±2ºC and 65±2ºC) on product quality. Optimization of drying temperature was also done by analyzing the retention of vitamin C, rehydration properties and sensory attributes of cabinet dried *amla* at (55±2ºC, 60±2ºC and 65±2ºC). The samples dried at 55±2ºC retained significantly ($p \leq 0.05$) higher vitamin C than that dried at 60±2ºC and 65±2ºC. In terms of rehydration characteristics, samples dried at 55±2ºC had significantly higher rehydration ratio and coefficient of rehydration than that dried at 60±2ºC and 65±2ºC. Samples dried at 55±2ºC were significantly different and had obtained higher value in terms of flavor and taste, color and overall acceptability. So, drying temperature at 55±2ºC was considered to be optimum in terms of vitamin C, rehydration characteristics and sensory properties evaluated.

Thus it was concluded that *amla* subjected to the pretreatment whole (blanching + sulphiting) prior to drying and dried at 55±2ºC will obtain a dried *amla* superior in quality.

Dried *amla* is a high potential value-added fruit product because of its rich nutrient content, good taste and long storage life. The cost of dried *amla* leather was calculated as NRs. 1250 per kg.

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Appendices

Appendix A

Specimen card for sensory evaluation

Hedonic rating test

Name of panelist…… Date…….

Product: Dried *Amla*

Please taste the sample and check out how much you like or dislike. Use the appropriate scale to show your attitude by giving the point that best describes your feeling about the sample.

Sample / Parameters	PA	PB	PC	PD	PE	PF
Color						
Flavor						
Texture						
Overall acceptability						

Give points as follows:

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

Comments……

……..

Signature

Appendix B

Specimen card for sensory evaluation

Hedonic rating test

Name of panelist…… Date…….

Product: Dried *Amla*

Please taste the sample and check out how much you like or dislike. Use the appropriate scale to show your attitude by giving the point that best describes your feeling about the sample.

Sample	PA	PB	PC
Parameters			
Color			
Flavor			
Texture			
Overall acceptability			

Give points as follows:

Like extremely **9** Like slightly **6** Dislike moderately **3**

Like very much **8** Neither like nor dislike **5** Dislike very much **2**

Like moderately **7** Dislike slightly **4** Dislike extremely **1**

Comments……
……

……..

Signature

Appendix C

Table C.1 Cost evaluation

Parameters	Quantity	Rate	Amount (NRs.)
Amla	5 kg	NRs. 200/kg	1000

Quantity of dried *amla* produced = 1 kg

Expenses required to produce 1 kg dried *amla* = NRs. 1000

Overhead cost (25%) = NRs. 250

Total cost = NRs. 1250

Therefore, price of 1 kg of dried *amla* is NRs. 1250. The packaging cost is not included.

Appendix D

Table B.1 Average sensory score for different pretreated samples

Sensory parameters	Pretreatments					
	A	B	C	D	E	F
Color	$5.6^{a}\pm(0.51)$	$7.3^{b}\pm(0.67)$	$6^{a}\pm(0.47)$	$5.8^{a}\pm(0.42)$	$7.6^{b}\pm(0.51)$	$7.2^{b}\pm(0.63)$
Flavor	$5.4^{a}\pm(0.51)$	$5.6^{ab}\pm(0.51)$	$7.6^{d}\pm(0.51)$	$6.6^{c}\pm(0.51)$	$5.9^{b}\pm(0.56)$	$8.5^{e}\pm(0.52)$
Texture	$5.1^{a}\pm(0.73)$	$6.7^{bc}\pm(0.48)$	$7.7^{d}\pm(0.48)$	$6.2^{b}\pm(0.78)$	$6.9^{c}\pm(0.56)$	$8.5^{e}\pm(0.52)$
Overall Acceptability	$5.4^{a}\pm(0.51)$	$6.7^{b}\pm(0.67)$	$7.6^{c}\pm(0.51)$	$5.5^{a}\pm(0.52)$	$6.9^{b}\pm(0.56)$	$8.4^{d}\pm(0.51)$

Appendix E

Table C.1 Average sensory score for different temperature dried samples

Sensory parameters	Drying temperature		
	A(50±2^{0}C)	B(60±2^{0}C)	C(70±2^{0}C)
Color	7.9^{c}±(0.73)	6.7^{b}±(0.67)	5.4^{a}±(0.51)
Flavor	8.6^{c}±(0.51)	6.8^{b}±(0.63)	5.4^{a}±(0.51)
Texture	8.4^{c}±(0.69)	7.3^{b}±(0.48)	5.5^{c}±(0.52)
Overall Acceptability	8.3^{c}±(0.48)	6.7^{b}±(0.67)	5.2^{a}±(1.13)

Appendix F

ANOVA Results

A. Optimization of pre-drying treatment

Table F.A.1. Two way ANOVA (no blocking) for Vitamin-C as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
treatment_1	7	12445.33	1777.90	158.28	<.001
treatment_2	5	1723.11	344.62	30.68	<.001
Residual	11	123.56	11.23		
Total	23	14292.00			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments. The LSD value at 5%level of significance was found to be 6.023.

Table F.A.2. Two way ANOVA(no blocking) for rehydration ratio as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
treatment_1	7	0.459229	0.065604	16.35	<.001
treatment_2	5	0.212733	0.042547	10.60	<.001
Residual	11	0.044133	0.004012		
Total	23	0.716096			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments. The LSD value at 5%level of significance was found to be 0.1138.

Table F.A.3. Two way ANOVA(no blocking) for coefficient of rehydration as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
treatment_1	7	0.0162373	0.0023196	15.88	<.001
treatment_2	5	0.0078874	0.0015775	10.80	<.001
Residual	11	0.0016066	0.0001461		
Total	23	0.0257313			

Since, F pr. ≤0.05, there is significant difference between samples with different pre-treatments. The LSD value at 5%level of significance was found to be 0.02172.

B. Sensory evaluation for optimization of pre-treatment

Table.F.B.1. Two way ANOVA (no blocking) for color as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	5	38.4833	7.6967	28.04	<.001
panelist	9	3.7500	0.4167	1.52	0.171
Residual	45	12.3500	0.2744		
Total	59	54.5833			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments on color. The LSD value at 5%level of significance was found to be 0.6092

Table.F.B.2. Two way ANOVA (no blocking) for flavor as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	5	75.4000	15.0800	66.10	<.001
panelist	9	4.7333	0.5259	2.31	0.032
Residual	45	10.2667	0.2281		
Total	59	90.4000			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments on texture. The LSD value at 5% level of significance was found to be 0.5554.

Table.F.B.3. Two way ANOVA (no blocking) for texture as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	5	69.5500	13.9100	34.24	<.001
panelist	9	1.8167	0.2019	0.50	0.869
Residual	45	18.2833	0.4063		
Total	59	89.6500			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments on texture. The LSD value at 5%level of significance was found to be 0.2602

Table.F.B.4. Two way ANOVA (no blocking) for overall acceptability as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	5	68.5500	13.7100	54.68	<.001
panelist	9	5.4167	0.6019	2.40	0.026
Residual	45	11.2833	0.2507		
Total	59	85.2500			

Since, F pr.<0.05, there is significant difference between samples with different pre-treatments on texture. The LSD value at 5%level of significance was found to be 0.5823.

Appendix G

ANOVA Results

A. Optimization of drying temperature

Table.G.A.1. One way ANOVA (no blocking) for Vitamin-C as variate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
tempr	2	1433.556	716.778	195.48	<.001
Residual	6	22.000	3.667		
Total	8	1455.556			

Since, F pr.<0.05, there is significant difference between samples with different drying temperatures. The LSD value at 5%level of significance was found to be 3.826.

Table G.A.2. One way ANOVA(no blocking) for rehydration ratio as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
tempr	2	0.4444222	0.2222111	317.44	<.001
Residual	6	0.0042000	0.0007000		
Total	8	0.4486222			

Since, F pr.<0.05, there is significant difference between samples with different drying temperature. The LSD value at 5%level of significance was found to be 0.0528

Table G.A.3. One way ANOVA(no blocking) for coefficient of rehydration as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
tempr	2	0.01596689	0.00798344	329.59	<.001
Residual	6	0.00014533	0.00002422		
Total	8	0.01611222			

Since, F pr.>0.05, there is no significant difference between samples with different drying temperature. The LSD value at 5%level of significance was found to be 0.00983

B. Sensory evaluation for optimization of drying temperature

Table G.B.1. Two way ANOVA (no blocking) for color as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	2	31.2667	15.6333	41.79	<.001
panelist	9	4.6667	0.5185	1.39	0.265
Residual	18	6.7333	0.3741		
Total	29	42.6667			

Since, F pr.<0.05, there is significant difference between samples with different drying temperatures on color. The LSD value at 5%level of significance was found to be 0.575

Table G.B.2. Two way ANOVA (no blocking) for flavor as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	2	51.4667	25.7333	70.90	<.001
panelist	9	1.8667	0.2074	0.57	0.803
Residual	18	6.5333	0.3630		
Total	29	59.8667			

Since, F pr.<0.05, there is significant difference between samples with different drying temperatures on texture. The LSD value at 5%level of significance was found to be 0.566.

Table G.B.3 Two way ANOVA (no blocking) for texture as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	2	42.8667	21.4333	54.08	<.001
panelist	9	1.8667	0.2074	0.52	0.839
Residual	18	7.1333	0.3963		
Total	29	51.8667			

Since, F pr.< 0.05, there is significant difference between samples due to different drying temperature on flavor and taste. The LSD value at 5%level of significance was found to be 0.591.

Table G.B.4. Two way ANOVA (no blocking) for overall acceptability as variant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
sample	2	48.0667	24.0333	34.33	<.001
panelist	9	5.2000	0.5778	0.83	0.602
Residual	18	12.6000	0.7000		
Total	29	65.8667			

Since, F pr.<0.05, there is significant difference between samples with different drying temperature in terms of overall acceptability. The LSD value at 5%level of significance was found to be 0.786.

List of Plates

P1 Sulphiting

P3 Drying of pretreated *amla*

P2 Pretreated *amla*

P4 Analysis of dried *amla*