ADDIS ABABA UNIVERSITY

Addis Ababa Institute of Technology (AAiT)

School of Chemical and Bio Engineering

Effect of Process conditions on Osmotic Dehydration of *Adama Red* Onion Slice Production

A thesis submitted to the school of graduate studies of Addis Ababa institute of technology in partial fulfillment of the requirements for the degrees of Masters of Science in Chemical Engineering (Food Engineering Stream)

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Addis Ababa, Ethiopia

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List of Abbreviations

ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
APC	Aerobic plate count
Cfu	Colony forming unit
C_p	Specific heat capacity
CSA	Central Statistical Authority
FAO	Food and Agriculture Organization
FDA	Food and Drugs Administration
MOARD	Ministry and Agriculture and Rural development
OD	Osmotic Dehydration
PHL	Post harvest loss
RSM	Response Surface Methodology
SG	Solid Gain
WHO	World Health Organization
WL	Water Loss

Abstract

Dehydration of vegetables is a process commonly used to preserve the product. However, collapse of the structure, discoloration and beneficial compound loss are frequent quality problem. The combination of osmotic dehydration (OD) and other drying techniques is widely used process that could improve the qualities of dried products. Osmotic dehydration (OD) is one of the most promising pre-treatment techniques. It gives product of high quality and preserves reasonably good quantity of naturally occurring microelements and vitamins in fruits and vegetables. It also provides good returns in terms of less energy consumption, palatable, aesthetically acceptable and consumer preferred product. This study was undertaken to investigate the drying characteristics of *Adama red* onion (*Allium cepa*) in an oven and fludized bed dryer after treating the onion slice in osmotic solution. Osmotic dehydration (OD) conditions of onion slices were optimized using response surface methodology(RSM) with respect to osmotic solution concentration 10–20 % (w/w), soaking time (30–60 Minutes) and soaking temperature (35–55 °C) for maximum water loss (WL) and minimum solid gain (SG) as response variables. General factorial design was used as experimental design. The models developed for all responses were significant ($p<0.05$). The optimized conditions obtained were osmotic solution concentration 11.08%, soaking time 38.75 minutes and soaking temperature 45.8 °C in order to obtain WL of 14.7 (g/100 g of fresh weight), SG of 6.3 (g/100 g of fresh weight). The osmotically dehydrated onion slices were then dried in a fluidized bed dryer and conventional oven at drying air temperatures of 50°, 60°, and 70°C. The quality parameters, such as rehydration ratio, ascorbic acid, microbiological quality and sensory quality (color, appearance, and overall acceptability) of the dehydrated onion were determined. The highest number of acceptable quality parameters was reported for osmotic fluidized bed dried samples at 50°C ($p<0.05$).

Key words: Osmotic dehydration, Onion, Optimization, Response surface methodology
Salt solution , Fluidized bed drying ,Oven drying

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CHAPTER ONE

1. INTRODUCTION

1.1 BACKGROUND

Onion (*Allium cepa* Linnaeus) is an important bulb crop in Ethiopia. It is widely produced by small farmers and commercial growers throughout the year for local use and export market. Onion is valued for its distinct pungency and form essential ingredients for flavoring varieties of dishes, sauces, soup, sandwiches, snacks as onion rings etc. Fresh onions are used for their flavor, aroma, and taste, being prepared domestically or forming raw materials for a variety of food manufacturing processes. Of the five common varieties of onions found in Ethiopia, *Adama Red* is the most widely grown in Ethiopia (EARO, 2004).

Onion, like most fruits and vegetables, is regarded as highly perishable food, with limited shelf life at room temperature due to its high moisture content (Atungulu et al., 2004).This fact, coupled with inadequate control of initial quality, incidence and severity of injury, exposure to improper temperature and long waiting period until consumption, results in significant losses in quality (Evranuz *et al.*, 2011).

Over the years, a number of technologies have been developed to reduce the postharvest losses and increase shelf life in perishable products like vegetables. Despite the availability of a number of drying technologies for vegetables, producing processed vegetable products of desirable quality attributes to ensure acceptance by consumers is still a challenge. Drying is an energy intensive operation, and a better understanding of the drying process is important if drying efficiency is to be increased while maintaining product quality. The main objective of any drying process is to produce a dried product of desired quality at a minimum cost and maximum throughput, and to optimize these factors consistently (Chua *et al*. 2001).

Production of dried fruits and vegetables by direct application of heat is a complex phenomenon and requiring carful study. This is due to, application of high temperature during and type of drying techniques drying result in loss of quality, such as color, Nutritive components such as Vitamin C (Ascorbic Acid), and etc. Hence, alternative methodology should be employed in order to minimize high temperature effect on quality attributes. Combination water removal systems such as: Osmotic dehydration/thermal drying and using different type of drying techniques tray drying, fluidized bed dryer, pulsed fluidized bed dryer, etc were tested(Grabowski et al. ,2002).

Osmotic dehydration (OD), initially proposed by Ponting (1973), has been studied in recent decades, especially as a pretreatment for foods to be subjected to air drying, freezing, freeze drying and other processes, in order to guarantee and improve the composition of food by partial water removal and impregnation without affecting its integrity. Osmotic dehydration involves the treatment of vegetable such as onion using osmotic solution i.e. salt solution (NaCl solution). Being a simple process, it facilitates processing of tropical fruits and vegetables such as leafy vegetables, tomatoes, onions banana, sapota, pineapple, mango, and etc. with retention of initial characteristics (color, aroma and nutritional elements (Pokharkar *etal*, 1998).

Osmotic dehydration is a less energy intensive than air or vacuum drying processes because it can be conducted at low or ambient temperature. (Gathambiri, 2005).There are some major advantages of osmotic dehydration process in the food industry : quality aspect (improvement in terms of color, flavor, texture, product stability and retention of nutrients during storage, energy efficiency, packaging and distribution cost reduction, chemical treatment not required and product stability during storage (Yetenayet etal., 2010).

Dehydrated onion, recently, has become standard ingredient in a vast range of processed foodstuff. They are being increasingly used as they retain their culinary quality and palatability, and economically feasible in storage space and transport cost. Besides, there is optimum utilization of the product during the glut season, and saving of packaging material and tinplate. Dehydrated onion is used extensively in overseas countries, unlike Ethiopia, as a condiment. Dried onions are used in all sorts of industrial food products, especially in instant foods which have a very short preparation time (between 5 and 15 minutes).Production of dried onion via osmotic dehydration/drying is relatively small scale, as other horticultural crops, but this produce has become a standard ingredient in processed foods in which raw onion can be used. It is used as seasoning in production of catsup, many sauces, meat casseroles, as well as cold cuts, sausages, potato chips, crackers and other snack items. Restaurants, canteens and cafeteria use dehydrated onion because of its convenience in storage, preparation and use (Kaymak *etal* ,2005).

The main aim of this research is to study the effect of osmotic treatment processing conditions and optimization for the production of dried onion slices from local *Adama Red* varieties by drying using conventional oven and fludized bed drier and produce a product which is palatable, aesthetically acceptable and consumer preferred product.

1.2 STATEMENT OF THE PROBLEM

The bulkiness and high perishability of fruits and vegetables such as fresh onions, coupled with high transportation costs, underdeveloped road infrastructure and the unavailability of cool storage facilities, generally leads to considerable losses during transport from farm to the processing site, and increases the cost of inputs. Some of constraints of postharvest products of fruits and vegetables condition and market life are highly affected by things like temperature, humidity and the composition of the atmosphere (Pal *etal*, 2002). This will result in fluctuation in the price of onions and shortage of these products will occur during the year and mainly these products are seasonal.

In Ethiopia, up to 30% of vegetable harvests are reported to be lost due to poor postharvest handling (Fekadu and Dandena, 2006). During peak harvesting seasons, the loss is high and the products are sold at low price because of lack of means to preserve and store the products. Therefore, in order to prolong the shelf life of the postharvest product, processing is necessary. Non-availability of onion during off-season creates major problem in the market and causes price fluctuations, which directly affects the consumer.

Currently, there is little knowledge on onion processing in Ethiopia. Onions can be dried commonly using sun drying. The composition of the final dried onion product may vary depending on the processing conditions. Sun drying has traditionally been the process employed for preparing dried onion from fresh onion. However, sun-dried products can become discolored and the process can be unhygienic and lengthy. Hot air drying is an alternative method that needs less drying time and improves the quality of the dried onion however it has been shown that hot air drying can promote a decrease in the vitamin C and other volatile matters .Drying at higher temperatures (i.e. 80 to 90°C) or for longer drying time temperatures (i.e. around 30 to 40°C) decreased the vitamin C and other volatile matters of the final product (Latapi *etal*., 2006).

It is important to convert the surplus into a valuable commodity, such as shelf stable sliced dried onion and onion powder via application of osmotic dehydration and drying techniques. Therefore this study will fill the gap in the processing of dried onion products using osmotic treatment coupled with other drying methods.

1.3 OBJECTIVE

General objective

To study the influence of processing variables during production of dried onions by application of osmotic dehydration treatment and subsequent drying techniques from fresh sliced onion (*Adama red*) on some quality attributes.

To achieve this overall objective, the following objectives were identified:

1. to prepare partially dehydrated Onion using osmotic dehydration technique from fresh sliced Onion (*Adama Red*)
2. to study and find the optimal processing variables (Osmotic Solution Concentration, soaking temperature and soaking time)osmotic dehydration process
3. to investigate the effect of drying methods (fluidized bed and over drying) on the physico chemical properties of dried onion
4. to conduct physico-chemical (Proximate, hydration ratio) and sensory analysis of both raw and processed onion
5. to perform to preliminary techno economic feasibility study and suggest process design for dried onion production

1.4 SCOPE OF THE STUDY

The study generally covers:

- The processing method for production of sliced dried onion
- Development of sliced dried onion
- Laboratory analysis:

  Physico-Chemical Analysis

  Proximate Analysis

  Microbiological Analysis
- Sensory Evaluation
- Suggestion of technology and economic analysis

1.5 SIGNIFICANCE OF STUDY

The water content of most of fruits and vegetables is higher than 80%, which limits their shelf life and makes them more susceptible to storage and transport conditions (Orsat *et al.,* 2006). Nowadays dehydrated onion attract attention because they can be easily produced, can be stored and transported at relatively low cost, have reduced packing cost, and their low water content avoids the development of some microorganisms responsible for deterioration of fresh food (Orishagbemi *et al.,* 2000).

Due to their high initial moisture content of fresh onion which is nearly 90 %, the energy needed for the removal of water is very high. Moreover, during drying of the onion using different types of driers volatile matters depleted and the organoleptic property will be changed. Unfavorable color change and loss of essential micronutrients and vitamins will occur. This research improved the nutritional quality and acceptance of the dried onion products by operating at lower temperature using osmotic solution as a pretreatment prior drying and in addition this treatment save energy cost related for drying the products. With growing incomes, changing lifestyles and hectic daily schedule, market for dehydrated onion is growing especially in urban areas. (Praveen Kumar et al. 2006).

Dehydrated onion product can be used in dry soup mixes, canned soups and sauces, frozen entrees, processed meats, baby foods, snack foods and seasoning blends (Praveen Kumar et al. 2006).

The study gives the consumers a product which is affordable with health benefits; furthermore the feasibility study will also serve a stepping stone for economic growth specially the farmers to enhance their farming as the main ingredient of this product and those who would want to put up their own business.

Small and medium-scale businesses that produce value-added products from onion will provide opportunities for economic development in of the country. These businesses create jobs and provide much needed incomes for the urban and rural poor. These value-added products, produced from locally sourced raw materials, are not capital intensive, and take advantage of local labor markets, providing decent incomes for those that otherwise would continue to exist in impoverished conditions**.**

CHAPTER TWO

2. LITERATURE REVIEW

2.1 GENERAL INTRODUCTION ON FRUIT AND VEGETABLES

Fruits and vegetables are one of the most important and fast growing sub sectors of the food processing sector, as fruits and vegetables form an indispensable part of healthy diet. China, India, Brazil, USA, Italy, Spain, Mexico, Iran, Philippines and France are the top ten aggregate fruit producers in the world. Global fruit and vegetables consumption increased by an average of 4.5% per annum between 1999 and 2009. This was higher than the world population growth rate, meaning that the global per capital consumption of fruit and vegetables has also increased. The total production of vegetables in Ethiopia during the long rainy season, Meher, in 2010–2011 was about 1.75 million tons (CSA, 2011). The average yield of potatoes in 2010–2011 was about 8.28 tons per hectare. The average yield of tomatoes was about 10.5 tons per hectare. The average yield of onions in 2010–2011 was about 10.8 tons per hectare (CSA, 2011). Current levels of vegetable production are low and insufficient to satisfy the growing demand for vegetables caused by population growth.

Vegetables are not only a major source of vitamins and microelements necessary for human health but also a good source of cash income for small-scale farmers. Vegetable products provide nutritional, economic, employment and social benefits. Vegetable production and consumption is increasing in Ethiopia because of increasing export to Djibouti, Somalia, South Sudan, the Sudan, the Middle East and European markets and urbanization (Tabor and Yesuf, 2012). In these countries there is a sustained demand for products such as chillies, onions, and cabbages, resulting in export increase from 25,300 tons in 2002/03 to 63,140 tons in 2009/10 (EHDA, 2011).

Fruits and vegetables including onion are regarded as highly perishable food due to their high moisture content. Accordingly, they exhibit relatively high metabolic activity compared with other plant-derived foods such as seeds. This metabolic activity continues after harvesting, thus making most fruits highly perishable commodities (Atungulu *et al.*, 2004).

In many African countries, the post-harvest losses of food cereals are estimated at 25% of the total crop harvested. For some crops such as fruits, vegetables and root crops, being less hardy than cereals, post-harvest losses can reach 50%. In East Africa and the Near East, economic losses in the dairy sector due to spoilage and waste could average as much as US$90 million/year (FAO, 2004).

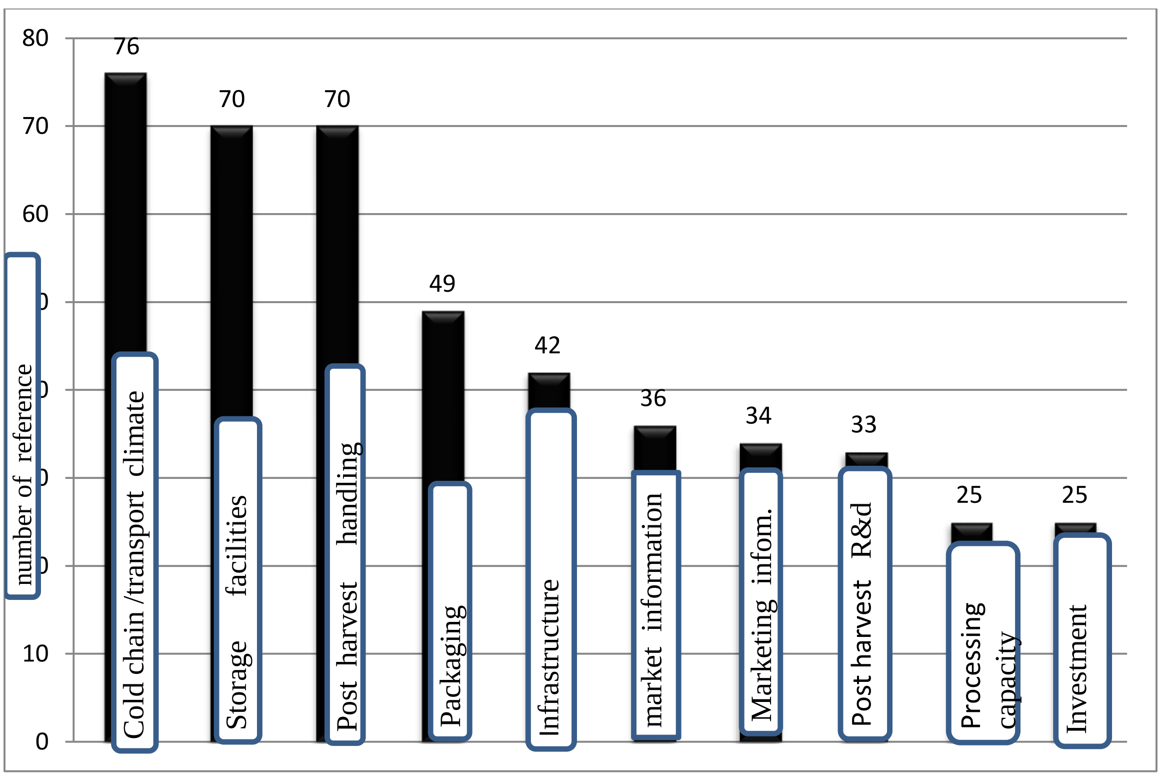


Figure 2.1 Major causes of post harvest loss throughout the value chain Source: FAO (2011)

2.2 PRODUCTION OF ONION

2.2.1 World Production

Alliums belong to the family Alliaceae and are thought to have originated in central Asia. Dry bulb onions (*Allium cepa* L.) are the second most important horticultural crop after tomatoes and are consumed worldwide for their unique flavor and health-related properties (Grffiths *et al*., 2002).At least 175 countries grow onion .According to FAO (2009) ,the world production of onion is 64.48 million tons from 3.45 million ha area . The production of this vegetable in 2007 was around 68 million tons (FAO ,2009). Onions are important crops in the tropics, which account for nearly 30% of total global production. Although some tropical countries are net importers, export potential of onions is developing in several tropical regions partly because if dried and packed properly, the bulbs can be transported for considerable distances without deteriorating (Linus, 2003).

The cultivated onion (*Allium cepa* L.) is one of the important condiments widely used in all households. The total world production of onion was about 86.34 million tonnes (FAOSTAT, 2011). Leading onion producing countries with share in production were China, India, USA, Iran, Egypt, Turkey, Russian Federation and Pakistan (Table 2.1). It was estimated that the value of the world production of dry onion approached 29490 million US $ during 2011

Table 2. 1 World onion production (million ton)

1	China	24.76
2	India	15.93
3	USA	3.36
4	Iran	2.5
5	Egypt	2.3
6	Turkey	2.14
7	Russia	2.12
8	Pakistan	1.94
9	Netherland	1.54
10	Brazil	1.52

Source: FAOSTAT, 2011

The average annual per capita onion consumption in the world is approximately 7 kg. Among all countries, Libya has the highest average per capital onion consumption of 30 kg (FAO 2009). Onion is one of important culinary value because of their characteristic flavor. These vegetables have also been recognized as important sources of valuable phyto nutrients. Both are consumed as fresh and as additives (powdered spice) to many food products. There are many possible preparations of these plants. The bulbs can be boiled, baked, or fried. They are also preserved in the form of pickles. Usually onions with yellow/brown skin are used in domestic cooking, although red skin onions are favored in some parts of the world. In general, most common varities of onion fall into one of the two classes, according to the day length: short-day (for southern latitudes) and long-day (for the northern latitude). The latter are very pungent, hard and can easily stand long storage periods, but the short -day onions are mild, soft fleshed and cannot be stored for a long time (Hui *etal*, 2008)

2.2.2 Onion Production in Ethiopia

Onion is considerably important in the daily Ethiopian diet. All the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews (MoARD, 2009). Temperature is noted to be one of the most important environmental factors for onion dry bulb and seed production in Ethiopia. The crop requires cool condition during the early part of its development and warm condition during bulbing, bulb maturity, harvesting and curing stages. It is important to identify locations with optimum climatic conditions favorable to attain high yield and quality of dry bulb and seed production. Onion can grow in all types of soils from sandy loam to heavy clay. Highest yield will be obtained from freely drained friable loam soil with pH of 6-6.8 (Adgo, 2008).

Table 2.2 Area, Production and Yield of onion for Private Peasant Holdings for Meher Season2010/11 (2003 E.C.)- 2012/13 (2005 E.C.)

Year	Total area(hectar)	Total production(quintal)	Yield(quintal/ha)
2010/11	22,035	2,369,221.6	107.52
2011/12	30,478.35	3,281,571.48	107.6
2012/13	21,865.37	2,191,886.03	100.24

Source CSA, 2012/13

2.2.3 Varieties and characteristics of onion in Ethiopia

Different types of onion cultivars are available in Ethiopia. These are fresh market, bunching and dehydrator types, which could be open pollinated, or hybrids. The fresh market types (red colored, highly pungent) have high acceptance in the local market compared to bunching and dehydrator types. The dehydrator onions are large and are commonly produced for flaxes, onion powder, and onion rings that are mainly used for snacks. The onion cultivars vary in vegetative characteristics such as foliage length, leaf arrangement (erect, pending) and leaf color. They also differ in bulb characteristics, internal structure (single, double, multiple) bulb shape (flat to cylindrical to spindle), color (red, yellow, white), flavor rate (sweet, mid pungent and pungent) (Geremew et al. ,2010).

The five common the varieties of onion in Ethiopia are; Adama red, Bombey red, Red creole, Melkam, and Nasik red (Dereselegn) to farmers. Bombay Red and Adama Red varieties are widely grown in Ethiopia (EARO, 2004). Oromia is the most important production region for onions (64%), followed by Amhara (30%) (CSA, 2008/09.)

Adama Red is a dark red colored and firm, very pungent, flat globe shaped. It flowers and set seed very easily. It is accepted both by producers and consumers and is successfully produced by small farmers and commercial growers in most regions of the country. The cultivars are grown in Awash valley and lake region in larger quantity. Melkam, high yielder but light red in bulb color than Adama Red (Kahsay *et al.*, 2013).

Red Creole, red colored and firm, very pungent, not easily bolting, relatively tolerant to purple blotch disease. Bombay Red, thick flat shaped, light red, light pungent, susceptible to purple blotch disease. It has a high proportion of split bulbs and have short shelf life compared to Adama Red. Dereselgn, early maturing, medium red, large bulb sizes and fits to short growing season. Adama Red and 'Nasik' Red having DMC (%) of 17.67 and 17.27, respectively showed higher and significant difference from 'Melkam' and 'Bombay' Red which had DMC (%) of 15.23 and 14.41, respectively . Adama Red varieties found to be superior for quality as measured by TSS content, DMC and storability (Kahsay *et al.*, 2013).

Table 2.3 Characteristics of different onion cultivar

Onion Cultivar	Maturity days	Bulb color	Bulb shape	Bulb size (gm)	Bulb yield (qt/ha)	Seed yield, qt/ha
Adama Red	120-135	Dark red	Flat globe	65-80	350	10-13
Red Creole	130-140	Light red	Flat globe	60-70	300	2-6
Bombay Red	90-110	Light red	Flat globe	70-80	300-400	13-20
Melkam	130-142	Red	High globe	85-100	400	11-15
Dereselegne	100-115	Red	Globe	85-100	380	

Source: Adapted from Lemma Desalegn and Shimelis Aklilu (2003),

2.3 COMMERCIAL PRODUCTS OF ONION

There is a general increase in demand for processed onions because of the high perishability of fresh onion. To satisfy this demand several types of natural onion products are currently available to food processors. These include dehydrated onion in powder or pieces: onion oil obtained by the distillation of fresh onions and offered as is diluted in vegetable oil or in form of an emulsion; onion juice concentrated to a viscous syrup or thick paste and also offered in dry form as dispersion on salt or dextrose (Farrel, 1985).

Dehydrated Onion Pieces

Cured or dried onion has 4 to 5% moisture to allow good storage and acceptable quality. The product is processed to make powder, granules, flakes or slices, then used for the formulation of sausages, meat products, many kinds of soups and sauces as well as dressings (ADOGA ,2005).

Onion Powder

Onion powder is a spice made from dried onions that retains some of the pungency and flavor of fresh ones. Some cooks like to use the powder because it is easier to handle than fresh onions, requiring no chopping or special treatment, and a number of recipes call for it. Most markets carry this spice, typically with the other dried spices, and there are several varieties available in many places. Onion powder is prepared either from dehydrated onion pieces or from puree. A stronger flavored product is obtained by spray drying. The powder is a uniform product of which 95% passes a sieve of 0.25 mm aperture size. This is the finest among onion products including grifts, flakes, slices and rings, and used for soups, relishes, sauces, and products that do not require onion appearance and texture. Discoloration develops during the processing of onion (Brewster, 1994).

Onion Oil

Onion oil is obtained by distillation of minced onion. Most onion oil components are generated enzymatically from their precursors such as S-1-propenylcysteine sulfoxide, S-1-propylcysteine sulfoxide and S-methylcysteine sulfoxide. The minced onion is allowed to stand at ambient temperature for a few hours prior to distillation to complete the enzymatic and successive chemical reactions. The onion oil can be obtained in 0.002 to 0.03% yields as a brown-amber liquid, and collected from the bottom of a vessel placed under a steam condenser (Brewster, 1994).

Pickled Onion

Onion may be preserved in vinegar as pickled products. A translucent product with a desired texture is preferable. Usually, onion is soaked in 10% saline solution for 24 h, is transferred to a bottle, and spiced vinegar is added (Corey *etal*, 2010).

2.4 PROCESS TECHNOLOGY OF DEHYDRATED FRUITS AND VEGETABLES

Dried or dehydrated fruits and vegetables can be produced by a variety of processes. Dehydration is the technique of removing moisture from solids and is an integral part of food processing. Many food products are dried to improve their shelf life by reducing the water activity. It also enhances the appearance, retain original flavor and maintain the nutritional value of the fruit or vegetable (Al-Muhtaseb *et al*. 2010).

2. 4.1 Predrying Treatments of vegetables prior to drying

Predrying treatments prepare the raw fruits and vegetables for the dehydration process, and include raw product preparation and color preservation. Most fruits and vegetables follow similar raw product preparation steps, although the peeling and the blanching steps may be specific to the type of fruit or vegetable that is being prepared. The color preservation method differs for fruits and vegetables, with most fruits using sulfur dioxide (SO2) gas and most vegetables using sulfite solutions (Kowalska etal., 2001).

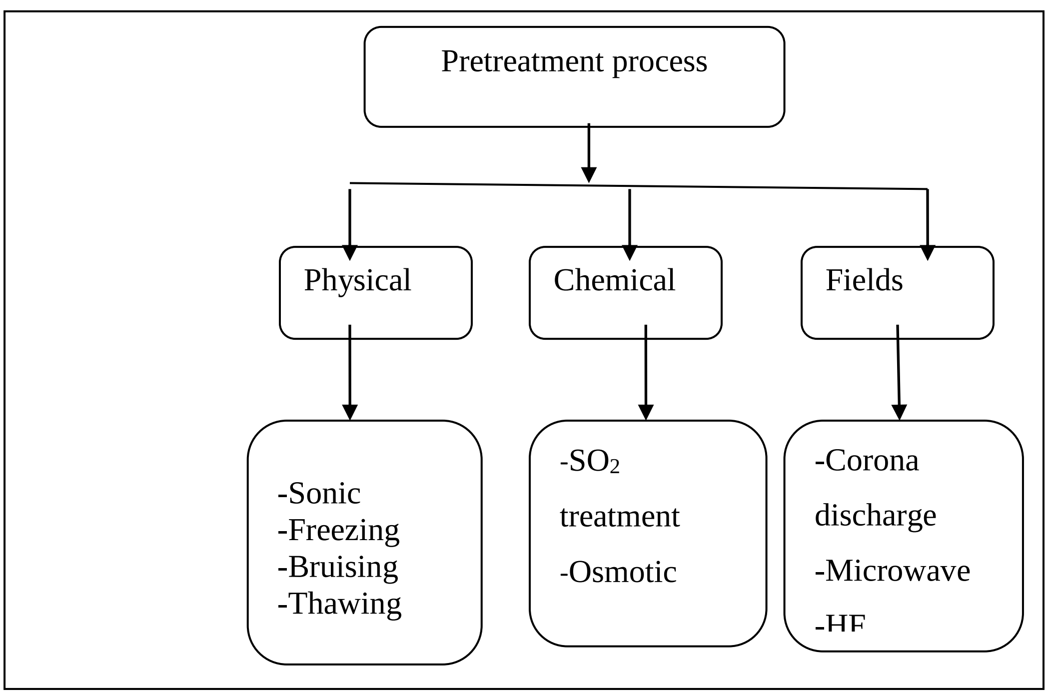


Figure 2.2 Classification of various pretreatment techniques

OD technology for food preservation is mostly used as a pretreatment step for other stabilizing steps, such as vacuum -drying, air drying, freeze drying and pasteurization, because OD generally will not reduce the moisture content of food products to a low enough for the product to be shelf stable .Therefore, OD is an intermediate step that is used to improve product quality during further processing (Chiralt *et al.*, 2001).

OD is a method for partial dehydration of water-rich foods, such as fruits and vegetables, by immersing them in a concentrate solution of sugar and/or salt. It results in two simultaneous crossed flows: a water outflow, from the food to the solution and a solute inflow from the solution into the food. The driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hypertonic solution (Rastogi *etal.*, 2004).

2.4.2 Drying or Dehydration

Drying is an energy intensive operation, and a better understanding of the drying process is important if drying efficiency is to be increased while maintaining product quality. The main objective of any drying process is to produce a dried product of desired quality at a minimum cost and maximum throughput, and to optimize these factors consistently (Chua *et al*. 2001). Different drying methods are available for drying of the agricultural crops. Rotary drums, widely used dryer in the drying of by-products of vegetable origin requires high temperature of the drying gas (about 600 ºC), solid agglomeration is frequently produced, large installation size and great size cyclones for the cleaning of the exit gases are necessary and the process control is difficult (Aragón et al., 2005). Fluidized bed dryers present some advantages over other types of dryers as the gas-solid contact is very good; and the operation control and monitorization are easy (Chua *et al.*, 2003).

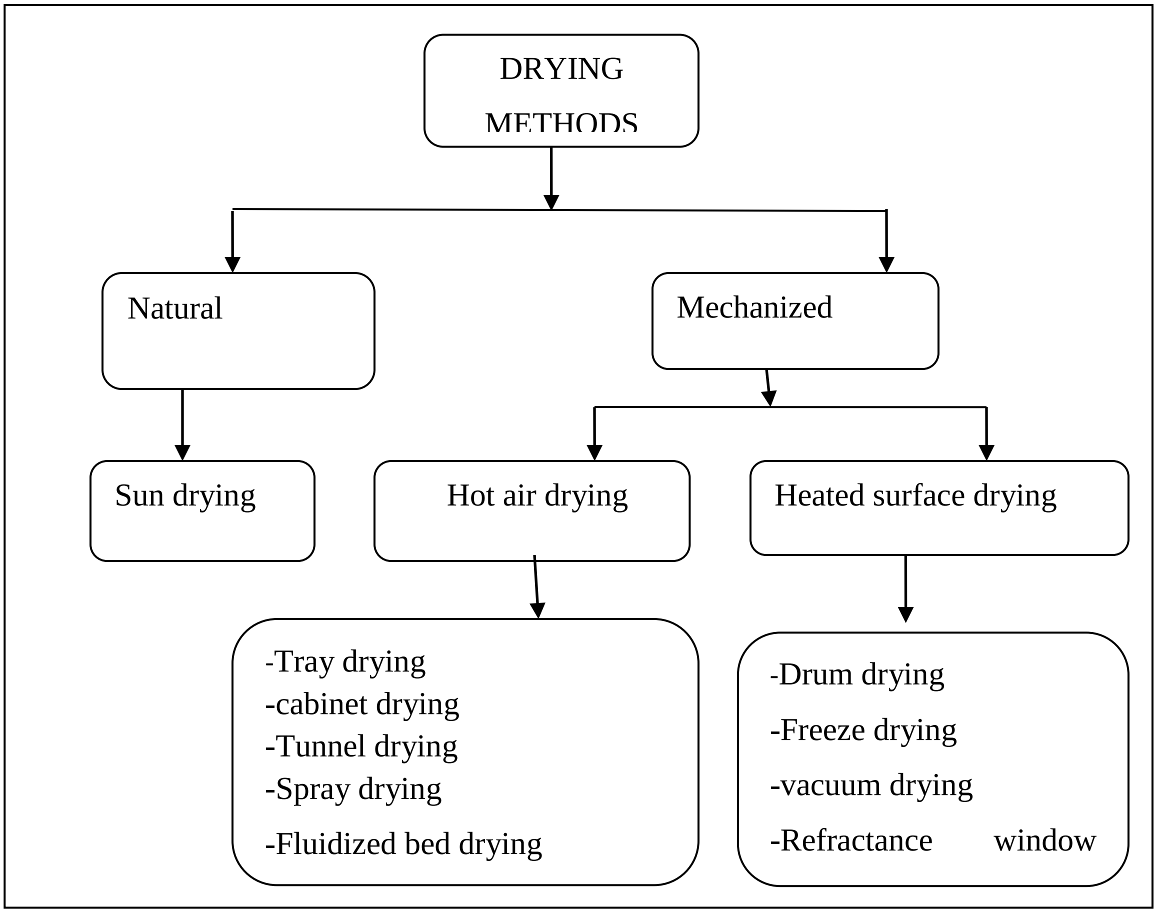


Figure 2.3 drying methods

Fluidized bed drying

Fluidized bed drying is carried out by passing the air at fluidization velocity through a bed of product so as to fluidize the material. In fluid bed drying, heat is supplied by the fluidization air, but the air flow need not be the only source. Heat may be effectively introduced by heating surfaces (panels or tubes) immersed in the fluidized layer. Uniform processing conditions are achieved by passing a gas (usually air) through a product layer under controlled velocity conditions to create a fluidized state. Some roots like onions, garlic, carrots can be dried using fluidized bed (Sutar *et al.*, 2007) carried out fluidized bed drying of osmotically dehydrated onion slices at different temperature.

The fluidization process had been known for long time and the results have shown that drying of vegetables in a fluidized bed produces dry products of excellent quality in a much shorter time than other types of dryers that are generally used (Bobic *et al*. 2002).

In the fluid bed dryers the drying time is greatly shortened and all the particles are equally dried while they float in the fluidized bed. During the fluidization process the batch is fluffed with a stream of warm fluid until all the pieces float in the fluid and form a homogenous bed. This homogenised bed of vegetable pieces is mixed and stirred and at some point of time the surfaces of all the pieces are exposed to the same conditions of drying (Kwauk *et al*., 2000).

Oven Drying

Another possibility to dry vegetables is oven drying. Oven drying can be done all the year around as it is not dependent on the weather conditions. The oven should be able to maintain constant temperature and it should have good ventilation. The oven drying method is quicker (between 6 and 24 hours). For oven drying the vegetables are put on the oven trays or better oven grids, and the oven is preheated. It is possible to put more than one tray into the oven at once but then the trays need to be 5 to 8 cm apart from each other and also from the top and the bottom of the oven. During drying open the oven door a little bit to allow moisture to go out. In addition, a fan put in front of the oven door can be used to increase ventilation and thereby reduce drying time. Special care has to be taken that the vegetables do not get burned in the oven (Naseer *etal*, 2013).

Hybrid Drying

Dried onion products are produced in several forms, such as flaked, minced, chopped, and powdered. The onions are generally dried by hot air drying methods, which are time consuming, have low efficiency, and result in low-quality product. New and innovative techniques that increase drying rates and enhance the quality of the dehydrated onion are receiving considerable attention fluidized bed drying in combination with osmotic dehydration is a possible alternative method for drying onion slices with better quality of the final product(Gabel *et al*., 2004).

Fluidized bed drying can remove moisture from the product rapidly. Since dehydrated onions are consumed in the form of flakes or powder, fluidized bed drying can be suitable for onions. Osmotic pretreatment prior to drying improves the color, flavor, and texture of the final product and it is a less energy intensive process as no phase change takes place (Ertekin *etal*, 1996).

Onions can be dried using combination of OD and fluidized bed drying to get the better quality with less energy consumption (Sutar *et al*., 2007). The combined osmotic and microwave drying results in more homogeneous heating of the product by modification of its dielectric properties due to the solute uptake, slightly reduced drying time, reduced shrinkage, high porosity and improved rehydration characteristics (Torringa et al., 2001). OD is usually followed by complementary processing such as thermal drying to attain a product with reduced moisture content and thus a long shelf life. Because OD is carried out at moderate temperatures, usually from 30-40^{o}c, it is regarded as energy -saving technology when used prior to thermal drying (Cristina, 2009).

Osmo-convective Drying

The majority of artificial drying operations are based on hot air drying, where air is heated by the combustion of fossil fuels or using electric heater prior to being forced through the product. According to Mujumdar and Beke, (2003), typical convective dryers account for about 85% of all industrial dryers. Heating of air before drying is the most energy intensive processes in food processing industries. Regarding osmoconvective drying as a hybrid technology, OD prior to thermal dryings results in reduced energy consumption, although to different degrees, depending on the drying kinetics.

Osmo-fludized Bed Dryer

Fluidized bed drying can dehydrate the product rapidly , osmotically dehydrated onions and using salt solution followed by fluidized bed drying. As dehydrated onions are finally consumed in broken form or are converted into powder form, fluidized bed drying is a suitable method for drying of osmotically dehydrated onions resulting in to quality product(Sutar *etal.,* 2007).

2.4.3 Osmotic treatment of onion

2.4.3.1 Mechanisms and characteristics of osmotic treatment

Drying is one of the most ancient food processing methods and is still being practiced worldwide as a means of improving shelf life of foods, preserving quality, preventing moisture-mediated deteriorative reactions, and easing handling, transportation and storage of products. Among various drying technologies available, osmotic treatment is an example of minimal dehydration for foods (Grabowski *etal., 2003*).

Osmosis, the basis of osmotic treatment, is a physical phenomenon driven by a difference in solute concentration of two areas separated by a semi-permeable membrane, causing a movement of water from a low-solute concentration area to a high-solute concentration area through the membrane. When a water-containing cellular tissue is immersed in a hypertonic solution of low molecular substances (e.g., salts, sugars), the concentration difference between the food material and the solution gives rise to two simultaneous counter-flows: 1) the outflow of water from the material into the solution, and 2) the migration of solutes from the solution into the material (Shi and Le Maguer 2003).

Osmotic treatment offers several advantages over conventional methods; some benefits include its relative mechanical simplicity, flexible nature of the process, and its low energy requirements because water can be removed without any phase change. In addition, because it is typically conducted at ambient or slightly elevated temperatures, the thermal degradation of color, texture, and nutritive values of the raw material is minimal. Since the material is kept immersed during the process, oxidative reactions and loss of volatile compounds can also be minimized (Marani , 2007).

Mass transfer phenomena during osmotic dehydration

There are three major types of counter current mass transfer in osmotic concentration process (Karthiayani, 2004)

1. Important water out flow from the product to solution.

2. A solute transfer, from the solution to the product; it makes thus possible to introduce the desired amount of an active principle, a preservative agent, any solute or nutritional interest, or a sensory quality improvement of the product.

3. Leaching out of products own solutes (sugar, organic acids, minerals, vitamins etc.), which is quantitatively negligible when compared to the first two types of transfer, but essential with regard to the composition of final product.

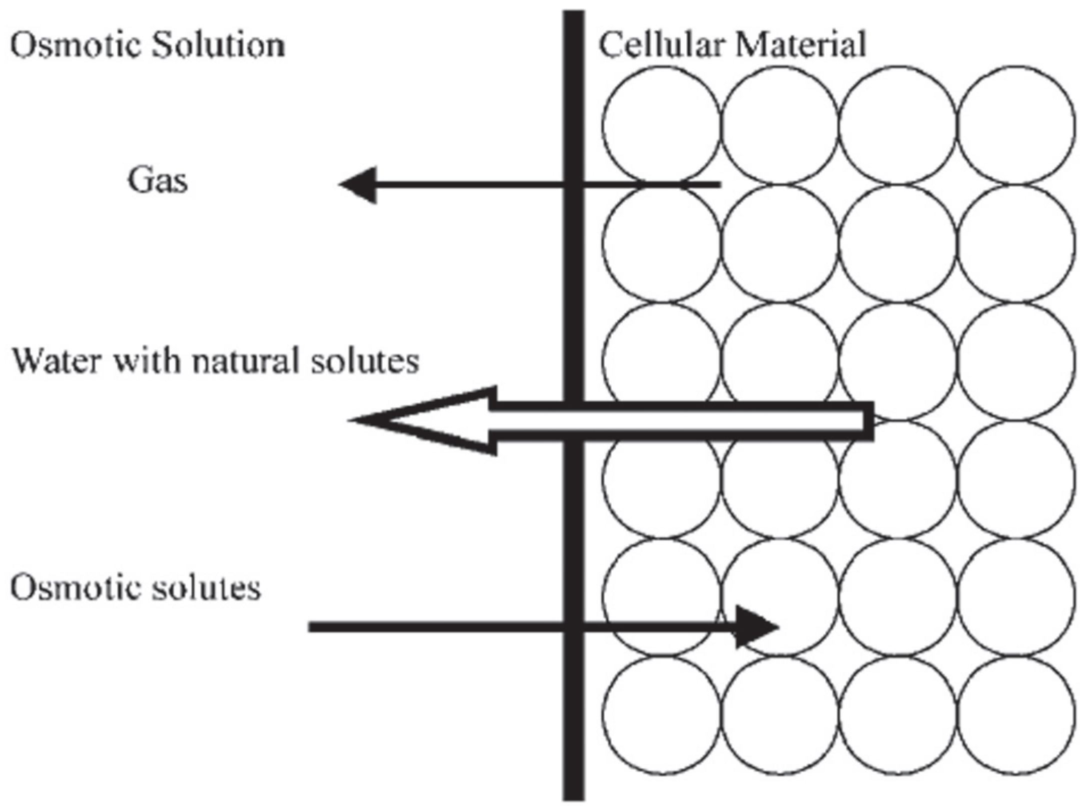


Figure 2.4 Mass transfer pattern when a cellular material is immersed in osmotic solution [Shi and Le Maguer 2003]

2.4.3.2 Major factors of osmotic dehydration

The kinetics of mass transfer in osmotic dehydration is usually described using terms such as water loss (WR), solids or solutes gain (SG) and weight reduction (WR) (Shi, 2008). The overall mass transfer kinetics during OD is affected by several factors. The sensory qualities of the food products with solute depend on the expected water loss to solid gain ratio. The prediction and control of (WL)/SG ratio resulting from a solute or solute combination is a basic requirement for process design. Solutes such as sugars (especially for fruits) and salts (for vegetables, fish, meat and cheese) are mostly used for osmotic treatment. Mixtures of solutes have also been used for both plant and animal treatment to obtain higher (WL)/SG ratios and to reduce impregnation. Salt and sucrose concentrations show a synergetic effect on food osmotic treatments, which has led researches to investigate optimum process conditions (Mayor *et al.*, 2007)

The final quality of osmotically dehydrated food products is mainly dependent on the nature of food material, the composition and concentration of the osmotic solution the treatment temperature, and time .OD has recently received increasing attention as a potential pretreatment to conventional drying and freezing processes for improving the quality of fruit. It is a slow process suggesting the need for enhancing mass transfer without affecting the food quality negatively. However, another problem taking place during OD is a large solute uptake. Solids uptake modifies final product composition (*i.e*. sugar to acid ratio) and taste. The solids uptake blocks the surface layers of the product, posing an additional resistance to mass transfer and lowering the rates of complementary dehydration (Matuska *et al*., 2006).

A. Type of osmotic agent

The kind of osmotic solution used in osmotic solutes affect the kinetics of water removal, solid gain, and final equilibrium water content. Obviously ,the selection of osmotic agents cannot only be made on the basis of its osmosity .The choice of the solute and the concentration used depend on several factors .The most important factors are the organoleptic evaluation of the final vegetable products and the cost of the solutes.

Osmotic solution must have a low water activity. Moreover, the solution must not be toxic and have high solubilty in water. The capacity of the compound to lower the water activity will affect the driving force responsible for the mass transfer. It is possible to select the most suitable solutes in order to obtain the best levels of water removal .The common solutes used in OD are sucrose ,glucose and salt .

Osmotic process is also affected by the Physico-chemical properties of the solutes employed, because differences in efficiency of dehydration arises mainly from differences in molecular weight, ionic state, and solubility of solute in water (Rahman , 2007). The selection of the solute must consider the following three main factors: solute impact on sensory characteristics of the product, the relative cost of solute in relation to the final value of the product, and the molecular weight of the solute. Some of the solutes often used in OD processes are sodium chloride, saccharose, glucose, and corn syrup.

B. Concentration of Salt Solution

In general, it has been shown that water loss in osmosed vegetables is improved by increasing solute concentration in osmotic solution. Some factors have been employed to speed up water transfer such as using a high concentration of osmotic solution, low molecular weight of osmotic agent, high processing temperature, stirring process or some pretreatment techniques. Thus, these factors were important to review. However, another concern in OD is currently to minimize the uptake of osmotic solids, as it can severely alter organoleptic and nutritional characteristics of the product. In the case of vegetables, sodium chloride solutions in the range 5–20% are generally used. At high salt concentrations, the taste of the end product may be adversely affected (James G. Brennan, 2006).

C. Temperature of OD Treatments

Flink found that the rate of osmosis and diffusion is markedly affected by temperature. Increasing temperature of the osmotic solution results in an increase in the rate of water removal and solid gain. Osmotic pre-concentration is an effective way to reduce water content with minimal damage on fresh product quality. This is largely due to the use of a mild product treatment at relatively low process temperatures (30-50°C); such temperatures do not affect the semipermeable characteristic of cell membranes, which is an essential requirement for maintaining the osmotic phenomenon (Lazarids, 2001).

D. Time Duration of OD Treatments

When the concentration of salt solution is kept constant, an increase in contact time results in an increase water loss. Although water loss increases as a function of time with regard to osmosis, the rate of water loss decreases.

E. Osmotic Solution and Food Mass Ratio

Flink (1979) reported that an increase of osmotic solution to sample mass ratio resulted in an increase in both the solid gain and water loss in OD. To avoid significant dilution of the medium and subsequent decrease of the (osmotic) solution to product ratio (4:1 or 3:1) in order to monitor mass transfer by following changes in the concentration of the salt solution.

F. Slice Thickness

The slice thickness between 2 and 6 mm do not cause color changes, where as a slice thickness above 6 mm influences strongly the color of the dried product (Adam *et al.*, 2000). Therefore, to minimize color changes the thickness of onion slices should be selected as small as possible. For practical purpose the thickness should not be greater than 6 mm.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. RAW MATERIAL COLLECTION, TRANSPORTATION, SAMPLE PREPARATION AND STORAGE

Fresh Onion Collection and pretreatment

Fresh well-graded *Adama Red* good quality onions were obtained from Melkasa Research Institute and stored in a refrigerator until the drying experiment. All the onions were put in a refrigerator at $4^{O}C$ prior to the experiments so that the storage condition would be kept the same for all samples before dehydration. The onion samples were peeled carefully and washed with potable water and sliced into circular discs. The onion bulbs were sliced with a stainless knife of approximate 4mm+/- 1mm thickness. The thickness was measured using caliper. The prepared onion samples were weighed approximately 100 g for every experiment and immersed in a beaker containing salt concentration of (10%, 15% and 20% w/v).

Osmotic Solutions Preparation

Analytical grade salt (NaCl) was purchased and used to prepare osmotic solution. The osmotic solutions of different concentration (10%, 15% and 20% w/v) were prepared by dissolving required amounts of salt in distilled water. NaCl salt solution was chosen for osmosis as it is an excellent osmotic agent for retarding oxidative and non-enzymatic browning in vegetables. Potassium metabisulfite was added to the osmotic solution to prevent pink discoloration, browning of dried onion, and loss of ascorbic acid by retarding oxidation. The level of potassium metabisulfite pretreatment was maintained to 0.2% (w/v), which was reported as a relatively low concentration that is effective in preserving the quality of dehydrated product to some extent.

Framework of the experiments: The research was conducted to develop and evaluate sliced dried onion from fresh *Adama red* variety. The overall framework of experiments of the thesis is shown in Figure 3.1

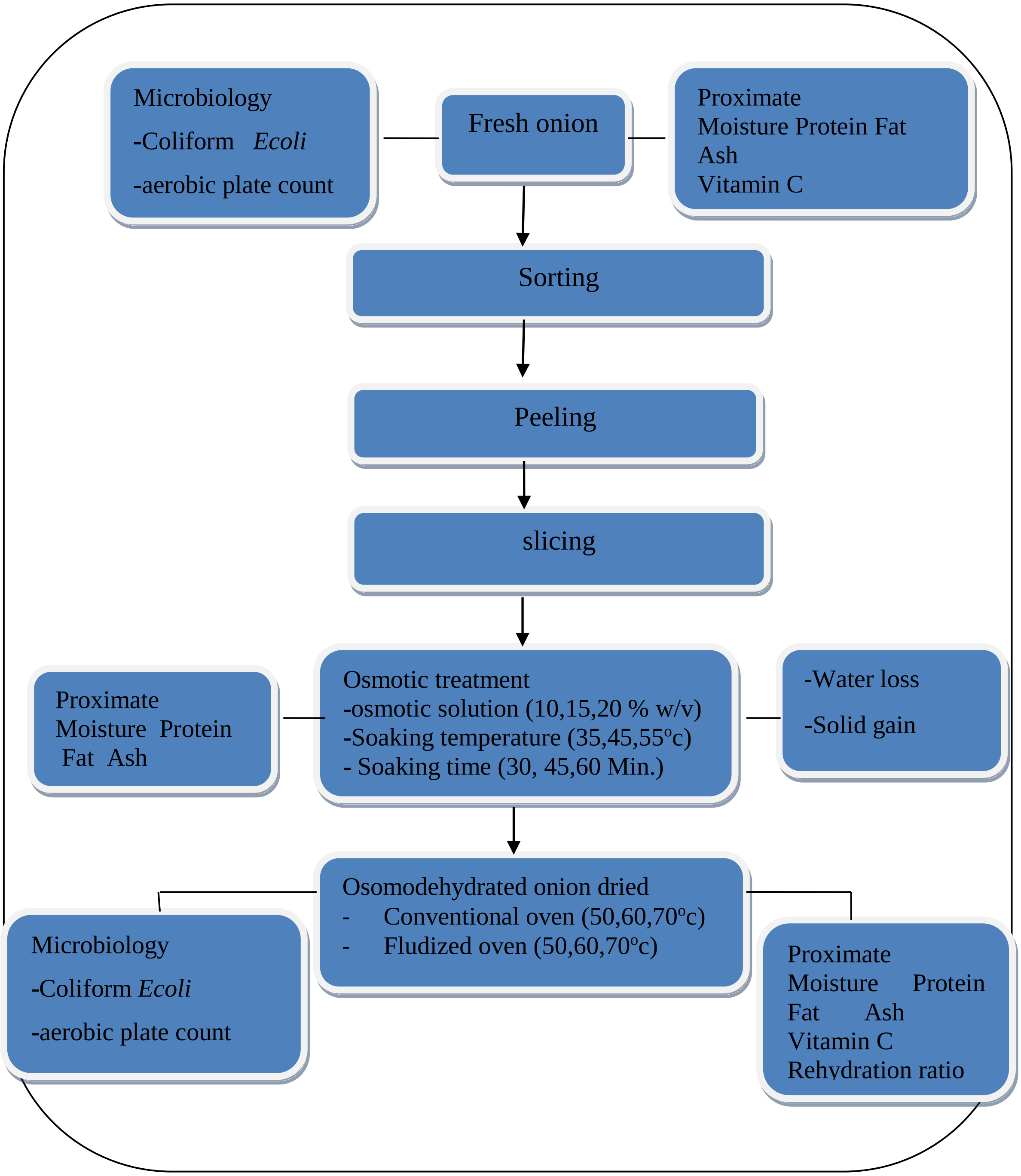


Figure 3.1 Framework of the experiment

3.2PROCESSING METHOD

3.2 .1 Osmotic Drying (OD) Experiment

Osmotic drying (OD) was carried out in order to remove the moisture content prior to thermal drying. The osmotic dehydration experiment was performed in a beaker placed in a water bath which was equipped with temperature regulator and timer. The effect of processing variables; Osmotic Solution Concentration (10, 15 and 20 % w/v), Soaking Temperature (35^{o}C,45^{o}C, and55^{o}C) and Soaking Time (30, 45, and 60 min) on some quality attribute of pretreated onions were investigated.

A salt solution was first warmed to the designated temperature and sliced onions (previously weighed) were immersed into the solution. The weight/volume ratio of osmotic medium to onion samples was maintained at 5:1(w/w), in order to avoid significant dilution of the medium. The solution in the beakers was manually stirred at regular interval to maintain uniform temperature. At the end of dehydration experiment, the samples were removed, immediately rinsed in flowing water and placed on adsorbent paper for 5 minutes to remove the surface moisture to eliminate excess solution from the surface before weighing.

Finally the samples were weighed and their moisture content (water loss) and solid gain was determined. Water loss was the quantity of water lost by the food during OD. All analytical determinations were performed in duplicate. Values were expressed as the mean ±standard deviation.

3.2.2 Drying procedure

After pre-drying treatment via osmotic dehydration, the treated samples were drained for about ten min before they are arranged into the dryer. Drying was stopped when the products have reached their calculated final mass and this gave their targeted final moisture content of about 7wt/wt%. The products were withdrawn from the dryer spread on a net for 10 min to cool before being packaged and transferred to the laboratory for analysis.

Fluidized Bed Drying Method

For each replication of the experiment, 170g prepared onion slice samples were taken. A 15g sample was used for initial moisture content determination. Remaining 150g sample was first osmotically dehydrated for a time period as determined in the first phase of the study. This sample size would provide sufficient osmo-hot air dried product for quality parameters evaluation. A 15g osmo-dried sample was used for the determination of moisture content after osmosis. Left out osmo-dried sample was used for subsequent hot-air drying which was carried out in a fludized bed dryer. The dryer was set at the desired temperature and was allowed to run for about 30min to attain steady state condition. Osmotically treated *Adama red* onion with thickness 4mm was dried at different temperatures of 50,60,70 ^{O}C until the desired moisture level was attained. The hot air velocity passing through the material bed was kept at a constant value of 1 ms^{-1} for a single set experiment.

The temperature control was within ±1^{0}C. The osmo-dried samples were hot-air dried up to the desired moisture content. To determine the final moisture content, the sample was periodically removed during drying period and weighed on an electronic balance which took about 20 s. The dried samples were cooled in a desiccator containing silica gel for 1h, packed in zip-lip low-density polyethylene (LDPE) bags, sealed properly and kept at ambient temperature for quality analysis.

Oven drying method

For each replication of an experiment, 170g prepared onion slices sample was taken. A 15g sample was used for initial moisture content determination. Remaining 150g sample was first osmotically dehydrated for a time period as determined in the first phase of the study. This sample size would provide sufficient osmo-hot air dried product for quality parameters evaluation. A 15g osmo-dried sample was used for the determination of moisture content after osmosis. Left out osmo-dried sample was used for subsequent hot-air drying which was carried out in a conventional oven dryer. The dryer was set at the desired temperature and was allowed to run for about 30min to attain steady state condition. Osmotically treated *Adama red* onion with thickness 4mm was dried at different temperatures of 50,60,70 ^{O}C until the desired moisture level was attained.

The temperature control was within ±1^{0}C. The osmo-dried samples were hot-air dried up to the desired moisture content. To determine the final moisture content, the sample was periodically removed during drying period and weighed on an electronic balance which took about 20 s. The dried samples were cooled in a desiccator containing silica gel for 1h, packed in zip-lip low-density polyethylene (LDPE) bags, sealed properly and kept at ambient temperature for quality analysis.

3.3 LABORATORY ANALYSIS

The effect of processing during development of dried onion was studied by analyzing the moisture loss and the texture of the final product, conducting proximate analysis, physico-chemical analysis and sensory evaluation. The influence of temperature the drying of onion was also studied to find out how the drying process affects the qualities of the onion.

3.3.1 Proximate Analysis

The proximate analysis was conducted at Bless agri food laboratory, and all the moisture content, protein, fat, crude fiber, carbohydrate and ash were determined according to AOAC methods. All of the chemicals and reagents used for the analysis were supplied by Bless agri food laboratory

Moisture Determination

The amount of water present in the onion sample was considered to be equal to the loss of weight after drying the sample to constant weight at a temperature of 100o C according to Method AOAC (Formula:

$$\% \text{ Moisture} = \frac{W2 \times 100}{W1}$$

Where W_1 = Weight of wet sample

W_2 = Loss of Weight

Crude Fiber

The crude fiber content of the onion sample was analyzed according to Method AOAC (2003); a fat-free or low fat content sample is treated with boiling sulfuric acid and subsequently with boiling potassium hydroxide or sodium hydroxide, the residue after subtraction of the ash is regarded as fiber.

Crude fiber g/100g= $\frac{(W1 - W2)\ (100\text{-}M)}{W3}$

Where W_1 = Crucible weight before drying (g)

W_2 = Crucible weight after drying (g)

W_3=Sample dry weight

M = Moisture content of sample (%)

Crude Protein

Kjeldahal method of nitrogen analysis was used during determination of crude protein (AOAC, 2003) as follows. All nitrogen is converted to ammonia by digestion with a mixture of concentrated sulfuric acid and concentrated orthophosphoric acid containing potassium sulfate as a boiling point raising agent and selenium as a catalyst. The ammonia released after alkalinization with sodium hydroxide is steam distilled into boric acid and titrated with sulfuric acid.mg nitrogen×100 mg sample

mg nitrogen = (T- B)×N×14× 100

g nitrogen/100g sample = $\frac{\text{mg nitrogen}\times 100}{mgsample}$

Total nitrogen % = $\frac{(T - B)\times N\times 14\times\ 100}{W}$

Where B= Volume sulfuric acid solution used in titration for blank

N= Normality of acid

14 = Equivalent weight of nitrogen

W= Weight of sample

T= Volume of sulfuric acid solution used in the titration of test materials

Fat Content

Soxhlet method of solvent extraction was used during determination of fat as stated in AOAC (2003) as follows. Fat is extracted with ether (peroxide free) from dried samples in a soxhlet apparatus, and the other is evaporated from the extraction flask. The amount of fat is calculated from the difference in weight of the extraction flask before and after extraction.

Fat g/100g fresh sample= $\frac{W \times 100}{WD}$

$W = W_2 - W_1$

Where W = weight of fat

W_2= weight of flask after extraction (g)

W_1= weight of flask before extraction (g)

Ash Content

The organic matter is burned off at low temperature and the inorganic materials remaining are cooled and weighed. Heating is carried out in stages, first to derive the water, then to char the product thoroughly and finally to ash at 550oC in a muffle furnace (AOAC, 1984).

% Ash = $\frac{W2 \times 100}{W1}$

W_2= weight of ash (g)

W_1= weight of sample (g)

Carbohydrates

The total carbohydrate contents of the onion sample (C %) by mass including crude fiber can be obtained as follows:

Formula:

C% =100-(P+F+A+M)

Where: P – The mass percent of protein

F – The mass percent of fat

A – The mass percent of ash

M – Moisture content (%)

Therefore, the Utilizable Carbohydrate (CHO) = Total CHO – Crude fiber

Determination of Vitamin C (Total Ascorbic Acid) Content

Vitamin C content of fresh and dehydrated onion was measured by potentiometric titration method. The onion samples were mashed with a mixer and then weighed into the beaker. After the addition of 50 mL deionised water the beaker is purged with nitrogen to avoid oxidation of the vitamin C. Prior to the analysis the pH of the sample solution has to be adjusted by either oxalic acid (2 %) for samples with a higher initial pH-value or with NaOH 0.1 mol/L for samples with an initial pH lower than 3.0.

Sample size: The sample size depends on the amount of vitamin C present in the sample. 1 - 15 mg of vitamin C lead to a consumption of 0.5 - 8.5 mL DPI.

Standard

100 mg ascorbic acid is weighed into a 100 mL volumetric flask and diluted with deionised water. The solution has to be kept in the dark and should be prepared fresh daily.

Preparation of the titrant

0.36 g of 2,6-Dichlorophenolindophenol (DPI) sodium salt monohydrate is weighed in a 250 mL volumetric flask, which is filled up with deionised water to obtain a titrant concentration of 0.01 mol/L. If 2,6-Dichlorophenolindophenol sodium salt dihydrate is used, an excess has to be weighed in due to its bad solubility and the titrant has to be filtrated prior to use. The DPI titrant has to be prepared fresh daily. It has to be stored in brown glass bottles.

Standardization of DPI

The same parameters of the titration method should be used for both standardization and determination. 5 mL of standard solution are pipetted into a titration beaker, diluted with deionised water and the beaker is purged with nitrogen to avoid oxidation of vitamin C. The pH is adjusted to 3.0 with oxalic acid (2 %).

3.3.2 Physico-chemical Analysis

The weight and moisture content of samples before and after the osmotic process were determined and used to calculate the variables water loss (WL) and solid gain (SG) of processed onion. Solid gain is the amount of solid added from the osmotic solution to the sample during OD. Solid gain (g/100g fresh sample), and water loss (WL, g/100g fresh sample) was calculated as follows:

Based on review of earlier works (Lenart and Flink, 1984), the Water loss (ML) was characterized using the following equation:

$$WL = \frac{X_O^w . M_O - X_t^w . M_t}{M_O} * 100$$

The solid gain (SG) was measured by the following equation as suggested by Lenart and Flink, 1984.

$$SG = \frac{X_t^{ts} . M_t - X_o^{ts} . M_o}{M_O} * 100$$

where:

Mo = initial mass of the sample

X_t^{ts} total solid concentration of sample at time t

X_o^{ts}intial solid concentration of sample

X_O^wintial water concentration of sample

X_t^w water content of sample at time t

Rehydration ratio

The rehydration ratio, as a measure of quality characteristics of dried onion slices, was determined by immersing 1 g of dried samples in distilled water at 30 and 100 ^{o} C temperatures. The samples was drained and gently blotted with tissue paper in order to remove the superficial water and finally weighed at every 30-min and2-min intervals for those immersed at 30 and 100^{o}C, respectively. Rehydration ratio was defined as the ratio of the weight of rehydrated samples to the dry weight of the sample (Abbasi, 2011)

3.3.3 Microbiological Analysis

The microbiological analysis was conducted at Bless agri food laboratory for two samples selected from the final products of both fresh onion and dried products. The analysis methods and procedures were listed in the annex. For microbiological assessments, samples were examined for total plate count (TPC), and total coliforms and *Ecoli* as per the procedure described by Vanderzant and Splittstoesser (1992).

3.3.4 Sensory Evaluation

Sensory evaluation with 9-point hedonic scale for the products was carried out by 15 (5 males and 10 females) panelists who were selected from Hilina food processing who have already experience of the concept of sensory analysis. They were requested to express their perceptions about the products by scoring the following attributes: color, flavor and overall acceptability.

The sensory attributes; visual color, flavor and overall acceptability were evaluated using a nine point hedonic scale rated from 1 (dislike extremely), 5(neither like nor dislike) to 9 (extremely like). Just before the test session, orientation was given to the judges on the procedure of sensory evaluation. Coded dried onion product samples were arranged in a random order on white plates and served to the panelists. Just before test session, panelists were given a 20 min orientation about the procedure of sensory evaluation

3.3.5 Statistical Analysis

Response surface methodology **(**RSM) was used to study the main effects of the process variables on mass transfer during OD of fresh onion and to find the optimum operation conditions. The experimental design adopted was a full factorial design with three factors and three levels. The actual factor values, chosen from preliminary tests, and the corresponding coded values (-1, 0, 1) are given in Table 3.1. Weight loss and solids gain of the dehydrated samples were the dependent variables. The complete design consists of 32 experimental runs with five replications of the center point. Experimental runs were carried out in random order.

All experiments were conducted in duplicate and the data was subjected to analysis of variance. Differences were identified as significant or non-significant based on student test for each variables (i.e dehydration time OD). A significance level of 0.05 was used in all cases. The design of experiment was done by full factorial design and using statistical software design expert 6.0.8. Response surface methodology RSM was employed using general factorial design for three numeric factors. The experiments for OD of onion slice using three factors: salt concentration (10 to 20%, w/w), contact time (30-60 minutes) and temperature (35 to 55 °C). The variables were process temperature, solute concentration and duration of OD process.

Three different levels for each experiment in coded form were –1, 0 and +1. The levels of input variables in coded and uncoded form are given in Table 3.1. Further, it was assumed that three functions exist between each response and the input factors. A second order polynomial equation was fitted to the experimental data of each independent variable as given below.

$$Y_k = B_{k0} + \sum_{i=1}^{3} B_{ki}x_i + \sum_{i=1}^{3} B_{kii}x_i^2 + \sum_{i=1}^{3} B_{kij}x_ix_j + e_k$$

where Yk = response variable (Y1 = water loss; Y2 = solid gain) and xi represent the coded independent variables (i = 1,2,3 = A, B, C respectively, where, A = process temperature; B = solute concentration; C = process duration), Bk0 is the value of the fitted response at the center point of the design, Bki, Bkii and Bkij are the linear, quadratic and interaction regression coefficients, respectively.

Table 3. 1 coded and uncoded values of variables and their level

Independent variable	Coded value	-1	0	+1
Temperature(process temperature ,^{O}C)	A	35	45	55
Osmotic Solution concentration (w/v %)	B	10	15	20
Soaking Time(Minutes)	C	30	45	60

Regression analysis and analysis of variance was carried out for fitting the model to the experimental data and to examine the statistical significance of the model. Three dimensional response models were generated. The response surface plots were generated for different variables, while holding the values of third variable as constant (at the central value). Such response surface plots give accurate geometrical representation and provide useful information about the behavioral system with experimental design.

The models obtained were used to interpret the effect of various variables on the responses i.e. WL and SG. The optimization of the OD process was aimed at finding the levels of three independent factors (salt concentration, time and temperature) which would give maximum possible WL, minimum SG and maximum RR. Once the OD characteristics were established, osmotically dried onion two drying methods oven drying and fluidized bed drying were employed.

Results were expressed as mean values ± standard deviations. Each analysis assay was done two times from the same sample to determine reproducibility. Analysis of variance (ANOVA) was used to test any difference in properties of fresh and dried onion samples. Duncan's new multiple range test was used to determine significant differences.

CHAPTER FOUR
4. RESULTS AND DISCUSSION

The first part of this section determines the influence of temperature, osmotic solution concentration and soaking time during osmotic dehydration of fresh onion slices on water loss (WL) and solid gain (SG).Using these data, the optimal operating conditions were evaluated. In the second section, two types of drying methods such as conventional oven drying and fluidized bed drying were investigated and the effect of drying temperature on the quality of dried onion were discussed. Finally the quality of dried product sensory and nutritional measurements was conducted.

4.1 GENERAL NUTRITIONAL COMPOSITION OF FRESH *ADAMA RED* ONION BULBS

The preliminary test results of the proximate analysis of the *Adama red* onion varieties are presented in Table 4.1. Fresh onion from Melkasa research institute with the initial moisture content of 87.11% (±2) was used for experiments. The composition of was measured using AOAC test methods. From the results the chemical analysis, as given in table 4.1, it could be illustrated that the moisture, total carbohydrate, crude protein, crude fat, ash and crude fiber contents of fresh *Adama red* onion were found to be 87.11, 9.2, 1.03, 0.5, and 2.1 % on wet weight basis; respectively.

Table 4.1General nutritional composition of fresh *Adama red* onion

Component	Average value /100g fresh weight
Energy(Kcal)	43.14
Moisture(g)	87.11±2.1
Protein(g)	1.03±0.14
Fat (g)	0.5±0.07
Carbohydrate(g)	9.2±0.19
Fiber (g)	2.1±0.21
Ash (g)	0.5±0.01
Vitamin c(mg)	18.5±1.45

4.2 OSMOTIC DEHYDRATION OF FRESH SLICED ONION

In this section the results obtained from the pretreatment of onion in osmotic solution were presented in table 4.2. The effect of different parameters on the osmotic treatment of onion slice dehydration was explained. The influence of operation variables on water loss and solid gain was discussed. The variables selected which significantly affect water loss and solid gains were Osmotic Solution Concentration (OSC), Soaking Temperature (T) and Soaking Time (t). The effect of these parameters on water loss and solid gain was discussed as follows.

Table 4.2 Designed experiments according to full factorial design and measured responses of system

No	Soaking Temperature (^{o}c)	Osmotic Solution Concentration (%)	Soaking Time(Minutes)	Water loss(%)	Solid gain(%)
1	45	15	45	18.71±0.033	9.31±0.024
2	35	15	30	11.35±0.03	7.88±0.053
3	45	15	45	17.54±0.019	8.86±0.036
4	45	10	30	10.49±0.021	4.14±0.020
5	45	15	45	16.10±0.041	10.31±0.019
6	55	15	60	16.87±0.037	10.49±0.016
7	35	20	45	12.96±0.048	8.98±0.035
8	45	20	60	18.89±0.009	11.77±0.035
9	45	10	45	12.94±0.022	6.31±0.013
10	55	20	45	18.91±0.012	10.68±0.62
11	45	10	60	14.0±0.007	8.79±0.048
12	45	15	45	18.02±0.021	10.37±0.008
13	55	20	30	15.60±0.016	10.33±0.007
14	35	20	60	13.66±0.016	9.03±0.003
15	45	15	60	18.48±0.003	10.14±0.004
16	35	10	30	17.40±0.004	4.88±0.001
17	55	15	45	16.30±0.08	8.57±0.045
18	55	10	60	11.64±0.29	5.59±0.013
19	45	15	30	17.40±0.10	10.44±0.028
20	55	10	30	9.97±0.014	3.20±0.016
21	35	10	60	14.27±0.22	9.17±0.026

No	Soaking Temperature (^oc)	Osmotic Solution Concentration (%)	Soaking Time(Minutes)	Water loss(%)	Solid gain(%)
22	55	20	60	18.73±0.49	10.81±0.012
23	35	20	30	12.58±0.14	8.31±0.011
24	55	10	45	10.07±0.28	5.65±0.45
25	35	15	45	13.08±0.016	8.97±0.016
26	45	15	45	18.54±0.011	11.31±0.027
27	55	15	30	13.06±0.012	7.27±0.023
28	35	15	60	14.27±0.030	10.17±0.014
29	35	10	45	11.82±0.008	5.34±0.010
30	45	15	45	17.59±0.023	9.76±0.053
31	45	15	30	16.96±0.016	10.31±0.024
32	45	20	45	17.92±0.004	11.42±0.022

WL -water loss (g/100g fresh sample)   SG-solid gain (g/100g fresh sample)

4.2.1 Effect of Osmotic Solution Concentration on Sliced Onion Water loss and Solid Gain

Osmotic solution concentration has a more noticeable effect on the physico-chemical Characteristics (water loss and Solid gain) of treated onions. The effect of solution concentration on water loss and solid gain of fresh sliced onions were conducted at10%, 15% and 20% salt concentration maintaining soaking time and soaking temperature constant at 45 minutes and 45^0 c respectively as shown in Figure 4.1 and 4.2 respectively. As shown in Figure 4.1, the water loss associated with fresh sliced onion immersed in osmotic solution, with concentration of 10%, 15%, and 20% was 12.938, 17.75, and 17.92% respectively. Increased osmotic solution concentrations lead to increased water loss. This was attributed to the water activity of the osmotic solution which decreases with the increase in solute concentration in the osmotic solution. Increased osmotic solution concentrations lead to increased weight reductions (Marcotte, 1991; Tortoe, 2010).Therefore, increased osmotic solution concentrations lead to increased weight reductions. This was attributed to the water activity of the osmotic solution which decreases with the increase in solute concentration in the osmotic solution.

As shown in figure 4.2, solid gain of fresh sliced onion immersed in osmotic solution with concentration of 10%, 15%, and 20% was 6.31, 9.99, 11.42% respectively. From this result it can be seen that, increasing the osmotic solution concentration increases the solid gain of fresh sliced onions. This might be due to increase of osmotic pressure gradient and consequent loss of functionality of cell plasmatic membrane that allows solute to enter. Similar results were reported by (Lazarides1995). These results indicate that at a higher solution concentration, faster water loss could be achieved and a much greater solids gain is observed by Azoubel and Murr (2003).

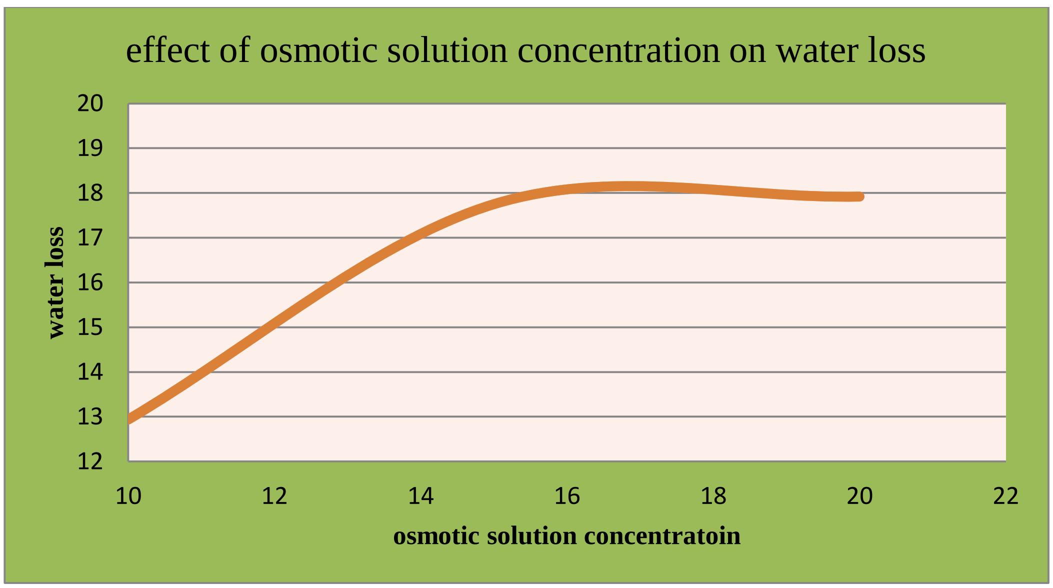


Figure 4.1   Effect of osmotic solution concentration on water loss

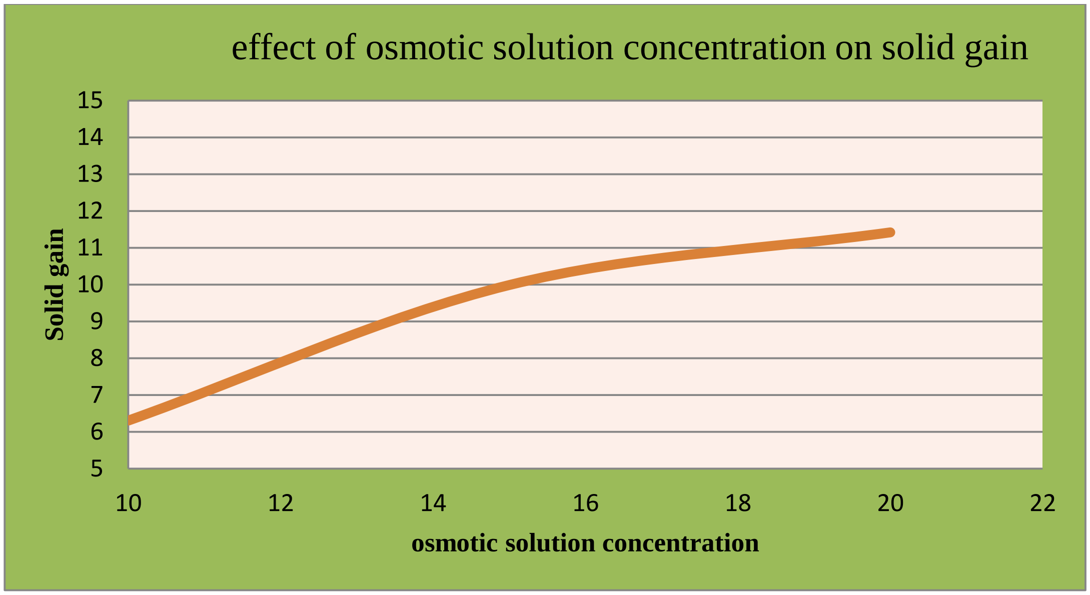


Figure 4.2 Effect osmotic solution concentrations on solid gain

4.2.2 Effect of Soaking Temperature on Sliced Onion Water loss and Solid Gain

Soaking Temperature has significant effect on the physico-chemical Characteristics (water loss and Solid gain) of treated onions. For the investigation of the effect of soaking temperature on water loss and solid gain were conducted ate 35°C, 45°C and 55°C and maintaining soaking time and osmotic solution concentration constant at 45 minutes and 15 % respectively as shown in Figure 4.3.

Water loss of fresh sliced onion immersed in osmotic solution with temperature of 35°C, 45°C and 55°C was 13.07, 17.75, and 16.29% respectively. increase in temperature of osmotic solution results in increases in water loss. Temperature has an effect on the cell membrane permeability that could allow solute to enter by losing its selectivity, Similar results were found (Rafiq Khan, 2012) .

As shown in figure 4.4, solid gain of fresh sliced onion immersed in osmotic solution with of 35, 45 and 55°c soaking temperature maintaining soaking time and soaking temperature constant at 45 minutes and 45^0 was 8.968, 9.99, and 8.57% respectively. Statistical results showed that there are no significance differences in % SG with increase in temperature of the osmotic solution. Processing temperature did not have significant effect on the solid gain of onion slices similar result have been reported for osmotic dehydration of onion by Sagar (2001)

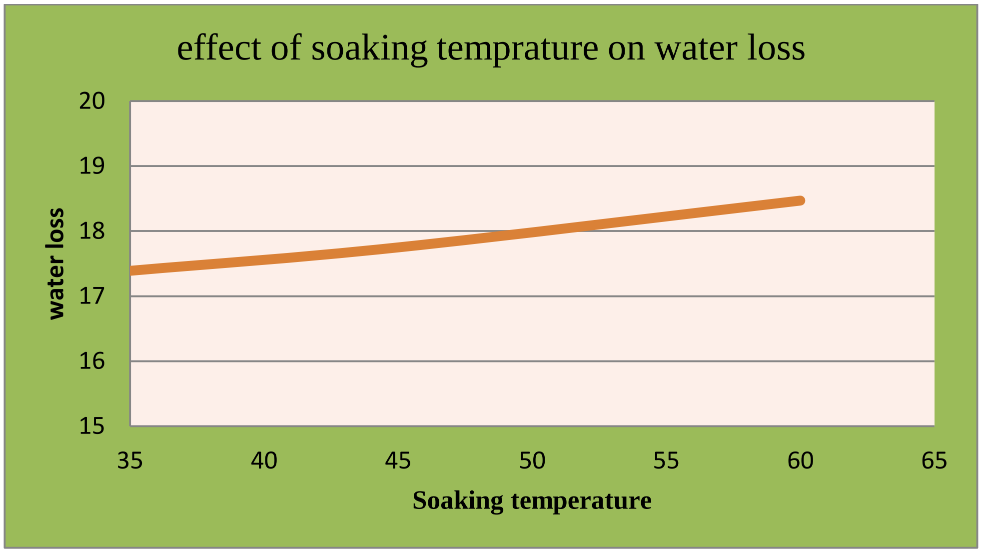


Figure 4.3 Effect of Soaking temperatures on water loss

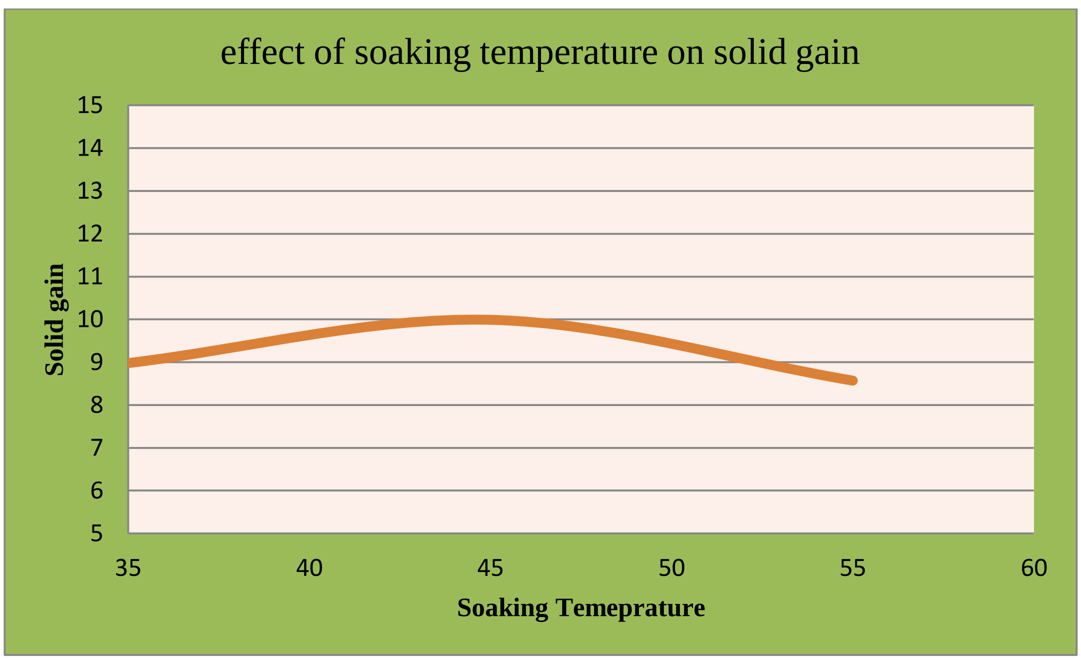


Figure 4.4 Effect of soaking temperature on solid gain

4.2.3 Effect of soaking time on Sliced Onion Water loss and Solid Gain

As shown in figure 4.5, solid gain of fresh sliced onion immersed in osmotic solution with soaking time of 30, 45, and 60 minutes maintaining osmotic solution concentration and soaking temperature constant at 15 % and 45^0c was 7.44, 9.99, 10.142% respectively. From this result it can be seen that, increasing the osmotic solution soaking time increases the solid gain of fresh sliced onions. This might be due to increase of osmotic pressure gradient and consequent loss of functionality of cell plasmatic membrane that allows solute to enter. Similar results were reported by (Lazarides, 1995).

As shown in figure 4.6, solid gain of fresh sliced onion immersed in osmotic solution with soaking time of 30, 45, and 60 minutes maintaining osmotic solution concentration and soaking temperature constant at 15 % and 45^0c was 17.398, 17.75, 18.476% respectively. From this result it can be seen that, increasing the osmotic solution soaking time increases the water loss of fresh sliced onions.

Solid gains were faster in the initial period of osmosis and then the rate decreased. This was because osmotic driving potential for moisture as well salt transfer was kept on decreasing with time as the moisture keeps moving from onion slice to solution and the salt from solution to onion slice. Similar results have been reported by Ertekin and Cakaloz (1996) .Uptake of solids near the surface in the beginning may result in structural changes leading to compaction of this surface layers and increased mass transfer resistance for water and solids.

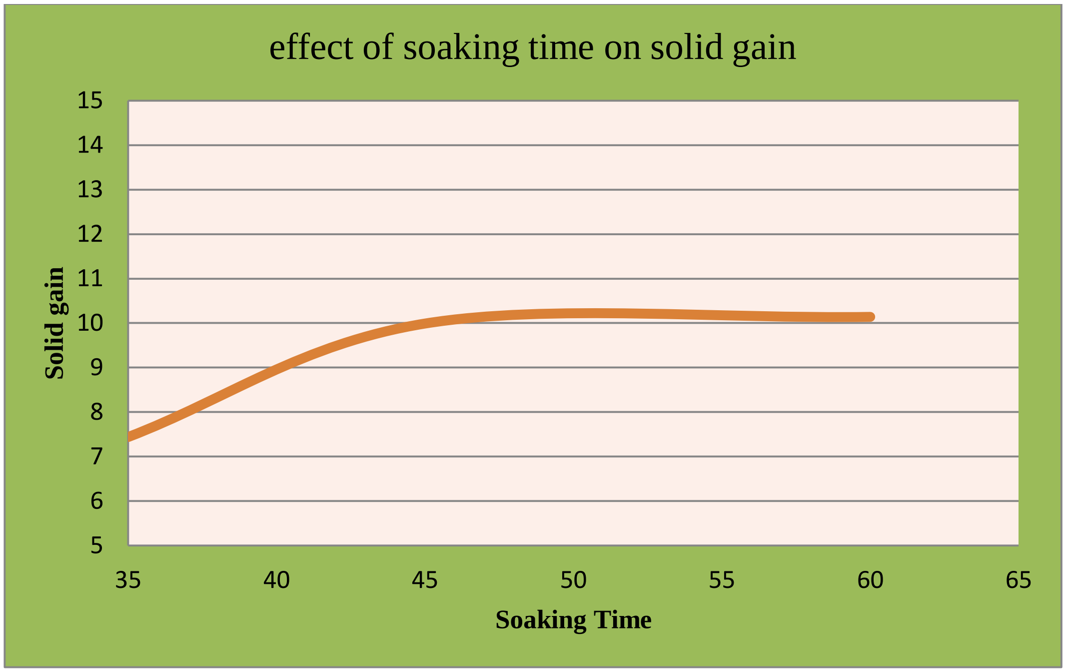


Figure 4.5 Effect of soaking time on water loss

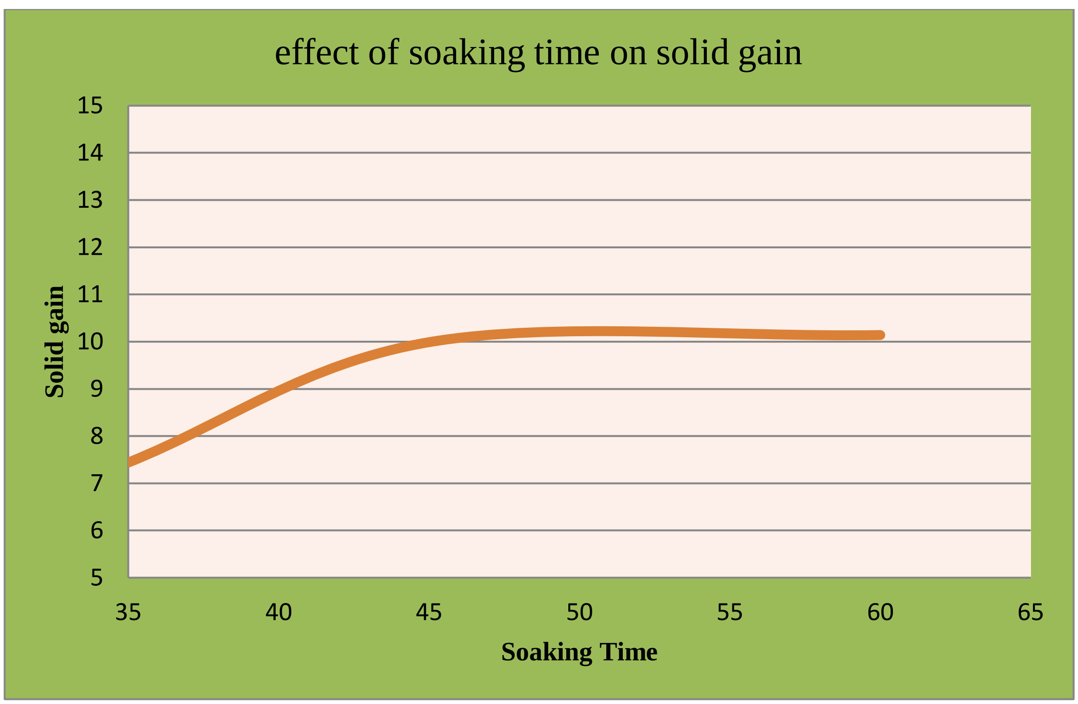


Figure 4.6 Effect of soaking time on solid gain

4.2.4 Interaction Effect of Soaking Temperature and Solution concentration

Figure 4.7 shows the contour plot of the interaction between soaking temperature and osmotic solution concentration maintaining soaking time constant (45 minutes), soaking temperature and osmotic solution concentration affect the water loss significantly ($p<0.0001$).However, this increase was less pronounced at 20 % osmotic solution concentration as compared to 10%.

Figure 4.8 shows the contour plot of the interaction between soaking temperature and osmotic solution concentration maintaining soaking time constant (45 minutes), soaking temperature and osmotic solution concentration affect the solid gain significantly ($p<0.0001$).

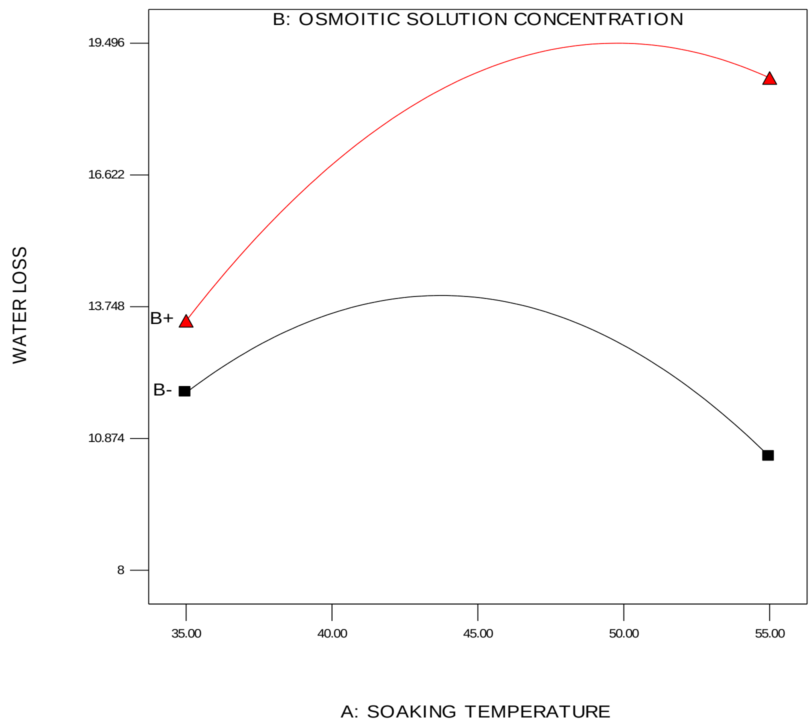


Figure 4.7 Interaction effect of Soaking Temperature and Solution concentration on water loss

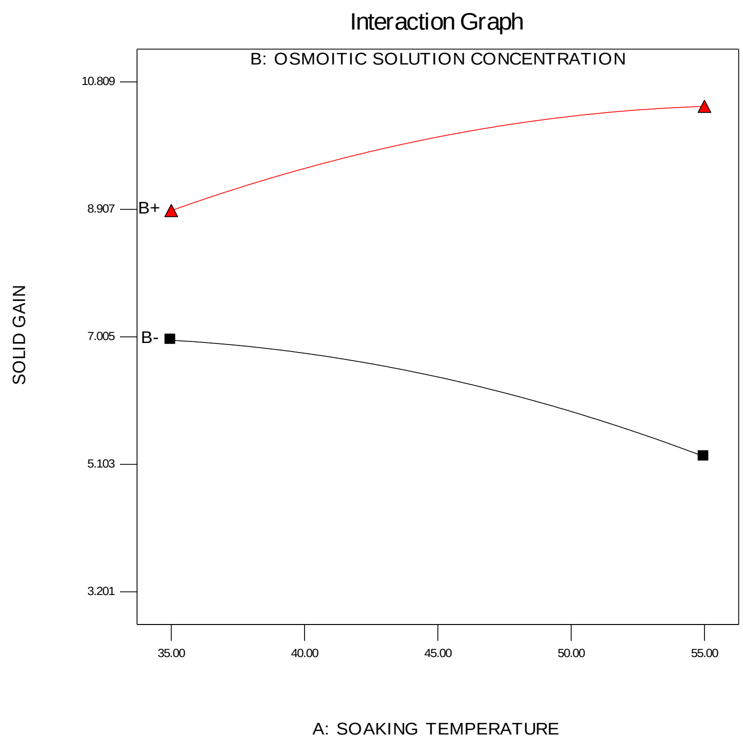


Figure 4.8 Interaction effects of soaking temperature and osmotic solution concentration on solid gain

4.2.5 Interaction effect of soaking time and osmotic solution concentration on water loss

At a 45^0 C soaking temperature the interactive effect of soaking time and osmotic solution concentration affect the WL positively at 0.5% level of significance. These results indicate an increase in WL with increase in osmotic solution temperature for specific immersion time. However, this increase was less pronounced when immersion time was increased (Figure 4.8). These results are in agreement with Park *et al.* (2002) who also observed an increase in water loss with increase in concentration of the osmotic agent. As the salt concentration was increased, water loss was more pronounced with increase in time showing the positive interaction effect of process time and salt concentration on WL. Increased concentration showed it pronounced effect on WL taking more time as further increase of salt concentration reduces the water loss that might have lead to the salt gain by the onion which was not desirable. This is attributed to the diffusion of water from dilute medium to the concentrated hypertonic solution developed in the onion.

Maintaining constant soaking temperature 45^0 C, the interactive effect of soaking time and osmotic solution concentration was found to be negative. Similar result was also reported by Manivannan and Rajasimman (2008) during the osmotic dehydration studies on in salt solution.

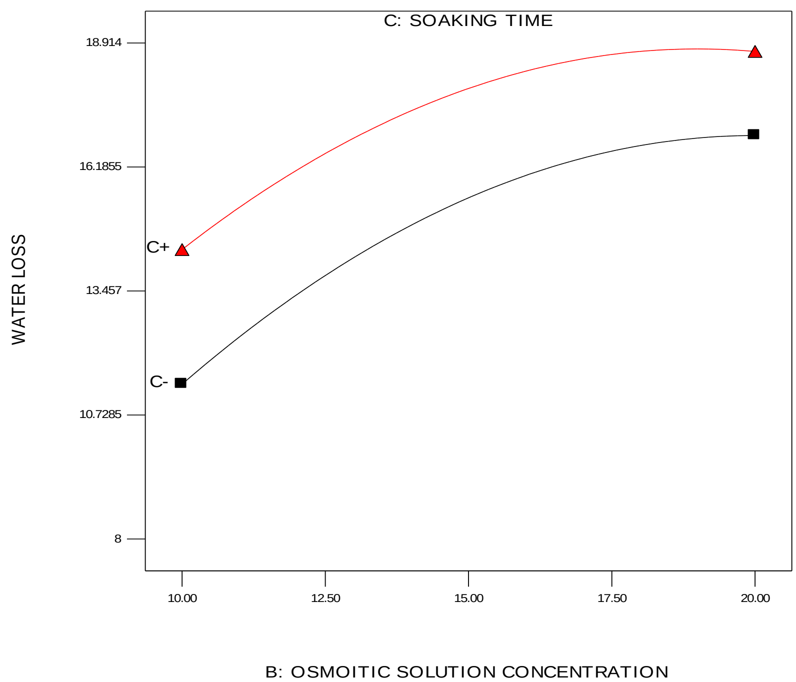


Figure 4.9 Interaction effect of soaking time and Solution concentration on water loss of Sliced Onion

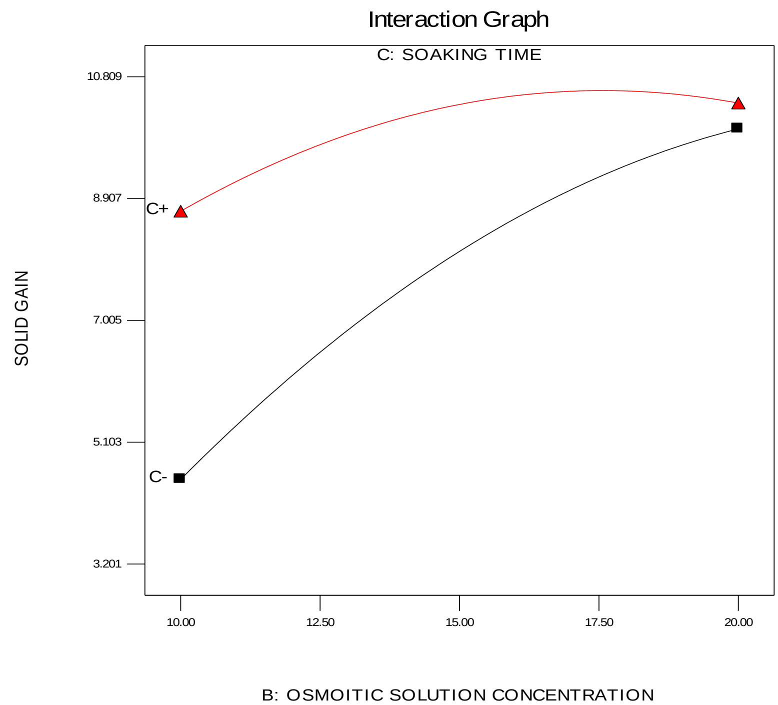


Figure 4.10 Interaction effect of soaking time and solute concentration on solid gain

4.2.6. Interaction Effect of Soaking Temperature and Soaking Time on Water loss and Solid Gain

The c plot (Figure 4.10) demonstrates that both soaking temperature and soaking time has individual impact on water loss, while their interaction effect was negative. At a 15% salt concentration the interactive effect of soaking temperature and soaking time donot affect the WL positively at 0.5% level of significance. These results indicate an increase in WL with increase in osmotic solution temperature for specific immersion time. However, this increase was less pronounced when immersion time was increased. The present results are also in agreement with those of Singh *et al.* (2007) who observed increase in WL with increase in soaking temperature and soaking time.

The plot (Figure 4.11) demonstrates that both soaking temperature and soaking time interaction effect is negative. Maintaining osmotic solution concentration constant 15%, the solid gain do not change with increase in immersion temperature but increase with soaking time.

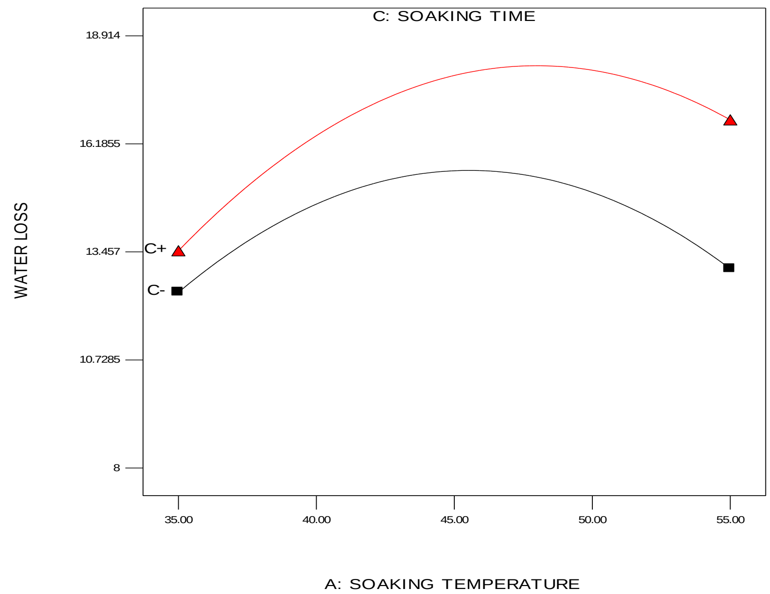


Figure 4.11 Interaction effects of Soaking Temperature and Soaking Time on WL

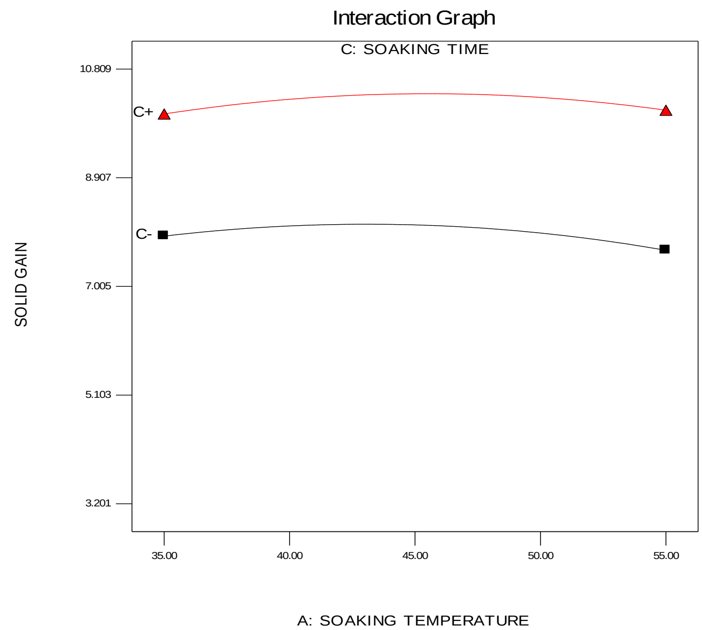


Figure 4.12 Interaction effects of Soaking Temperature and Soaking Time on SG

4.2.7. Interaction Effect of Soaking Temperature, Solution Concentration and Soaking Time on Sliced Onion Water loss and Solid Gain

As shown in annex 9 and 10 , all the process variables osmotic solution concentration ,soaking time and soaking temperature at interaction level had positive effect on WL ($p < 0.0001$).

In linear terms, soaking time and salt concentration were found to be significant model terms with an increasing effect on SG ($p < 0.0001$) whereas, process temperature was non-significant model term.

4.2.8 Response surface plot Analysis for Optimizing conditions of osmotic dehydration of *Adama red* onion

Optimizing of independent variables for osmodehydrated onion slices was determined by superimposing the plot for selected responses. The contour plot for all responses were superimposed and the region that best satisfy all the constrains were selected as optimum conditions. The main criteria for constrain the optimization were minimize solid gain and maximize water loss. The optimum osmotic dehydration pretreatment was predicted at soaking time 38.79 minutes, soaking temperature 45.8 ^{o}c and osmotic solution concentration 11.08%.

The constraint criteria for optimization were shown below in Table 4.3.

Table 4.3 Constraints, criteria for optimization, solution along with predicted and actual response values

Constraints	Goal	Lower limit	Upper limit	Importance	Solution
Salt concentration (%)	In range	10	20	3	11.08
Time (minutes)	In range	30	60	3	38.78
Temperature (°C)	In range	35	55	3	45.8
WL	Maximize	8	18.914	3	14.7
SG	Minimize	3.2	10.805	3	6.3

The predicted values and actual reported values for any response differed non-significantly ($p < 0.05$)

Verification of the model

Osmotic dehydration experiments were conducted at the optimum process conditions for testing the adequacy of the model equation for the prediction of the response values .The observed experimental values and predicted by the equation of the model are presented in the table 4.4 below.

Table 4.4 Verification of the model

Response	Predicted value	Experimental value	CV %
Water loss	14.7	14.7 6 ± 0.7	5.01
Solid gain	6.3	6.27± 0.3	4.95

The predicted and the experimental value of response conditions for osmodehydratedd onion slice are significantly the same ($P< 0.05$).

Water Loss and Solid Gain

Water loss

The maximum WL in osmotically dehydrated onion slices observed was 18.94%, while the minimum was 8.0%. It was indicated in Annex 8 that model was significant and the lack of fit was non-significant showing the significance of model at 5% level of significance. The coefficient of determination (R^2) was 0.960 and the predicted R^2 of 0.901 was in reasonable agreement with adjusted R^2 of 0.964 in case of WL. The regression equation describing the effects of process variables on water loss in terms of coded values of variable is given as

$$\text{Water loss}=-46.39+1.889\times T +0.7039\times C +0.357\times t +0.03T\times C +4.52\times10^{-3} T\times t -3.71\times10\text{-}^{3}C\times t$$

Where T= Temperature, C= Concentration, t= time

The linear positive terms indicated that water loss increased with increase in soaking temperature, osmotic solution concentration and soaking time. The presence of positive interaction terms between soaking temperature and soaking time as well as osmotic solution concentration and soaking time indicated that increase in their levels increased water loss. The negative values of osmotic solution concentration and soaking time indicated that higher values of these variables further reduced water loss.

Solid gain

Annex 9 indicated that the model was significant and lack of fit was non significant for SG, which again confirms that the model was significant at 5% levels of significance. The coefficient of determination (R^2) was 0.964 and the predicted R^2 of 0.9357 was in reasonable agreement with adjusted R^2 of 0.9502 in case of SG. In linear terms, process time and salt concentration were found to be significant model terms with an increasing effect on SG ($p < 0.005$) whereas, process temperature was non-significant model term.

The regression equation describing the effects of process variables on solid gain in terms of coded values of variables is given as

Solid Gain $=-7.95+0.0136\times T +1.173\times C +0.158\times t +0.0164 T\times C +5.23\times 10^{-4} T\times t - 0.0126\times 10^{-3} C\times t$

Where T= Temperature, C= Concentration, t= time

The linear positive terms indicated that water loss increased with increase in osmotic solution concentration and soaking time. The presence of positive interaction terms between soaking temperature and soaking time as well as soaking temeprature and soaking time indicated that increase in their levels increased solid gain. The negative values of osmotic solution concentration and soaking time indicated that higher values of these variables further reduced solid gain.

Optimization Solutions obtained from the osmotic treatment Conditions

In order to optimize the process of OD the maximization of WL, and minimization of SG were the considerations. The constraint criteria for optimization, solution along with predicted and actual values are shown in Table 4.4. Using the given criteria, process conditions were optimized at salt concentration of 11.08 %, time 38.78 minutes and temperature 45.80 °C in order to obtain WL of 14.7%, SG of 6.3%. Experiments were conducted based upon solution obtained.

The predicted and actual values for all responses were not statistically different at 5% level of significance as verified from *t*-test. The results showed that coefficient of variance (CV) of the responses were less than 5.0%, which confirmed that the predicted and actual values of all the responses were in close agreement with each other. Therefore, optimum conditions obtained in the model was recommended for OD of onion. Therefore, OD of onion could effectively be used as a pretreatment prior to fludized bed and oven drying to reduce energy costs and maintain the naturalness of the product.

4.3 EFFECT OF DRYING TECHNIQUES (CONVENTIONAL OVEN AND FLUIDIZED BED OVEN) ON CHARACTERISTICS OF DRIED ONIONS

In this section the two kinds of drying were compared for drying (Conventional oven and fluid bed dryers) of the pretreated onion slice. In addition, treated onions were dried at three different air dry bulb temperatures (50°C, 60°C and 70°C) to determine the influence of temperature on nutritional quality using a conventional drying oven and fluidized bed dryer. The quality of onion slices were studied by analysis of different parameters at drying temperatures. The quality parameters investigated were nutritional composition, vitamin C, rehydration properties, microbiological and sensory properties.

4.3.1 Effect of drying techniques (Conventional Oven and Fluidized Bed Oven) on chemical composition of dried onion

Table 4.5 Effect of dehydration method on chemical composition of dried onion (on wet basis)

Name of Sample	Temp. (°c)	Moisture (%)	Constituents				
			Protein (%)	Fat (%)	Ash(%)	Fiber (%)	Carbohydrate (%)
Fresh		87.11± 2.1	1.03± 0.14	0.5± 0.07	0.5± 0.01	1.5± 0.21	9.2± 0.19
Conventional oven							
Without OD treatment	70 °c	7.9± 0.014	12.97± 0.014	1.12± 0.01	0.84± 0.01	6.1± 0.09	71.97± 0.29
Dried Onion (Osmotically Pretreated)	50 °c	8.7± 0.035	13.7± 0.031	0.4± 0.07	0.5± 0.012	5.6± 0.01	73.4± 0.049
	60 °c	7.5±0.049	13.6±0.0421	1.7±0.035	1.3±0.018	5.7±0.02	74.4±0.4
	70 °c	6.83± 0.071	14.8± 0.049	1.6± 0.002	1.4± 0.062	6.6± 0.07	74.6± 0.5
Fluidized bed dryer							
Without OD treatment	70 °c	7.22± 0.04	9.88± 0.038	1.29± 0.01	1.35± 0.07	6.4± 0.05	73.88± 0.6
Dried Onion (Osmotically Pretreated)	50 °c	6.25± 0.028	10.2± 0.021	1.6± 0.014	1.2± 0.01	5.3± 0.04	75.1± 0.2
	60 °c	5.88± 0.064	10.5± 0.035	1.3± 0.12	1.3± 0.04	5.1± 0.09	74.92± 0.4
	70 °c	5.44± 0.021	12.1± 0.018	1.6± 0.02	1.2± 0.08	5.03± 0.01	75.6± 0.7

From data in table 4.5, it could be noticed that, proximate composition was gradually increased by increasing of processing temperature. The moisture content in the samples of the dehydrated onion was in the range of 5-9%. Maximum moisture content was observed in oven dried sample (8.7 %) and minimum was in the fludized bed dried sample (5.44%). Proximate analysis of fresh and dehydrate onion shows that mean value of ash, crude fiber, fat, protein and carbohydrate content of dehydrate onions were higher than the fresh onion due to moisture loss and condensation of nutrients. However there is no significant difference in the proximate result of the two drying methods ($p > 0.05$).

4.3.2. Effect of drying techniques (Conventional Oven and Fluidized Bed Oven) on ascorbic acid (Vitamin C) content of dried Onions

Ascorbic Acid (Vitamin C) content of dried onion samples was determined. The results are shown below in Table 4.6 Amount of vitamin C was found in 100 g of fresh onion was18.5 mg, however after dehydration, the amount of vitamin C contained in dried onions decreased significantly ($p<0.05$) irrespective of type of drying technique employed. As shown in Table 4.5 and Figure 4.13, the ascorbic acid content (mg/100g of sample) of dried onion obtained using osmotic dehydration process followed by conventional ovens set at 50^oC, 60^oC and 70^oC was 5, 2.1, and 1.85 respectively. This signifies that at 50^oC, 60^oC and 70^oC drying temperature, 73%, 89%, and 90% of ascorbic acid was lost showing the adverse effect of high drying temperatures respectively. The result clearly shows that as the drying temperature increases, the amount of retained ascorbic acid (Vitamin C) in dried onion significantly decreases.

Table 4.6 Effect of dehydration on the retention of Vitamin C

Sample names	Drying Temp (º c)	Ascorbic acid Content (mg/100g)	Retained Ascorbic Acid Content (%)
Fresh Onion		18.5	100
Driedby conventional oven			
Without OD treatment	70 º c	ND	-
Dried Onion (Osmotically Pretreated)	50 º c	5.0^{d}	27.0
	60 º c	2.1^{f}	11.3
	70 º c	1.85^{g}	10.0
Driedby fluidized bed dryer			
Without OD treatment	70 º c	3.33^{e}	18
Dried Onion (Osmotically Pretreated)	50 º c	14.17^{a}	76.59
	60 º c	8.77^{b}	47.4
	70 º c	6.88^{c}	37.18

Values in the same column with different superscripts for each type of analysis are significantly different ($P<0.05$)

As shown in Table 4.6 and Figure 4.13, the ascorbic acid content (mg/100g of sample) of dried onion obtained using osmotic dehydration process and employing fluidized bed dryer set at 50ºC, 60ºC and 70ºC was 14.17, 8.77,and 6.88 respectively. This signifies that at 50ºC, 60ºC and 70ºC drying temperature, 23.5%, 52.6%, and 68.9% of ascorbic acid was lost showing the adverse effect of high drying temperatures respectively ($p< 0.05$). The result clearly shows that as the drying temperature increases, the amount of retained ascorbic acid (Vitamin C) in dried onion significantly decreases. Similar observation was made by (Adam *etal.*,2000) that high temperatures have adverse effect on vitamin C content of dried onion samples.

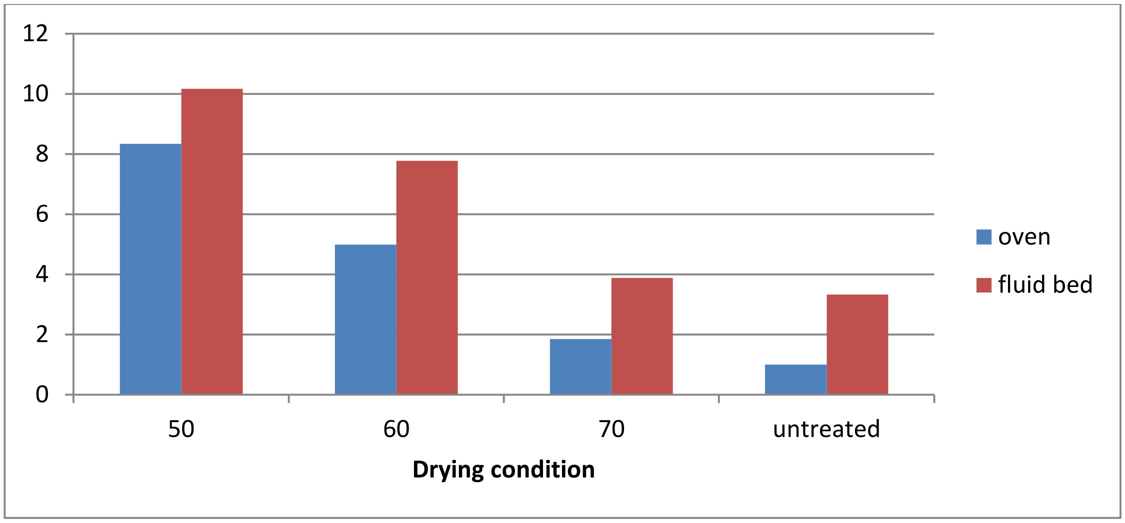


Figure 4.13 Effect of drying methods on ascorbic acid of dried onion

When comparing two types of drying techniques i.e. fluidized bed dryer and conventional oven, the former resulted in higher Vitamin C retention at all temperatures. This is due to heat sensitivity in nature of fluidized bed dryer but in the oven drying the sample is in direct contact with the dryer and loss of vitamin C was maximum. In addition, the osmotically dehydrated and dried in fluidized bed dried onion and oven dried samples slices at all the conditions showed significantly higher retention of ascorbic acid than the control samples. This may be due to the potassium metabisulfite pretreatment in combination with osmotic pretreatment of the onion slices prior to fluidized bed drying, which retarded the loss of ascorbic acid and further prevented oxidation.

4.3.3. Effect of drying techniques (Conventional oven and Fluidized bed oven) on Rehydration properties of dried Onions

Rehydration ratio is considered to be one of the important quality attribute for dry onion slices in the present study. Therefore, the rehydration values of the onion slices dried under various drying conditions were presented in Table 4.7 and Figure 4.14.

Table 4.7 Effect of dehydration method on rehydration ratio

Sample	Drying Temp (°C)	Rehydration ratio
Conventional oven		
Without OD treatment	70 °C	4.15[b]
Dried Onion (Osmotically Pretreated)	50 °c	2.9[c]
	60 °c	4.0[b]
	70 °c	3.85[b]
Fluidized bed dryer		
Without OD treatment	70 °c	4.74[a]
Dried Onion (Osmotically Pretreated)	50 °c	3.21[c]
	60 °c	3.65[b]
	70 °c	4.12[b]

Values in the same column with different superscripts for each type of analysis are significantly different ($P<0.05$)

During rehydration, the absorbed salt may be dissolved in water, which decreases the weight of the sample and hence the rehydration ratio. The structural damage and tissue shrinkage during drying generally affect the rehydration ability. During fluidized bed drying, the onion slices were exposed to a high air velocity for fluidization, and a large amount of heat was transferred to the sample for moisture evaporation. As a result, the drying rates were very high for the fluidized bed dried samples in comparison to the samples that were oven dried by hot air.

Rehydration efficiency was better at a higher temperature, because of faster drying at higher temperature, less damage occurred to the pore structure while for lower temperature; due to the prolonged heating the extent of shrinkage was greater which lowered the rehydration efficiency. Similar results were observed by (Jayeeta, 2011).For the treated samples, the amount of the collapsed cells was larger and hence the rehydration attained was lower.

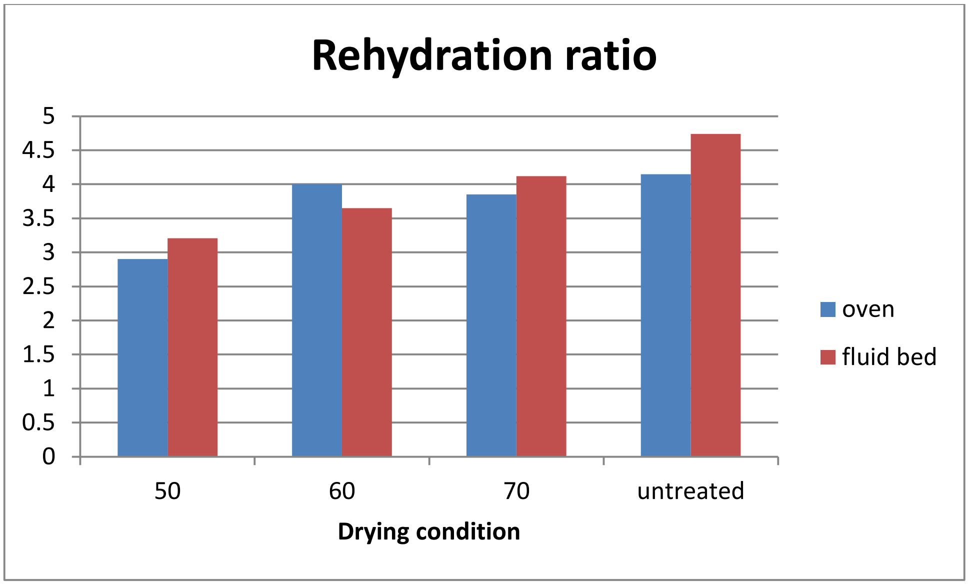


Figure 4.14 Effect of drying methods on rehydration property of dried onion

The rehydration ratio of fluidized and oven dried sample was lower than the untreated samples .The lowering of rehydration ratio has also been reported by (Patil *etal.*, 2011). The lowering of osmo-dried product could be due to higher amount of salt gain in the osmotic treated onion which hindrance to water absorption of the pore space of the onion. From the anova in annex 7 it was observed that there was no significant difference at ($P < 0.05$) between the rehydration ratios of onion slices dried under different between samples dried in the fludized bed dryer and those dried in the oven dryer.

4.3.4. Effect of drying techniques (Conventional Oven and Fluidized Bed Oven) on Microbiological Property dried Onions

The result of the microbiological analysis on prepared dried onion is shown in Table 4.8 The total plate count of fresh onion was reduced to standard limit due to the removal of moisture and increase of dried temperature that can inhibit as well as kill most microorganisms. In the counts $< 1 \times 10^1$ is the standard reporting format for plates from all dilution of the sample has no colonies. All the microbiological test results were within the acceptable range as specified by FDA, 2013 for dried onion prod

Table 4.8 Microbiological analysis

Sample Name	Drying Temp (°C)	Coli-forms,MPN/g	E.coil, MPN/g	Aerobic plate count, CFU/g
Fresh		150	Nil	$1.2x10^{6}$
Conventional oven				
Without OD treatment	70 °c	$<10^{1}$		$<10^{3}$
Dried Onion (Osmotically Pretreated)	50 °c	$<10^{1}$	absent	$<10^{3}$
	60 °c	$<10^{1}$	absent	$<10^{3}$
	70 °c	$<10^{1}$	absent	$<10^{3}$
Fluidized bed dryer				
Without OD treatment	70 °c	$<10^{1}$		$<10^{3}$
Dried Onion (Osmotically Pretreated)	50 °c	$<10^{1}$	absent	$<10^{3}$
	60 °c	$<10^{1}$	absent	$<10^{3}$
	70 °c	$<10^{1}$	absent	$<10^{3}$

4.3.5. Effect of drying techniques (Conventional Oven and Fluidized Bed Oven) on Sensory Properties of dried Onions

Means comparison for the parameters overall acceptability, color, odor used to evaluate the onion samples was shown in Table 4.9. Sensory evaluation was undertaken for the dehydrated onion compared to fresh onion sample.

Table 4.9 Sensory evaluation data of dehydrated onion

Sample	Drying Temp (°C)	Color	Aroma	Overall acceptability
Fresh				
conventional oven				
Without OD treatment	70 °c	4.32[d]	4.92[c]	4.57[d]
Dried Onion (Osmotically Pretreated)	50 °c	6.90[a]	5.71[b]	6.04[b]
	60 °c	5.61[b]	5.44[b]	5.62[c]
	70 °c	5.08[c]	4.91[c]	5.15[c]
fluidized bed dryer				
Without OD treatment	70 °c	5.12[c]	4.81[c]	5.13[c]
Dried Onion (Osmotically Pretreated)	50 °c	7.24[a]	6.80[a]	7.17[a]
	60 °c	7.11[a]	6.72[a]	6.76[a]
	70 °c	6.82[a]	6.54[a]	6.38[b]

Values in the same column with different superscripts for each type of analysis are significantly different ($P<0.05$)

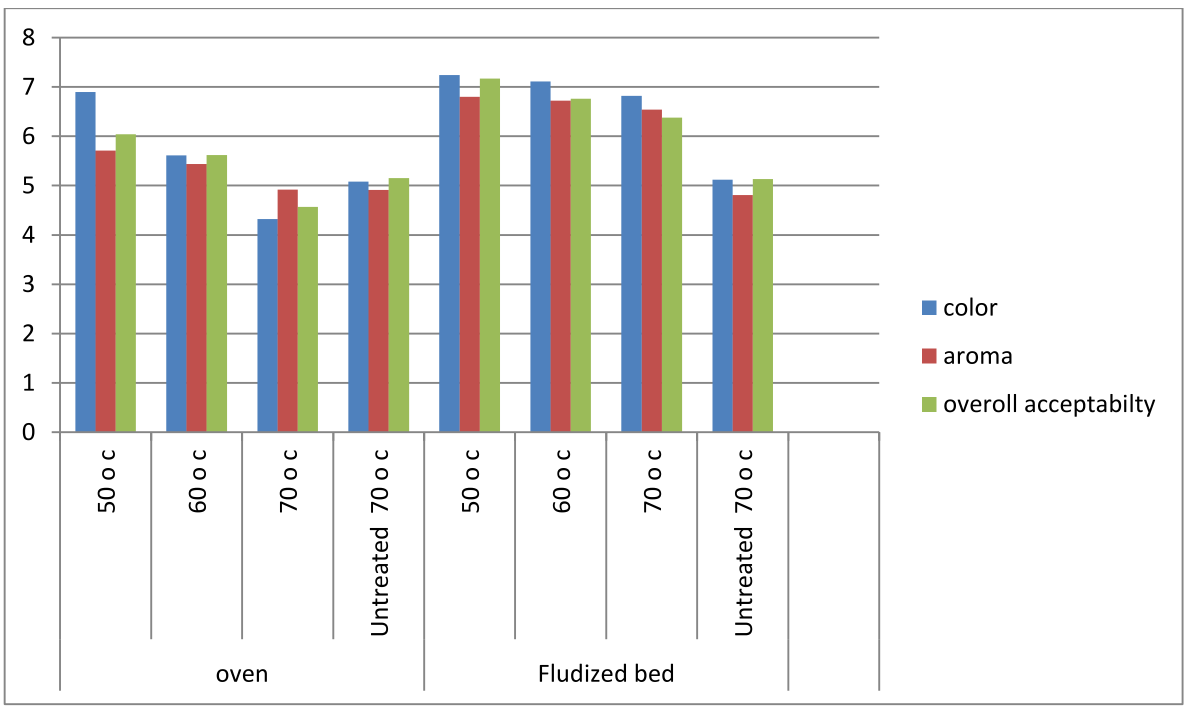


Figure 4.15 Sensory evaluation of drying methods on dried onion

Color

Color is also one of the most important sensory qualities of food product. As can be noted from *annex 10,* the dried onion color from the two drying method was found not significantly different ($p > 0.05$) but temperature significantly affect the color of dried onion. Colour development in onion increased due to non-enzymatic browning (NEB) which occurred faster at high temperature. However, the treated slices showed less colour development due to sulfite treatment. Thus, the colour value can be minimised by involving the sulfite treatment and adopting a lower drying temperature as well as slice thickness. On average, the color of the dried onion at 50^0C and 60^0C was liked moderately by the respondents and the other which was dried at 70^0C was preferred significantly ($p < 0.05$) (Table 4.9).

Aroma

Aroma is imparted by volatile compounds and perceived by the odor receptor sites of the smell organ. As shown in *annex* 11 , aroma of the dried onion was found significantly influenced by drying method ($p < 0.05$) and processing temperature. Higher drying temperature is reported to affect aroma and flavor loss onion significantly by(Adam *etal.*, 2000). According to the tastes of the panelist, the aroma of sample treated in fluidized bed at a temperature of 50^oc was preferred; this might be due to the less removal of volatile matters which are primarily responsible for the typical aroma of dried onion.

Overall acceptability

The final sensory analysis conducted by the panelist was the overall acceptability of the dried onion. As shown in annex 12 the overall acceptability of the dried onion was significantly influence by both drying temperature and drying methods ($p < 0.05$). The dehydration of onion by Fluidized drier improved significantly ($p<0.05$) the overall acceptability for the onion samples, when compared with conventional oven drying methods. Table 4.9 indicates that the overall acceptability of the fludized bed dried onion slices was moderately liked, whereas the conventional oven was liked slightly. Therefore, according to the panelists' preference, the fluidized bed dried onion slices dried at 50^0C was considered to be the best dried onion slices in terms of overall acceptability ($p \leq 0.05$).

Table 4.10 Summary of quality parameter after drying

Dryer	Drying Temperature (^{o}c)	Retention vitamin C (%)	Rehydration ratio	Sensory overall acceptability
Conventional Oven	50	27	2.9	6.04
	60	11.3	4.0	5.62
	70	10.0	3.85	5.15
Fluidized bed	50	76.59	3.21	7.17
	60	47.4	3.65	6.76
	70	37.18	4.12	6.38

CHAPTER FIVE

5. SUGGESTED PROCESS TECHNOLOGY FOR THE PRODUCTION OF DRIED ONION

The dehydrated onion shall be prepared from clean sound bulbs of suitable varieties of onion (Allium cepa.), after proper washing, peeling, trimming and slicing. The bulk of moisture from the slices is removed by dehydration under controlled conditions, in a manner, which would ensure the effective preservation of the colour, flavour, texture and food value of onions.

Processing of onion is intended to preserve them by slowing down the natural processes of decay caused by microorganisms, enzymes in the food, or other factors such as heat, moisture and sunlight and to change them into onion slice form, which are attractive and in demand by consumers. The processors should use their skills to develop attractive recipes and make dried onion that consumers want to eat. By doing this successfully, they can increase sales and earn an income.

5.1 MANUFACTURING PROCESS

Raw onions are collected from market at the most economic prices. The onions should be ripe, matured and are kept in storage. The storage rooms are airy, well ventilated, dry and at low temperature. The cold storage is kept at 0-40°C and RH 50 – 55%

The onions are then cleaned. Spray washers are used for cleaning the onions. The cleaned onions are surface dried by hot air and then the using different types of drier.

PROCESSING LINE EQUIPMENT

Drying onion processing line consists of following operating units:

1. Onion preparation (pre-dehydration unit),
2. Osmotic treatment unit,
3. Drying unit and
4. Packaging unit.

Processing line also includes the following supporting-auxiliary units:

1. Air compression unit

3. Steam generating unit.

Operating Units

Onion Preparation-Pre-Dehydration Unit

Machines and appliances of the unit are used for the purpose of achieving the pre-dehydration treatment operations. The unit is composed Inspecting conveyor, Elevating conveyor and Check weigher.

Osmotic Treatment Unit

The unit is used for the osmotic treatment processes which include: preparation of the osmoticactive solutions and for osmotic-active solutions storing OD, osmotic-active solutions purification, osmotic-active solutions regeneration.

Operational characteristics of the unit are:

- Capacity of water removal from raw commodity is: up to 400 kg /h.
- Minimum dehydration time is 15 min.
- Maximum dehydration time is not limited.
- The average energy consumption is 3.400 KJ per kg of removed water.
- Capacities of OD for onion processing, are: up to 430 and 215 kg /h of fresh onion.
- Osmotic treatment processes can be performed in temperature ranges from 35^0C to 55^0C.

Osmotic Treatment Unit consists of the following operating systems: System for preparation of the fresh osmotic-active solutions,

System for purification of the osmotic-active solutions,

System for storing of the used osmotic-active solutions

Fresh Osmotic-Active Solutions Preparation System The system consists of:

- 1.000 liters capacity tank thermally isolated,
- Cast stainless steel circulating pump**,**
- Stainless steel plate exchanger, thermal power 70 kW,
- Cast stainless steel pump, used for delivery of the fresh osmotic- active solution.

The pump capacity is 5 m3/h of osmotic-active solution, discharge pressure is 3 bars, sealing of the shaft is by flushing water,

- 1.000 liters capacity tank, used for balancing the required volume of osmotic-active solution, thermally isolated, with level and temperature indicators and connectors,

- Stainless steel plate exchanger**,** maximal thermal power 350 kW,

- OTC osmo-active solution feeding pump**,** driven by geared motor with integrated frequency inverter (pump is of volumetric type, capacity 15 m3/h, sealing of the shaft by flushing water),

- Drum and barrel emptying pump,

- Drum and barrel electrically heated mantle**,**

- Pipes, valves, fittings, necessary parts and connectors for use of the CIP system, electric panel for thermostatic and flow control.

Osmotic-Active Solutions Storing System,

The system consists of:

- 5000 liters capacities thermally isolated tanks,

- Cast stainless steel circulating pump**,**

- Stainless steel plate exchanger**,** thermal power 70 kW,

- Cast stainless steel delivery pump, 5 m3/h of osmotic-active solution capacity, discharge pressure is 3 bar, shaft sealing by flushing water,

- Pipes, valves, fittings, necessary parts and connectors for use of the CIP system, electric panel for thermostatic and flow control.

Process Parameters Measurements and Control

- Measuring and control of the constant temperature of the liquid outlet flow from plate heat exchanger,

- Measuring and control of the used osmotic-active solution inlet mass flow in, Control of the pumps working parameters**.**

Drying Unit,

Conveyor, fluized bed drying , loader/ un-loader.

Packing Unit

Machines of this unit are offered and manufactured all around. Auxiliary units present standard equipment type, offered and manufactured all around.

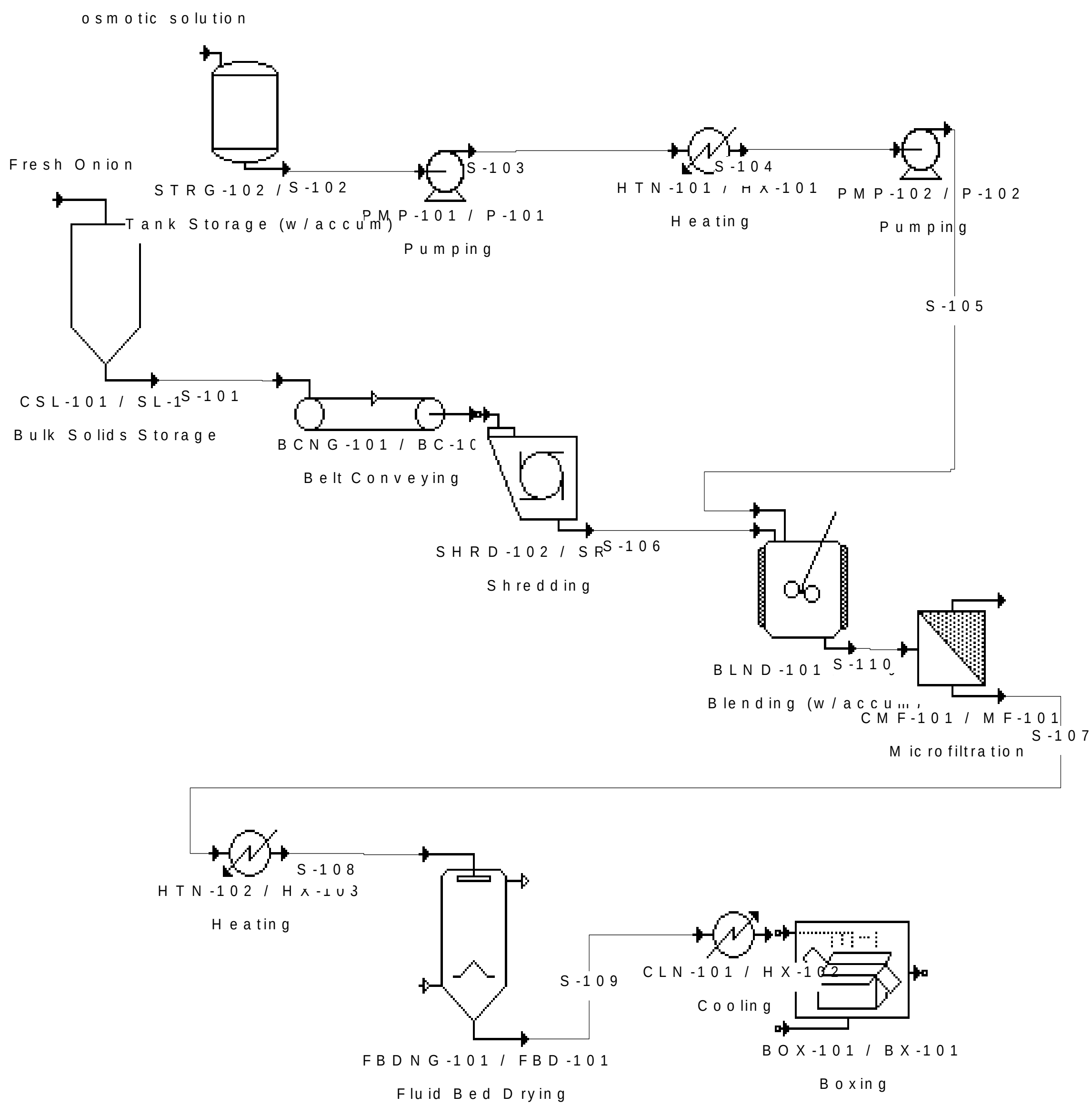


Figure 5.1 Equipment layout of the plant

5.2 MATERIAL AND ENERGY BALANCES

Material balance as per laboratory work:

The material balance will enable us to quantify the substances going in and out of the entire process and piece of equipment.

Data (Assumptions)

The plant has a capacity of 2.69 ton /day (i.e, 168 Kg/h) batch process

13.3 ton/ day of fresh onion is required (i.e, 832 Kg/h)

5.2.1 Material Balance

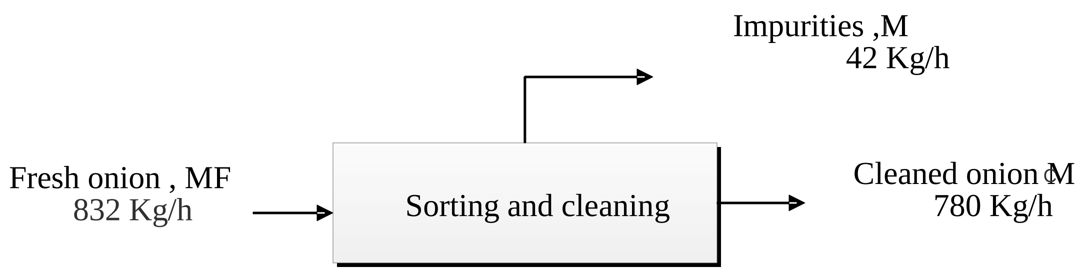
The raw onion was first cleaned then sorted. Assume 5% loss in weight in the cleaning and sorting section. After cleaning peeling is followed, in which 10% of the onion is peeled off. In the slicing section it is assumed that 5% of the onion considered as a waste. Onion contains 12% total solid and after drying the moisture content of the dried mass is expected to be 72 %. After Osmotic drying the moisture content of the dried mass is expected to be 8%. Considering this important assumption the material balance was done and presented in the following material and energy balance flow diagram.

Table 5.1 Typical losses during processing of fruits and vegetables

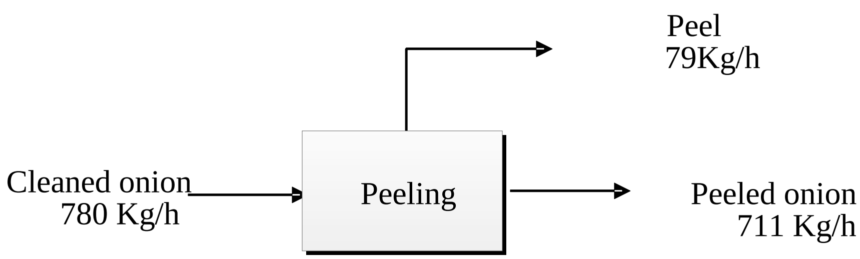
Stages in a process	Typical losses(%)
Washing fruits and vegetables	0-10
Sorting	5-50
peeling	5-60
Slicing/dicing	5-10
Batch preparation/weighing	2-5
drying	10-20
packaging	5-10

Source: (Fellows, P., Midway Technology Ltd, Bonsall, UK)

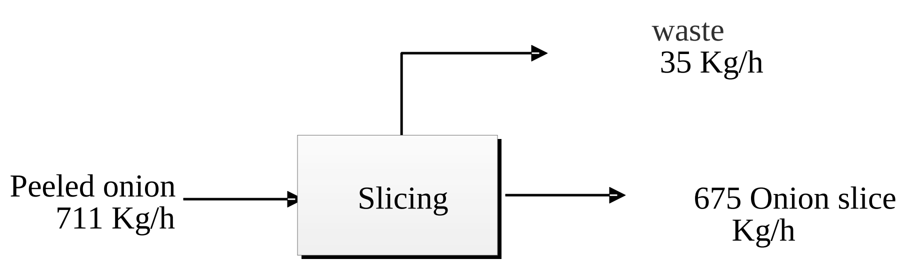
Material balance of cleaning and sorting unit



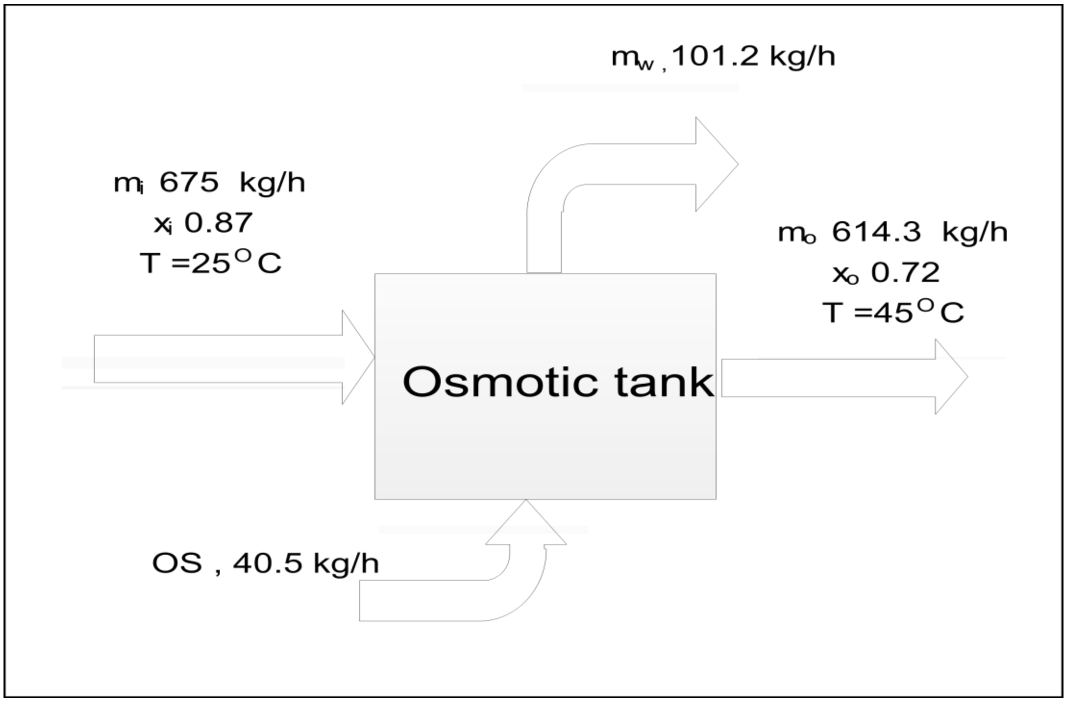
Material balance of peeling unit



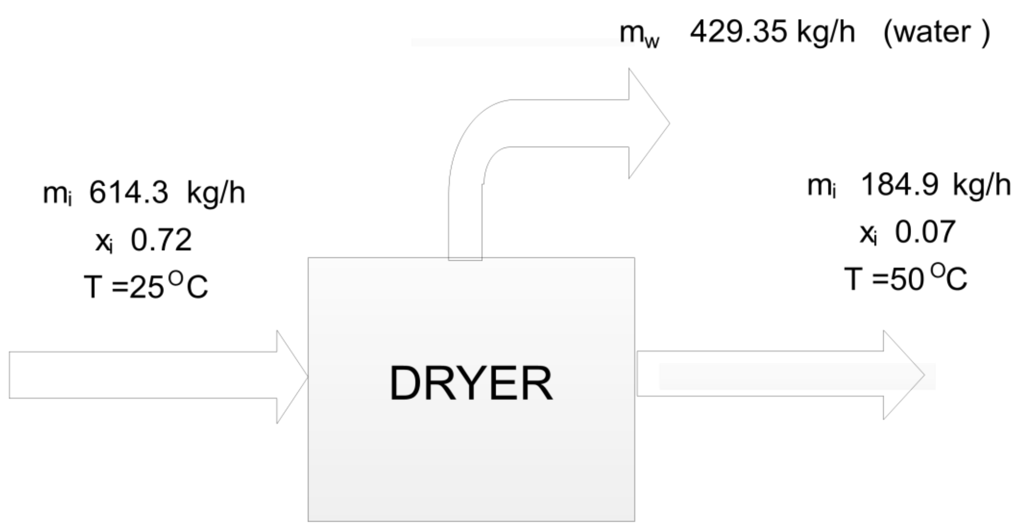
Material balance of slicing unit



Material balance of osmotic treatment unit



Material balance of drying unit



Solid balance on drying unit

$0.28 x 380 = M_P x 0.93$

$M_P = 184.9$ Kg/h

10 % loss related to drying defect and packaging and other processing loss

Taking 0.1x184.9Kg/h =18.5 kg /hr

(184.9-18.5) Kg/h=166.4 Kg/h of dried onion will be produced.

5.2.3 Energy Balance

Energy balance of the osmotic treatment unit

The result of proximate analysis revealed that the fresh onion contain 1.03% protein, 0.5% fat, 0.5% ash, moisture 87.11% and total carbohydrate 9.2%. Assume an increasing in temperature of onion during osmotic treatment is rise from room temperature (25^0C) to 45^0C.

$Q_{steam} = M_{fresh\ onion} * C_{p\ of\ raw\ onion} * \Delta T$

Cp sliced onion= (∑Cpi Mi)

Where

Mi= mass of fraction of dried onion component

Cpi= specific heat capacity of individual components of fresh onion

Specific heat of the component at the temperature of 25^0C

Protein, $Cp = 2.0082 + 1.2089 * 10^{-3}T – 1.3129 *10^{-6} T^2$

$Cp = 2.0082 + 1.2089 * 10^{-3}(25^0C) – 1.3129 *10^{-6}(25^0C)^2$

Cp= 2.04 kJ/kg ^{0}C

Fat , $Cp =1.9842 + 1.4733*10^{-3}T- 4.8008 * 10^{-6} T^2$

Cp = 2.02 kJ/kg ^{0}C

Ash $Cp = 1.0926 + 1.8896*10^{-3}T- 3.6817 * 10^{-6} T^2$

Cp = 1.14 kJ/kg^{0}C

Cho $Cp = 1.54884 + 1.9625* 10^{-3}T – 5.9399*10^{-6} T^2$

Cp = 1.71 kJ/kg ^{0}C

Moisture $Cp = 4.1762 – 9.0864 * 10^{-5} T + 5.4731*10^{-6} T^2$

Cp = 4.286 kJ/kg^{0}C

Fiber Cp = 1.89

Cp fresh onion= 2.04 kJ/kg ^{0}C (0.0103) + 2.02 kJ/kg 0C (0.005) + 1.14 kJ/kg 0C (0.092) + 4.286 kJ/kg 0C(0.87) + 1.89 kJ/kg 0C (0.015)

Cp fresh onion= 3.89 kJ/kg ^{0}C

Q sliced onion = $M_{sliced\ onion} * C_{p\ of\ sliced\ onion} * \Delta T$

= 675*3.89*25

= 65697.11KJ/h

Energy balance on osmotic tank
Q sliced onion +Q steam =Q osmotic dried onion +Q water vapor
Q osmotic dried onion = M osmodried * $C_{p\ of\ osmodried\ onion}$*ΔT
=621*3.56*(45-25)^{0}C
=44,310KJ/h
Q water vapor= M*λ (latent heat of vaporization of water (100^{0}C)
Q water vapor= 54 kg/h * 2257 kJ/kg
=121, 878kJ/h
Over all energy balance

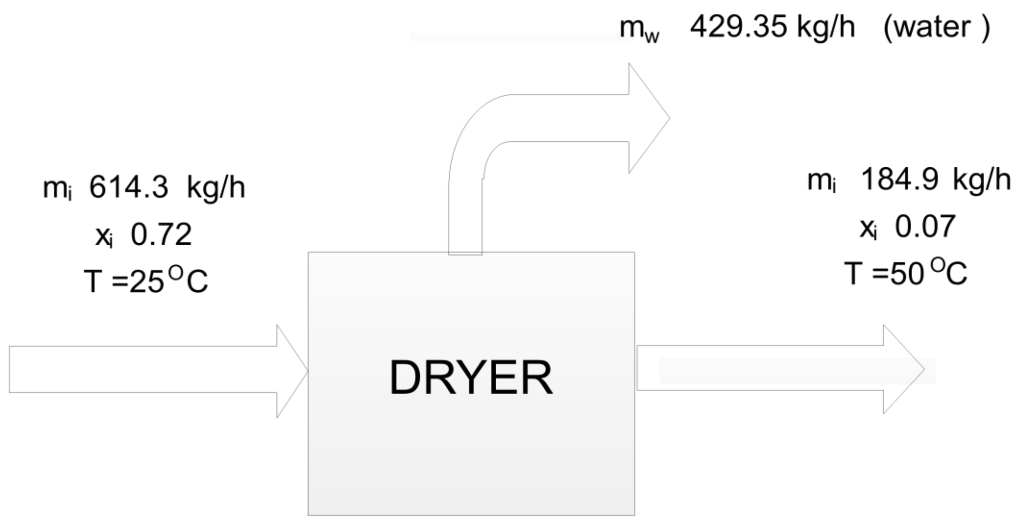
Q sliced onion +Q steam =Q osmotic dried onion +Q water vapor

65,697.11KJ/h+ Q steam=44,310KJ/h+121, 878kJ/h

Q steam=10,049kJ/h

Energy balance on the dryer

Drying



The dryer require steam energy in order to heat the incoming air

Input Energy = output energy

Q osmotic dehydrated + Q steam= Q water vapor+ Q dried onion
Q osmotic dehydrated onion
Q osmotic dehydrated onion = M * Cp* (250C – Tref(0C))
Q osmotic dehydrated onion = 8kg/h * 3.18kJ/kg0C * 25^{0}C
Q osmotic dehydrated onion = 762kJ/h
Q water vapor
Q water vapor= M*λ (latent heat of vaporization of water (1000C)
Q water vapor= 429.35 kg/h * 2257 kJ/kg

Q water vapor = 979,538 kJ/h
Q dried onion

Specific heat of the component at the temperature of 25^0C
Protein, Cp = 2.0082 + 1.2089 * 10-3T – 1.3129 *10-6T^2
Cp = 2.0082 + 1.2089 * 10-3(1500C) – 1.3129 *10-6$(150\ 0C)^2$
Cp= 2.16 kJ/kg 0C
Fat , Cp =1.9842 + 1.4733*10-3T- 4.8008 * 10-6T^2
Cp = 2.1 kJ/kg 0C
Ash Cp = 1.0926 + 1.8896*10-3T- 3.6817 * 10-6T^2
Cp = 1.29 kJ/kg0C
Cho Cp = 1.54884 + 1.9625* 10-3T – 5.9399*10-6T^2
Cp = 1.71 kJ/kg 0C
Water Cp = 4.1762 – 9.0864 * 10-5T + 5.4731*10-6 T^2
Cp = 4.286 kJ/kg0C
Cp dried onion= 2.16 kJ/kg 0C (0.0687) + 2.1 kJ/kg 0C (0.0277) + 1.29 kJ/kg 0C (0.054) + 4.286 kJ/kg 0C(0.08) + 1.71 kJ/kg 0C (0.7696)
Cp dried onion= 1.935 kJ/kg 0C

Energy balance on the drier

The simplified energy balance equation becomes;
Q = (m, evaporated water) (λ) + (m, evaporated water) (cp, water liquid) (T2– T1)
Q = (429.5*2382.7) + (429.5*4.179)* (50-25)
=> Q = 1,068,241 kJ/h
Therefore, the amount of energy required by the dryer is1,068,241 kJ/h

5.3 ECONOMIC EVALUATION OF THE PLANT

This information is first used to calculate the daily production rate, so that ingredients and packaging can be ordered. Then the average amount of production per hour (termed the 'product throughput') can be calculated to find the size of equipment and numbers of workers required.

5.3.1 Plant Capacity and Production Programming

The plant is assumed to work for 300 days per annum and in double shift for 16 hr per day. Therefore, based on the market forecast and selected plant capacity of the plant from material balance (i.e., Kg/h), the production of dried onion of 600 ton per year is expected and the annual production program is formulated and assumed to achieve 80 % and 90% capacity utilization rate in the first and second year and full capacity will be attained in the third year and onwards as shown in the table 5.2.

Table 5.2 Plant capacity and production programming

	description	Production program		
		1st year	2nd year	3rd year
1	Capacity utilization (%)	80	90	100
2	Production rate (Ton/year)	645	725.6	806.4

5.3.2 Purchased Equipment Cost

Table 5.3 Purchased equipment cost

Sr.no	Equipment	quantity	Capacity (Kg/h)	Unit price (Birr)	Total price (Birr)
1	Raw material silo	2	$150m^3$(l=10m, D=4.5m)	250,000	500,000
2	screw conveyor	1	7m	316,000	316,000
3	pump	2	400 lt/h	300,000	600,000
4	Sorting conveyor	1	10m	18,000	18,000
5	Washing tank	1		50,000	50,000
6	Peeling machine	2	400	70,000	140,000
7	slicing	1	1000	20,000	20,000
8	boiler	1		60,000	60,000
9	Laboratory equipment				100,000
10	Stainless steel process tank	1	5000L		
11	Storage vessel	2	$100m^3$(L=10m,D=4m)	200,000	400,000
12	Sulphiting tank	1	1000L		
13	Dryer	2	400/batch	180,000	360,000
14	Mixer	1			60,000
15	Water storage tank	2	15,000 liter	15,000	30,000
16	Heat exchanger	1	700	10,000	10,000
17	Packing machine	1			90,000
18	Miscellaneous				413,100
	Total				3,167,100

5.3.3 Total Capital Investment Estimation

Table5.4 Direct cost

components	cost
Purchased equipment cost(PEC)	3,167,100
Purchased equipment installation -39%PEC	1,235,169
Instrumentation and control-13% PEC	411,723
Piping(installed)-31% PEC	981,801
Electrical equipment and materials-10%PEC	316,710
Building -29%PEC	918,459
Yard improvements -10%PEC	316,710
Service facilities -55%PEC	1,741,905
Land -6% PEC	190,026
Total direct plant cost(D)	9,279,603

Table 5.5 Indirect cost

components	cost
Design and Engineering -25% D	2,319,901
Contractors fee -18%D	1,670,329
Contigency -10% D	927,960
Total indirect cost (I)	4,918,190

Fixed capital investment (FCI)

FCI= Direct cost + Indirect cost

= 9,279,603+4,918,190

= 14,197,793

Working capital

Working capital is an additional investment needed above the fixed capital to start up and operate the plant to the point in which income is earned.

Working capital = 15% Fixed capital

= 2,129,669

Therefore,

Total capital investment =Fixed Capital + Working capital

=14,197,793 + 2,129,669

= 16,327,461

5.4.4 Estimation of Total Production Cost (TPC)

Assumptions:

300 working days /year and

16 working hours /day

Direct cost

Raw material cost

The major raw material in the production of dried onion is fresh onion.

The total amount of raw material per year is:-

Assuming 10% waste or spoilage into consideration.

3,990 ton of fresh onion

2,430 ton Salt

Unit price of onion per ton =5,000 Birr

Unit price of salt per ton =4,000 Birr

Therefore ,Annual raw material cost =3,990ton*5,000Birr/ton +2,340ton*4,000Birr /ton

= 29,310,000

Annual utility requirement and estimated cost

Electricity and water are the two major utilities used for the production of dried onion.

From the energy balance for the osmotic treatment tank

2.79Kw*h*/day*16h *300 day=4,800kWh

Energy consumption for the dryer calculated using data from energy balance

3048kW/day*16h *300 day=14,630,400kWh

Total energy required =720, 000

Assuming electric consumption for other equipment and lighting purpose of the company to be 150Kwh.

150kW/day*16h *300 day=720, 000 kWh

Total annual electric consumption = 15,355,200 kWh/year

Annual water consumption

Osmotic treatment

675*5L*16*300=16200000L=16200m^3

Annual water consumption for other purposes is:-

10m^3 /day *300=3000m^3

Total water consumption per year = (16200+3000) m^3=19,200 m^3

Table 5.6 Annual estimation utility

No	Description	Quantity per annum	Unit price (birr)	Sub total (birr)
1	Water (m^3)	19,200	9	172,800
2	Electricity(Kwh)	15,355,200 kWh	0.60	9,213,120
3	Packaging material 168 Kg/h*300day*16 h*10pac/Kg Carton box 10Kg/carton	8,064,000 504,000	0.50 4.90	4,03,000 2,469,600
	Total 1			11,855,520

Table 5.7 Annual raw material and auxillary

1	Raw material cost	29,310,000
2	Auxiliary and utility	7,329,400
3	Total 1	36,639,400

Maintenance & repairs = 6% FCI

=851867.58

Operating labor=678,000

Laboratory charge =15% operating labor

=101,700

Operating supervision = 17.5 % operating labor

=118650

Total 2 =1,750,218

Direct production cost (A) = Total 1+ Total 2

=38,389,618

Fixed Charge

Depreciation=10% FCI

=1,419,779.3

Local taxes=2.5%FCI

=3,549,448.25

Insurance=1%FCI

=1,419,779.3

Total =1,916,702.055

Plant overheads = 60% operating labor

=203,400

Manufacturing cost = Direct production +Fixed charge +plant overheads

=38,389,618 +1,916,702.055+203,400

=40,509,719.635

General expense

Administrative costs=15% (Maintenance+ Operating labor+ Operating supervision)

=247,277.6

General expense = Administrative cost + Distributing and selling cost

=247,277.6 +831775.5

=1,486,195.92

Distributing and selling cost =2% TPC=831775.5

Total production cost =Manufacturing cost +General expense

= 40,509,719.635 +1,486,195.92

=41,588,772.69

5.3.5 Profitability Evaluation

The most commonly used methods for profitability evaluation are:

1. Rate of return on investment
2. Discounted cash flow based on full- life performance
3. Net present worth (net earnings)
4. Capitalised cost
5. Payback period

Unit product cost =Total product cost /annual production

=41,588,772.69Birr/806.4 ton

=51,573.37883

Selling price of dried onion with a minimum profit of 15% =59,309.38

Total income= annual production *selling

=806.4 *59309.38565

=47,827,089

Gross earning (profit before tax) =Total income-Total product cost

= 47,827,089 -41,588,772.69Birr

=6,238,316.31

Assuming income tax of 20%,

Net annual earning (profit after tax) =Gross earning –Income tax

=6,238,316.31(1-0.2)

=4990653

Return on investment (ROI)

ROI= (net profit)/ (total capital investment)*100

= (4990653)/ (16,327,461)*100

= 30.56

Payback period

PBP=fixed capital investment /(net profit +depreciation)

=14,197,793/(4,990,653+1,419,779.3)

=2.21 years

The amount of production needed to get the break even point is:

$$BEP = \frac{TPC - DPC}{Sup - Vup}$$

Where, BEP = Break-even point (units of production)

Vcup = Variable costs per unit of production=47,606.17

Sup = Selling price per unit of production= 59,309.8

TPC = Total production cost = 41,588,772.69

DPC = Direct production cost = 38,389,618

BEP=237.43 Ton / year

BEP (%) $= \frac{237.43}{806.4} * 100$ where, the capacity of the plant is 806.4 ton /year

BEP =38.9%

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

This study aims in the production of dried onion from the selected *Adama red* variety. The first part of the study was to determine the influence of soaking temperature, osmotic solution concentration and soaking time during osmotic dehydration of fresh onion slices on water loss (WL) and solid gain (SG).Using these data, the optimal operating conditions were evaluated. In the second part of the study , two types of drying methods conventional oven drying and fluidized bed drying were investigated and the effect of drying temperature on the quality of dried onion were discussed. Finally the quality of dried product, i.e. rehydration experiments for various rehydration ratios, sensory and nutritional measurements were conducted for each final product.

In the present work, osmotic treatment were conducted at three levels of soaking temperature (35, 45,55ºc), osmotic solution concentration (10, 15 and 20%) and soaking time (30, 45, 60 minutes). It was demonstrated that osmotic process significantly affects the removal of moisture from the onion sample. The process optimisation was done using the response surface methodology, the maximum water loss was 18.9 % and minimum solid gain is 3.2%. The optimised condition were found to be 45.8°C soaking temperature, 38.78 minute soaking time and 11.08% osmotic solution concentration resulting in 14.7% water loss and 6.3% solid gain.

Two kinds of drying were compared for drying of the pretreated onion slice. Conventional oven and fluidized bed dryer were used for drying purpose. In addition, treated onions were dried at three different air dry bulb temperatures (50°C, 60°C and 50°C) to determine the influence of temperature on drying time using a conventional drying oven and fluidized bed dryer. The quality of onion slices were studied by analysis of different parameters at drying temperatures. The quality parameters investigated were nutritional composition, vitamin C, rehydration properties, microbiological and sensory properties.

Dehydration of onion by fludized bed drying caused less destruction of ascorbic acid and improved the rehydration ratios as well as general appearance and color scores, The final moisture content, vitamin C , microbiological quality and rehydration property of the dried *Adama Red* onion slice were well within the acceptable limits (ADOgA, 2005). The highest number of acceptable quality parameters was reported for osmotic fluidized bed dried samples at 50°C ($p<0.05$).

This study will help the food producer or dried vegetables manufacturer to select the appropriate osmotic treatment and drying conditions for making dried onion products and at the same time reduce the spoilage of onions by preserving them through making of different dried onion products.

6.2 RECOMMENDATIONS

Based on the result found the following recommendations are made.

- It would be interesting to carry out further experiment on a pilot-scale fluid bed drier to gather all pertinent data for a scale-up.
- A comprehensive study on shelf life Stability of the dried onion should be conducted to come up-with complete and usable information
- Design and implement sliced dried processing onion industry within the country in the near future.
- It is recommended that further researches need to be conducted on the processing of other related onion products like onion powder, pickled onion and onion oil.

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Annex 1 Determination of Aerobic plate count (APC) in food

Method principles

The aerobic colony count estimates the number of viable aerobic bacteria per gm or ml of a product. A portion of the diluted sample mixed with a specified agar medium and incubated under specific temperature for 48 hr. It is assumed that each viable aerobic bacterium will multiply under these conditions and give raise to colonies.

Terms:

Mesophillic bacteria: an organism whose optimum growth lies within a range generally accepted as 20-45^0 c Psychrophilic bacteria: an organism which grows optimally at or below 15 ^{0} c , which has an upper limit for growth at 20 ^{0} c , and which has a lower limit of 0 ^{0} c or lower.

Thermophilic bacterial: an organism whose optimum growth temperature is >45 ^{0} c

Positive Control: Reference material with known aerobic plate count.

Negative Control: check sterility of PCA medium and diluents used bypouring control plates.

Equipment to Calibrate: Incubator 37^0 c for Mesophillic bacteria, Incubator 55 ^{0} c for Thermophilic bacterial, Refrigerator 2-8 ^{0} c for Psychrophilic bacteria, Autoclave, PH meter, Safety cabinet, Pipettes controllers, Colony counting device, Centrifuge optional, only for some food type, Stomacher optional, only for none liquid sample, and Digital balance.

Media: PCA

REAGENT: 2% Sodium citrate (tempered to 45 ^{0} c) (for cheese sample only)

Diluents: peptone water diluents

Procedure:

1. Sample preparation

Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 10^1 dilutions (the first dilution) Mix well with shaker/stomacher

2. Dilutions

Mix the first dilution by shaking then pipette 1ml into a tube (labled10^2) containing 9 ml of normal saline. Mix carefully by aspirating 10 times with a pipette. From the 10^2 dilution, transfer with the same pipette 1ml to the tube (labled10^3) containing 9ml of the diluent, Mix with a fresh pipette. Repeat until the required numbers of dilutions are made.

3. Pour plating

Pipette 1ml of each serial dilution into each of the appropriately marked duplicate dishes. Pour 15-20ml of the molten PCA kept at 45^0 c into each Petri dish. Mix it thoroughly and allow it to solidify.

4. Incubation.

Incubate the dishes, inverted, at 35 ^{0} c or for dairy products at 32^0 c for 48 hr.

N.B: Avoid excessive humidity in the incubator, to reduce the tendency for spreader formation, but prevent excessive drying of the medium by controlling ventilation and air circulation. Agar in plates should not lose weight by more than 15% during 48 hours of incubation.

5. Counting the colonies.

Following incubation, count all colonies within the range of 30-300 colonies and record the results per dilution counted.

Sample preparation: weigh 10g of the sample in to a sterile 250ml Erlenmeyer flask; marked to indicate 100ml volume. Add sterile saline peptone to 100ml mark. Dissolve and shake thoroughly.

Dilution:

Dilution factor:

1:10, 1:100, 1:1000, etc $\quad$ 1 x 10^1, 1×10^2, 1×10^3 et

Counting colonies: Following incubation, count all colonies on dishes containing 30-300 Colonies, including those of pinpoint size and recorded the results per dilution counted.

Verification: If there is growth on the negative control and /or no growth on the positive control the test should be repeated with the corrected media

Expression of results: express the result in cfu per g /ml (if a liquid sample

Calculation formula: Use the best two consecutive dilutions, as n_1 and n_2 to calculate the results.

$N = C/V (n_1 + 0.1n^2)\ d$

Where, C = is the sum of colonies on all plates counted

V = is the volume applied to each plate

n_1= is the number of plates counted at first dilution

n_2= is the number of plates counted at second dilution,

d = is the dilution from which first count was obtained.

N= is the average plate count.

Round the result to two significant figures and express it as a number between 1.0and 9.9 multiplied by 10^{X} where X is the appropriate power of 10.

Annex 2 Enumeration of coliform (MPN)

Method principle

Graduated amount of food (diluted) sample are transferred to a series of fermentation tubes containing lactose or lauryl sulphite tryptose broth of proper strength, it is usual practice to inoculate to three fermentative tubes. The tubes are incubated at $35 \pm 0.5\ ^{0}C$ for 24 and 48hrs.The formation of gas in any of the tubes with in 48hr ,regardless of the amount, constitutes as positive for coliform and the absence of gas formation with in this period considered as negative for coli form . Confirm the coliform by BGBB

Positive Control: any Coliform spp. For total coliform test $44.5^{0}C$ gas positive *E.coli* for fecal coliform test.

Negative Control: Uninoculated tubes with the media and inverted tube $44.5^{0}C$ negative *E.aerogenes* for fecal coliform test.

Equipment to Calibrate: Incubator$37^{0}C$, PH meter, Safety cabinet, Pipettes controllers, Colony counting device, Centrifuge optional, only for some food type, Stomacher optional, only for none liquid sample, Digital balance, and Water bath 44^0 c .

Media: LSTB, BGBB, EC broth,

Diluents: Peptone water

Procedure:

Presumptive test for coliform group (MPN)

1. Preparation of the first dilution (10^{1})

Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 10^1 dilution (the first dilution) and Mix well with shaker/stomacher. Mix homogenate by shaking and pipette 1ml into a tube containing 9 ml of normal slain. Mix carefully by aspirating 10 times with a pipette. From the first dilution, transfer with the same pipette 1ml to 2nd dilution tube containing 9ml of the Ns, Mix with a fresh pipette. Repeat using 3rd or more until the required numbers of dilutions are made. Shake all dilution carefully.

2. Inoculation

Inoculate each of 3 replicate tubes of LSTB broth per dilution (containing inverted tubes) with 1ml of the previously prepared 1:10, 1:100 and 1:1000 dilutions using sterile pipette for each dilution.

3. Incubation: Incubate the LSTB tubes at $35 \pm 0.5\ ^0$c for 48hrs.

4. Reading: Record tubes showing gas production after 48hr

5. Result reading: Record all tubes showing gas within $48 \pm$ 2hrs and refer to MPN table for the 3 tube dilution and report results as the presumptive MPN of coliform bacteria per g (or ml of liquid product).

6. Confirmed test for coliform group (MPN)

Subculture all positive tubes showing gas within 48 ± 2 hours 2 hours in to BGB broth by means of the 3 mm loop. Incubate all BGB tubes at $35 \pm 0.5\ ^0$c for 48 ± 2 hours. Record all BGB tubes showing gas, and refer to the MPN table for 3 tube dilution. Report results as confirmed MPN of coliform bacteria per g (or ml of liquid product).

Annex 3 Determination of coliforms, fecal coliforms and E.coli by using MPN technique

50 g of the sample was weighted into sterile high-speed blender jar. Frozen samples can be softened by storing it for ≤18 h at 2-5°C, but do not thaw. 450 ml of Butterfield's phosphate-buffered and water were blended for 2 min. If <50 g of sample are available, weigh portion that is equivalent to half of the sample and add sufficient volume of sterile diluents to make a 1:10 dilution. The total volume in the blender jar should completely cover the blades.

Decimal dilutions with sterile Butterfield's phosphate diluents were prepared. Number of dilutions to be prepared depends on anticipated coliform density. Shake all suspensions 25 times in 30 cm arc or vortex mix for 7 s. Do not use pipettes to deliver <10% of their total volume. Transfer 1 ml portions to 3 tubes for each dilution for at least 3 consecutive dilutions. Hold pipette at angle so that its lower edge rests against the tube. Let pipette drain 2-3 s. Not more than 15 min should elapse from time the sample is blended until all dilutions are inoculated in appropriate media. Incubate tubes at 35°C. Examine tubes and record reactions at 24 ± 2 h for gas, i.e., displacement of medium in fermentation vial or effervescence when tubes are gently agitated. Re-incubate gas-negative tubes for an additional 24 h and examine and record reactions again at 48 ± 2 h. Perform confirmed test on all presumptive positive (gas) tubes.

Annex 4 Sensory evaluation score card using nine Hedonic scale

Panelist code/name: _______________ sample code: __________ date :________

Sensory perception (score)			Overall acceptability
	Appearance(color)	odor	Hedonic scale
1=dislike extremly			1=extremely unacceptable
2=dislike very much			2=very much unacceptable
3=dislike moderately			3=moderately unacceptable
4=dislike slightly			4=slightly unacceptable
5= neither like nor dislike			5=neither acceptable nor unacceptable
6=like slightly			6=slightly acceptable
7=like moderately			7=moderately acceptable
8=like very much			8=highly acceptable
9=like extremely			9=extremely acceptable

Annex 5 Manpower requirement

No	Human resource	number	Salary /month	Total monthly salary	Yearly salary
1	General manager	1	5000	5000	60,000
2	Food technologist	4	3000	12000	144,000
3	Accountant	2	2500	5000	60,000
5	Semi skilled labor	10	1000	10000	120,000
6	Security guard	4	800	3200	38,400
7	Driver	2	800	1600	19,200
8	Store man	2	800	1600	19,200
9	Sales	2	2500	5000	60,000
10	Casher	1	2000	2000	24,000
11	Cleaner	3	700	2100	25,200
12	Chemist	2	2500	5000	60,000
13	Secretary	2	2000	4000	48,000
					678,000

Annex 6 Analysis of variance for ascorbic acid

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Fluid bed drying	3	29.82	9.94	14.3127
Oven drying	3	8.95	2.983333	3.065833

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	72.59282	1	72.59282	8.354309	0.044546	7.708647
Within Groups	34.75707	4	8.689267			
Total	107.3499	5				
Total	0.711667	2				

The anova for the drying methods shows that there was a significant difference with the two drying methods.

Annex 7 Analysis of variance for rehydration

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Fluid bed drying	3	10.98	3.66	0.2071
Oven drying	3	10.75	3.583333	0.355833

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.008817	1	0.008817	0.031324	0.86812	7.708647
Within Groups	1.125867	4	0.281467			
Total	1.134683	5				
Total	0.711667	2				

Annex 8 Analysis of variance for response variable Water loss

Source	Sums of square	df	Mean square	F-value	P value Prob> F
Model	306.83	9	30.55	61.62	<0.0001
A	17.11	1	17.11	30.78	<0.0001
B	108.71	1	108.71	195.55	<0.0001
C	26.05	1	26.05	46.85	<0.0001
AB	33.61	1	33.61	6.46	<0.0001
AC	5.59	1	5.59	9.93	0.0046
BC	0.93	1	0.93	1.67	0.2091
A^2	55.09	1	55.09	99.10	<0.0001
B^2	33.33	1	33.33	23.98	0.0001
C^2	8.07	1	8.07	14.51	0.001
Residual	12.23	22	0.56		
Lack of fit	10.17	17	0.60	1.45	0.3614
Pure error	2.06	5	0.41		
Total	319.06	31			

A- temperature B –concentration C –time

In this case A, B, C, A^2, B^2, AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Std. Dev.	0.75	R-Squared	0.9617
Mean	14.85	Adj R-Squared	0.9640
C.V.	5.05	Pred R-Squared	0.9013
PRESS	28.93	Adeq Precision	28.85

Annex 9 Analysis of variance for response variable Solid gain

Source	Sums of square	df	Mean square	F-value	P value Prob> F
Model	106.7	9	11.89	66.78	<0.0001
A	0.038	1	0.038	0.21	0.6502
B	57.69	1	57.69	324.16	<0.0001
C	23.70	1	23.70	133.19	<0.0001
AB	8.13	1	8.13	8.13	<0.0001
AC	0.074	1	0.074	0.074	0.5259
BC	10.74	1	10.74	10.74	<0.0001
A^2	3.88	1	3.88	0.74	0.0542
B^2	4.85	1	4.85	4.85	<0.0001
C^2	0.31	1	0.31	0.31	0.1981
Residual		22			
Lack of fit		17		0.26	0.9838
Pure error		5			
Total		31			

A- Temperature B –Concentration C –time

In this case B, C, A^2, B^2, AB, BC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Std. Dev.	0.42	R-Squared	0.9640
Mean	8.49	Adj R-Squared	0.9502
C.V.	4.97	Pred R-Squared	0.9357
PRESS	6.91	Adeq Precision	32.562

Annex 10 One way analysis of color by drying methods

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Fluid bed drying	3	21.17	7.056667	0.046233
Oven drying	3	17.59	5.863333	0.876233

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.136067	1	2.136067	4.631206	0.097759	7.708647
Within Groups	1.844933	4	0.461233			
Total	3.981	5				
Total	0.711667	2				

Annex 11 One way analysis of aroma by drying methods

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Fluid bed drying	3	20.06	6.686667	0.017733
Oven drying	3	16.06	5.353333	0.165633

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.666667	1	2.666667	29.08562	0.005718	7.708647
Within Groups	0.366733	4	0.091683			
Total	3.0334	5				
Total	0.711667	2				

Annex 12 Oneway analysis of overall acceptability by drying type

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Fluid bed drying	3	20.31	6.77	0.1561
Oven drying	3	16.81	5.603333	0.198233

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.041667	1	2.041667	11.52399	0.027411	7.708647
Within Groups	0.708667	4	0.177167			
Total	2.750333	5				
Total	0.711667	2				

Annex 13 Pictures while conducting the experiments

Adama red onion

Sliced onion prior drying

Fludized bed dried onion Oven dried onion

Traditional way of sun drying of onion

Germinated onion

Vitamin C analysis