EFFECT OF DRYING TIME AND TEMPERATURE, PACKAGING MATERIALS, STORAGE TIME AND TEMPERATURE ON QUALITY AND ACCEPTABILITY OF DRIED TOMATO (*Lycopersicon esculentum* L.VAR COCHORO)

M.Sc. THESIS

BY

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M.Sc. Thesis

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By:

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DEDICATION

This Thesis is dedicated to my beloved husband and parents for all the sacrifices, wishes and praiseworthy to my success in all my endeavors.

STATEMENT OF THE AUTHOR

I declare this thesis is my original work and all sources of materials used in this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. Degree at Jimma University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author, Mawarde Yusufe Adame was born in September 5, 1991 G.C in Muti Kebele, Metta Woreda, East Hararge, Oromia Regional State. She had attended primary school education at Muti Primary school from 1997 to 2005 G.C. She attended her secondary and preparatory education at Chelenko secondary and preparatory school from 2006 to 2009 G.C. She joined Jimma University in 2010 G.C and completed her undergraduate studies with B.Sc., Degree in Postharvest Management in 2012 G.C. Continuously she joined in the School of Graduate Studies of Jimma University to pursue her M.Sc study in Postharvest Management in September 2013 G.C.

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LISTS OF ACRONYMS AND ABBREVIATIONS

EIAR	Ethiopian Institute of Agricultural Research
RDA	Recommended dietary allowance
PG	Polygalacturonase
PPO	Polyphenol oxides
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RH	Relative humidity
MDPE	Medium Density Polyethylene
TPC	Total plate count
ANOVA	Analysis of Variance
SAS	Statistical Analysis System
HDPF	High density polyethylene
LDPF	Low Density Polyethylene
°C	Degree Centigrade
FAOSTAT	Food and Agricultural Organization
USDA	United States Department of Agriculture
PDA	Potato Dextrose Agar
CFU/g	Colony forming unit per gram

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ABSTRACT

*Tomato (Lycopersicon esculentum L.) is popular and widely grown vegetable crop in the world as well as in Ethiopia. However, marketing of fresh tomato during peak season is a great problem because of its short postharvest life and traditional ways of managing the post harvest system (inadequate handling, processing and storage facilities). Therefore, drying is one of the most convenient methods in extending the shelf life and minimize postharvest loses. During drying, some physicochemical quality may be degraded and thus affect general quality characteristic of the dried tomato. The main purpose of this investigation was to study the effects of duration and temperature of oven drying on physicochemical property, sensory acceptability and shelf life of dried tomato. Processing type Cochoro variety was collected from Maki (Ziwai). The drying experiment were carried out by two phases, the phase I is the drying studies which were carried out in two factorial design (3*2) which consist three levels of drying temperature (70^oC,80^oC and 90^oC) and two levels of duration of drying (7and 8 hours) based on preliminary trial was arranged in CRD. Phase II(storage study) was selected based on the analysis of phase I (drying study) by comparing physicochemical property and sensory acceptability analysis of dried sample with fresh (control) and then the selected treatments was carried out using 2*3*2*3 factorial CRD arrangement which consist two sample(sample dried at 90°C for 7 hours and 8 hours),three packaging material(Glass jar, plastic jar and plastic bag(low density polyethylene),the storage temperature(room temperature and refrigerated storage) and the storage period(1^{st}, 2^{nd} and 3^{rd}months) respectively and three times replicate. The data were analyzed using SAS software (version 9.2).Every significant treatment effect was compared using Tukey at 5% probability level. As the result indicated that the drying processes (interaction effects of duration and temperature) affect the physicochemical and sensory quality of dried tomato. Furthermore, vitamin-C content of the samples dried at 90^oC for 7 and 8 hours were badly affected recording an average value of 2.03mg/100g of vitamin-C compared to fresh and those dried at 70^oC and 80^oC for 7 and 8 hours with average values of 7.03 mg/100g, 3.86 mg/100g, 3.7 mg/100g, 3.16 mg/100g and 2.83 mg/100g respectively. In the storage study (Phase II) also vitamin C and Lycopene contents of tomato powder was decreased more in 3-months of storage period in plastic bag (low density polyethylene bag). But the degradation rate was lower in glass jar and plastic jar for both vitamin-C and Lycopene. In general the result showed that drying can reduce the amount of postharvest losses experienced by farmers and tomato sellers and dried tomato could contribute to daily intake of nutrition especially proximate composition better than fresh tomato.*

Key words: *Tomato, oven drying, quality, shelf life, packaging, drying duration, drying temperature, storage condition, storage period.*

1. INTRODUCTION

1.1 Background of study

Despite the remarkable progress made in increasing food production at the global level, approximately half of the population in the third world does not have access to adequate food supplies. There are many reasons for this, one of which is food losses occurring in the post-harvest and marketing system (FAO, 2002).

Even if factors affecting post-harvest food losses of perishables vary widely from place to place and become more and more complex as systems of marketing become more complex. Primary factors responsible for post-harvest produce losses include poor pre-harvest measures, adoption of poor production techniques (varieties with low shelf life, imbalance use of nutrients, insect pest and disease infestation and abiotic stresses), non-application of pre-harvest recommended treatments/practices, harvesting at improper stage and improper care at harvest; and post-harvest problems, non-removal of field heat, dumping produce, moisture condensation causing pathogen infestation, packaging in bulk without sorting and grading of produce, improper transportation and storage, and distant and time consuming market distribution. These factors bring low return to growers, processors, traders and country also at large suffers in terms of losing foreign exchange earnings (Kader, 1992) and food as well as nutrition security.

Tomato *(Lycopersicon esculentum Mill.)* is one of the most popular and widely grown plants in the world as well as in Africa (Osemwegie *et al.*, 2010). It is one of the most economically important vegetable crops and is widely cultivated worldwide with a total production of 162 million tons and thus ranks third next to potato and sweet potato with respect to world vegetable production. The leading tomato-producing countries are China, United States of America, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia (FAO, 2012). It is also popular and widely grown vegetable crop in Ethiopia. Since 1994 up to present, tomato acreage increased to 5338 ha with a total production of 55,635 Mg (CSA, 2011). Currently tomato is one of the regional export crops of the country (Wiersinga and Jager,

2009).However, poor postharvest practices are serious concerns and contribute to the poor quality perception and high postharvest losses of domestically produced tomato (Genova *et al*., 2006).This is due to improper postharvest sanitation, poor storage, packaging practices and mechanical damage during harvesting, handling and transportation resulting from vibration by undulation and irregularities on the road mechanical can enhance wastages (Idah *et. al*., 2007). It is distressing to note that much is being devoted to planting crop, so many resources spent on irrigation, fertilizer application and crop protection measures only to be wasted in few days after harvest. All these factors contribute to greater post-harvest losses, which may not be fully compensated by better facilities and technologies (Bourne, 1986).However there is a wide range of post-harvest technologies that can be adopted to improve losses throughout the process of pre-harvest, harvest, cooling, temporary storage, transport, handling and market distribution. But recommended technologies vary depending on the type of loss experienced (Kadar, 2003).

To increase the shelf life of tomatoes, different preservation techniques are being employed that comprise of manipulation of storage temperature and relative humidity, addition of chemical preservatives, protection against air / germ pollution through waxing, modified atmosphere packaging, dehydration and processing into other products. But, the success of these methods depends on how it meets certain requirements of the product quality for consumption. On the other hand most of the above methods are extend shelf life maximum for one month, Nasrin *et al*.(2008) studied on effect of postharvest treatments on shelf life and quality of tomato. They extended shelf life of tomato up to 17 days without excessive deterioration in quality by treating the fruits with chlorine, packed in perforated polyethylene bag and kept at ambient temperature. Therefore, it is essential to preserve the tomatoes using one of the food preservation techniques and to be made available in an acceptable form throughout the year at relatively minimum cost with extended storage life.

Several processing technologies have been employed on an industrial scale to preserve food products; the major ones are canning, freezing, and drying. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. Drying of fruit and vegetable are not familiar in Ethiopia for this reason

the information is scarce. However there is only limited published study regarding drying for example, Zeberga (2010**)** studied on production and quality evaluation of spray dried fruit products. Drying is attractive technology because it is very simple and can easily be adapted by farmer and small scale processor with minimal capital investments. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply (Sheshma *et al*., 2014).

Similar to other fruits and vegetable tomato can be dried using various methods such as sun drying, spray drying, oven drying and also more sophisticated and high capital cost drying technologies such as infrared radiation heating and freeze drying (Gowen *et al*., 2008; Lewicki, 2006).Generally, the choice of a drying technology depends on its efficiency in terms of energy consumption, final food quality and cost involvement. Preservation of nutritional quality, flavor and visual characteristics significantly influence the operational parameters of the drying method. Criterion such as maximum product temperature, long duration and environmental humidity during drying affect the final product quality (Humberto *et al*., 2001).More specifically, the duration and temperature of the drying process are the important factors affecting sensory quality and nutritive value of the final products (Yang and Atallah, 1985; Krokida *et al*., 1998).

Even though processing of tomatoes using sun drying with cut pieces, drying of whole tomatoes, spray drying and convection drying using solar or mechanical systems have been used for many years (Baloch *et al.,* 1997; Collins *et al*., 1997; Hawlader *et al.,* 1991; Olorunda,*et al*.,1990; Shi *et al.,* 1999; Zanoni *et al*., 1999), traditional sun-drying is a slow process requires 7 to 12 days compared with other drying methods and quality losses may result from high moisture content, color degradation by browning and microbial growth during storage (Okos *et al*., 1992; Lewicki *et al*., 2002). Therefore in order to improve the quality of dried tomato products, industrial drying methods such as hot-air is preferred (Doymaz, 2007) as control of product quality, achievement of hygienic conditions, and on reduction of product loss (Corzo *et al*., 2008).

As the quality losses in the dried products may have adverse economic effects (Sacilik *et al*., 2006) there is also a need for safe packaging which producer of tomato get by cheap and locally available materials should be utilized and storage conditions that should be simple to store and helps to retain the overall quality parameter of dried tomato. Thus, proper packaging and storage conditions for dried tomato could be designed to reduce quality losses during storage.

Therefore, the objectives of this study were to quantify the losses in nutritional, sensory quality after drying, establish appropriate drying temperature, duration of drying, packaging material and storage condition that result in optimum retention of the nutritional and sensory property as well as ensuring shelf stability of dried tomato.

1.2. Statements of problem

In Ethiopia the bulk of fresh market tomatoes are produced by small-scale farmers in several place of the country. Products vary in visible tomato characteristics important for fresh market and processing values, which differ in acceptability in the local market, quality, and storability (Lemma, 2002; Allen, 2008). However, tomatoes are especially vulnerable to postharvest loss due to their highly perishable nature and to a combination of factors such as pre-harvest diseases and inefficient post-harvest handling procedures (Bombelli and Wright, 2006). On the other hand lack of awareness of existing improved technology such as processing, lack of standard packaging material, storage, road network and transportation facility in the farmers' field, poor marketing systems are the major production constraints of tomato production in Ethiopia (Lemma, 2002).Short shelf life coupled with inadequate processing facilities results in heavy revenue loss to the country especially in Ethiopia. Therefore, during peak harvest seasons tomato is sold at throw away price because of lack of means to preserve and store the products.

On the other hand in Ethiopia, fruits and vegetables processing sector is underutilized and limited to some fruit and vegetable. Although fruits and vegetables, tomato being one of the top, are economically important commodities, there is limited published and unpublished study made on them to reduce these huge losses in Ethiopia. For example, Genanew*et*

al.(2013) studied on effect of post harvest treatments on storage behavior and quality of tomato fruits and reported that they can preserve for a month period only without much affecting fruit quality. Temesgen *et al*.(2011) studied the effect of tomato cultivars, honey finisher and processing methods on quality of tomato ketchup and Meseret (2010) studied on evaluation of tomato varieties for fruit yield, quality and shelf life. But most research conducted in Ethiopia focused on market assessment of fruit and vegetables (Abay, 2007; Adugna, 2009; Alemnew, 2010; Birhanu, 2011).

1.3. Significances of study

The study has a great importance because processing plays an important role in the conservation and effective utilization of fruits and vegetables. It converts perishable fresh products to more durable processed products in cases of sluggish markets or when there are profit-generating demands for processed products. It can be done for farm household consumption and for commercial purposes. For farm household consumption it provides a more varied diet and also means tomatoes can be eaten out of season, convenient for handlings due to the product is reduced in weight, require little time to prepare and save energy during home processing. For commercial purposes it is a way of generating extra income and means more products to offer to buyers. On the other hand it reduce post harvest loss by minimizing the moisture content and water activity which affect shelf stability by creating favorable condition for microbial growth and enzymes' activity which cause susceptible to damage. Generally this study help wholesaler and retailer of tomato by filling the information gap on processing of vegetable, tomato in Ethiopia by asking government interventions.

1.4. General Objective

- To identify the appropriate drying temperature, duration of drying and packaging material suitable for production and storage of dried tomato fruit.

1.4.1. Specific Objectives

- To determine the appropriate duration and temperature of drying required to produce dried tomato with minimum losses of physicochemical and sensory quality

- To determine the effects of packaging material , storage temperature and storage periods on shelf life of dried tomato
- To evaluate the interaction effects of duration, drying temperature, packaging material, storage condition and storage period on shelf life of dried tomato

2. LITERATURE REVIEW

2.1. Origin, distribution and production of tomato

The tomato is native to South America. Genetic evidence shows the progenitors of tomatoes were herbaceous green plants with small green fruit with a center of diversity in the highlands of Peru. According to Smith *et al*. (1994) one species, *Solanum lycopersicum.*L, was transported to Mexico where it was grown and consumed by Mesoamerican civilizations. Many historians believe that the Spanish explorer Cortez may have been the first to transfer the small yellow tomato to Europe after he captured the Aztec city of Tenochtítlan, now Mexico City, in 1521. Others believe Christopher Columbus, an Italian working for the Spanish monarchy, was the first European to take back the tomato, as early as 1493. The earliest discussion of the tomato in European literature appeared in an herbal written in 1544 by Pietro Andrea Mattioli, an Italian physician and botanist, who named it Pomod'oro, golden apple (Smith *et al.*,1994).The large, lumpy tomato, a mutation from a smoother, smaller fruit, originated in Mesoamerica, and may be direct ancestor of some modern cultivated tomatoes.

It was introduced to cultivation in the Middle East by John Barker, British consul in Aleppo *circa* 1799 to 1825 (Appleton *et al* .,1876).The crop was introduced into West Africa in the 16^{th} and 17^{th} centuries by the Portuguese, and it has since become the most popular vegetable crop (Norman, 1992).It was also introduced in Ethiopian agriculture dates back to the period between 1935 and 1940 (Samuel *et al*., 2009). Now tomato is grown worldwide as edible vegetable, with thousands of cultivars having been selected with varying fruit types, and for optimum growth in differing growing conditions.

Hence, tomatoes are of great nutritional value, they represent a source of vitamins, minerals and essential for human diet. Its production can be adopted as a strategy for improving livelihood and alleviating the nutritional status of the people. And it is the answer to the perpetual problems of hunger and malnutrition in developing country (Bankole *et al*., 2012).

In Ethiopia also there is a variety of vegetable crops grown in different agro ecological zones by small farmers, mainly as a source of income as well as food. The production of vegetables varies from cultivating a few plants in the backyards, for home consumption, to large-scale production for the domestic and home markets (Abraham, 2013). Since the Ethiopian Institute of Agricultural Research (EIAR) was established in 1966 (Setotaw, 2006; Roseboom *et al*., 1994) during the preparation of research for vegetables, tomato was recognized as a commodity crop. The first record of commercial tomato cultivation is from 1980 with a production area of 80 ha (Lemma, 2006) in the upper Awash by Merti Agro industry for both domestic as well as export markets.

In the year 2000 the land cropped with tomato was 4,344 ha and the productivity was about 123.623 qt/ha. Showing fluctuated figure in between for harvested land and yield, the 2010-recorded data revealed that yield was 89.70 qt/ha from 4593 ha of land which shows lower yield from relatively wider harvested land (FAOSTAT, 2012).Since several factors affect tomato production, the growers have been challenged by inconsistent production, shortage of varieties and recommended information about processing, packaging, lack of awareness of existing improved technology and poor marketing systems are the major constraints in Ethiopian tomato production (Lemma 2002). Due to this reason post harvest technology is important to minimize this challenge.

2.2 Health benefit of tomato for human nutrition

Tomatoes and tomato products are well known by adults and children alike and have the unique advantage of meeting consumer demands on cost, convenience, availability, and taste while delivering a healthful food option with flexibility for inclusion in a variety of culturally diverse dishes (Freeman and Reimers, 2010).

Starting with the basics, tomatoes contain large amounts of vitamin C, providing 40% of the daily value (DV), 15% DV of vitamin A, 8% DV of potassium, 7 % of the recommended dietary allowance (RDA) of iron for women and 10 percent RDA for men and it loaded with all kinds of health benefits for the body. Besides one of the most well known tomato eating

benefit is its' Lycopene content. Lycopene is a vital anti-oxidant that helps in the fight against cancerous cell formation as well as other kinds of health complications and diseases (Bhowmik *et al*., 2012). Lycopene is the major dietary carotenoid of tomatoes and tomato-based foods. Free radicals in the body can be flushed out with high levels of Lycopene, and the tomato is so amply loaded with this vital anti-oxidant that it actually derives its rich redness from the nutrient.

Even if, Lycopene is not a naturally produced element within the body, the human body requires sources of Lycopene in order to make use of this powerful anti-oxidant. Tomatoes, lycopene is also found in watermelon and red grapefruit; however, tomatoes and tomato products represent more than 85% of all the dietary sources of lycopene (Rao,1999). In addition to lycopene, tomatoes also contain other carotenoids, including phytoene, phytofluene,α-carotene, γ-carotene, β-carotene, eurosporene, and lutein. These carotenoids have also attracted attention for benefiting health (Olmedilla*et al*., 2002).

Average daily lycopene intake of males and females is 5305 mg, higher than the average daily intake of all other carotenoids combined (3388 mg). Lycopene intake is about three times that of β-carotene (1742 mg) (USDA, 2009). Reduced blood pressure after lycopene supplementation was reported in studies (Engelhard *et al.,* 2006; Paran *et al.,* 2009). Its supplementation in prostate cancer patients has been shown to be safe and well tolerated in doses up to 120 mg/day for up to one year. Eating more tomato products can also play a role in reducing inflammation, cancer, heart disease, ultraviolet light induced skin damages and osteoporosis. Thus, in addition to their culinary role in the diet, tomatoes represent a low energy dense food with unique constituents that may positively affect health (Clark*et al*., 2006).

Even if our community have no awareness' about importance's of tomato, research is now slowly proving that there is a high likelihood that the consumption of tomatoes and tomato based products actually may prevent serum lipid oxidation and reduce the risk of macular degenerative disease. Generally tomato are by far the healthiest of the fruit and vegetable with power to ward off some of the worst known disease to man. So, encouraging

consumption of tomato product may be a valuable tool in promoting health (Bhowmik *et al*.,2012).

2.3 Fundamental and principles of drying

Drying is one of the oldest known food preservation techniques and it's an essential operation in the chemical, agricultural, biotechnology, food, polymer, ceramics, pharmaceutical, pulp and paper, mineral processing, and wood processing industries. The operation of drying converts a solid, semi-solid or liquid feedstock into a solid product by evaporation of the liquid into a vapor phase via application of heat. This definition excludes conversion of a liquid phase into a concentrated liquid phase (evaporation), mechanical dewatering operations such as filtration, centrifugation, sedimentation, and supercritical extraction of water from gels to produce extremely high porosity aerogels (extraction) or so-called drying of liquids and gases by use of molecular sieves (adsorption) (Mujumdar and Devahasti, 2013).

It is also different from frying, baking and roasting because there is a significant water reduction by evaporation in all of these processes. Such processes are intended for purposes of texture and additional flavor development in the products rather than merely to remove the water (Ramaswamy, 2006). Phase change and production of a solid phase as product are essential features of the drying process. Drying of various feed-stocks is needed for one or several reasons: need for easy-to-handle free-flowing solids, preservation and storage, reduction in cost of transportation, achieving desired quality of product, etc. (Mujumdar *et al*., 2004).

2.3.1 Drying process

2.3.1.1 Heat and mass transfer

The most important thermodynamic process in food drying is heat and mass transfer. During hot-air drying, there is a simultaneous exchange of heat and mass between the food and the drying air. Heat is transferred from foods to surrounding surface by way of radiation, convection or conduction. In the common case of air-drying, convection is the predominant mechanism (Brennan, 2006). This heat transfer to the food surface increases

the sample temperature and supplies the required latent heat of vaporization for both the surface water and the water within the product. At the same time, internal moisture (mass) migrates to the surface of the food and then it evaporates to the surrounding hot air (Aversa *et al*., 2007).

The transport of moisture from the product surface to the air and the transfer of heat from the air to the product surface are functions of concentration and/or water vapor pressure, and temperature gradients, respectively (Srikiatden *et al*., 2005).These transport phenomena involve both external and internal resistance to heat and/or mass transfer and they control the drying rate. In general, it is accepted that the rate of the drying may be limited either by the rate of internal migration of water molecules to the surface or by the rate of evaporation of water molecules from the surface into the air, depending on the conditions of drying (Ibarz *et al* .,2003). This indicates that the resistance to mass transfer is considered to be the primary rate-limiting mechanism and the resistance to heat transfer may hence be neglected. Because in food, heat is usually transported easily than moisture and the temperature gradients inside the food can be assumed to be no resistance to internal heat transfer, especially when compared to the steep moisture content gradient (Karel *et al*.,2003).

On the other hand, heat transfer within the food may be limited by the thermal conductivity of the product as its water evaporates (Geankoplis, 2003). In combination with the external heat transfer, the temperature of the food increases rapidly at the beginning of drying towards the air temperature, indicating a decreasing resistance effect. (Wang and Brennan, 1995) attribute this phenomenon to the decrease in the thickness of the samples during drying, which leads to a faster heat transfer within the food. However, the difference between the food and the air temperature becomes negligible (external heat transfer) only after most of the initial water of the food has evaporated.

The air temperature, air humidity, velocity, and exposed surface area all influence the resistance to external heat and mass transfer whereas the internal mass transfer is only affected by the physical nature of the food, its moisture content and temperature. At the beginning of drying, since the internal resistance in the food is low to maintain the surface at

saturation, evaporation takes place at a constant rate depending mainly on external heat and mass transfer. When the drying rate starts to decrease due to in sufficient water at the surface, resistance to internal mass transfer governs the process. At this time most foods switch from an external drying process during the initial stages to an internal drying process as the product dries out (Heldman *et al*.,1997). In addition, the drying rate in the food sample, which decreases from the very beginning of the process, may also indicate that the internal resistance to mass transfer controls the drying (Marquez *et al*.,2006).

2.3.1.2 Mechanism of mass transfer

Mass transfer in the foods occurs in the form of liquid, gas and solid due to concentrations gradient and convection. Moisture transfer from food product is when water vapor pressure in the food is higher than the air. Food moisture contents influences microbial, organoleptic, functional and structural qualities, enzymatic reaction, non-enzymatic browning, lipid oxidation, textural changes, and aroma retention of foods. Therefore, mass transport is required in the analysis of basic food processing operations such as drying, crystallization, humidification, distillation, evaporation, leaching, absorption, membrane separation, rehydration, mixing, and storage. In leaching, a solute is separated from food matrix to a liquid solvent, while in extraction solute is separated from liquid mixture to a liquid solvent. In crystallizations, a solute is transferred from liquid phase to solid liquid interface. In many food processes mass transfer is accompanied by heat transfer such as drying, evaporation, and distillation (Farid *et al*., 2010).

Mechanism of moisture movement is depends on types, physical state of food material and drying process. The food material can be classified as homogenous gels, porous material with interconnecting pores or capillaries and material having outer skin that the main barrier to moisture flow . The type or structure of food always plays an important role in drying process. Drying is simultaneously a heat and mass transfer process. Hence, there are two resistances: heat and mass transfer. In drying processes, two drying periods are usually observed: an initial constant rate period in which drying occurs as if pure water was being evaporated and falling rate period. During the constant rate period, it is considered that there exists thin film of water on the slice and there is no internal or external mass transfer resistance, now the drying is

controlled by external heat transfer. The drying condition used during constant drying rate period can produce physical modification on the material that influences moisture transport properties. Therefore, it has been suggested that the internal moisture movement during the constant-rate period is due to the capillary flow (Geankoplis *et al*., 2003).

On the other hand diffusion is considered to be the main moisture transport mechanism during the falling-rate period in the drying of food materials. In addition to diffusion, during the falling-rate period, moisture transport may also take place through other mechanisms such as capillary flow, Knudsen diffusion and hydrodynamic flow, depending on the structure of the food material (i.e. size, shape, and connection of pores in the sample). In this period, the drying is controlled by internal mass transfer resistance. The absences of constant rate period indicate that the drying is controlled from beginning by the internal mass transfer resistance. The moisture content at which the drying periods change from a constant to a falling rate period can be considered the critical moisture content. Several researchers have observed this behavior during drying of high moisture fruit and vegetable.In tomatoes drying most studies have mainly observed only the falling rate period. Giovanelli *et al*.(2002) reported that the absence of constant rate period during drying of tomato slab at 70^0C. Drying of tomato seed also took place mainly under falling rate period (Sogi *et al*., 2003). Furthermore, convective drying of tomato quarter at 60^0C showed no constant rate period demonstrated by Lewicki *et al*.(2002).

The critical moisture content depends on characteristics of the food and drying condition. The critical moisture content is varied from 0.78 to 0.83(kg/kg, wet basis) for vegetable and 0.85 to 0.89 (kg/kg, wet basis) for fruit. However, at high moisture contents liquid flow due to capillary force dominates. At the decreasing moisture content the amount of liquid in the pores also decrease and a gas phase is built up, causing a decrease in liquid permeability. Gradually the mass transfer is taken over by vapor diffusion in a porous structure. At the saturation point there is no longer liquid available in the pores and mass transfer taken over completely by vapor diffusion (Coumans *et al*.,1994).

2.3.2Technology of drying

Drying process can be broadly classified, based on the water removing method applied as thermal drying, osmotic dehydration and mechanical dewatering. In thermal drying a gaseous or void medium is used to remove water from the material, thus thermal drying can be divided into three types: a, air drying b, low air environment drying c, modified atmosphere drying. In osmotic dehydration, solvent or solution is applied to remove water, where as in mechanical dewatering physical force is used to remove water. In mechanical dewatering centrifugal force or pressure is applied to material with this a physical barrier (i.e., membrane) in order to keep the liquid and solid phases separated (Gongora-Nieto *et al*.,2001; Cohen and Yang, 1995).

There are a number of drying methods currently employed in the food processing industry. The selection of drying method is based on several factors including the properties of food to be dried, investment cost of the dryer and energy cost. Moreover, the selection of a dehydrator should also include production capacity, initial moisture content of the product, drying characteristic of the product and maximum allowable temperature. The overall selection of a drying system for a particular food material is influenced by the desired to achieve a favorable combination of process efficiency and product quality. However Cohen and Yang (1995) conclude that there is no one best technique for all products.

There are many types of drying processes which fruit and vegetable can be dried: sun and solar drying; atmospheric dehydration including stationary or batch processes (kiln, tower, and cabinet driers) and continuous processes (tunnel, continuous belt, belt-trough, fluidized-bed, explosion puffing, foam-mat, spray, drum, and microwave-heated driers); and sub-atmospheric dehydration (vacuum shelf, vacuum belt, vacuum drum, and freeze driers). Sun drying (used almost exclusively for fruit) and solar drying (used for fruit and vegetables) of foods use the power of the sun to remove the moisture from the product. Sun drying of fruit crops is limited to climates with hot sun and dry atmosphere, and to certain fruits, such as prunes, grapes, dates, figs, apricots, and pears. These crops are processed in substantial quantities without much technical aid by simply spreading the fruit on the ground, racks, trays, or roofs and exposing them to the sun until dry. Advantages of this process are its

simplicity and its small capital investment. Disadvantages include complete dependence on the weather and moisture levels no lower than 15 to 20 percent (corresponding to a limited shelf life). Solar drying utilizes black-painted trays, solar trays, collectors, and mirrors to increase solar energy and accelerate drying. Although not many attention is paid to solar drying for fruit and vegetables in developed countries it can constitute a cost effective environmentally friendly way of drying, however, many times it is more labor intensive than other drying methods of fruit and vegetables (Somogyi *et al*., 1986).

Freeze drying is an alternative method to obtain high quality food, with good aroma retention and rehydration capacity. However, it is employed for high value fruits and vegetables, although the high cost involved, and unavailability prevents this technology from being widely used, especially in developing country. The cost of freeze drying has been found to be an order of magnitude higher than conventional drying systems (Chou and Chua, 2001).

In addition according to the technology employed and drier design the control of the process is more or less difficult. Imperfect control during the process as well as the existence of hot zones may also seriously affect the quality of the product. The control of driers is difficult because they are highly non-linear system, with variable product input and the controller relies on variables, like moisture, difficult to monitor (Bimbenet *et al*.,2002). Additionally changes in product characteristics during drying bring more complexity. This cost and the added control complexity has lead to considerlow cost, available material and simplicity of drying method like convectional hot air drying.

Osmotic drying is another common method; however it alone does not stabilize the product sufficiently to allow for long-term storage (Rahman *et al*., 1999). Indeed, after immersing the tomatoes in osmotic solutions (salt or sugar solutions), they are air-dried to reduce the water activity to such a level that spoilage is prevented or at least retarded. However, case hardening is reported to be more problematic with osmosed air-dried products due to the salt or sugar in the osmotic solution forming a crust on the surface (Demirel *et al*.,2003).

On the other hand the use of microwave heating (Vega-Mercado *et al*., 2001) and other radiation means like the use of radiofrequencies may help for the final stages, when internal heat resistance prevail. The drawbacks associated to uneven heating by microwaves are much less important for radiofrequencies.

Because of simplicity and most economical method among the various drying methods the majority of industrial drying installations rely on convectional hot-air drying at atmospheric pressure. A wide variety of food materials such as fruit, vegetables, herbs and cereal crops has therefore been dried by convectional hot-air dryers. In addition, it is easy to set and control the optimum drying conditions in these dryers, especially in cabinet dryers. Common atmospheric hot-air dryers include kiln, cabinet (tray), tunnel, and belt or conveyor dryers (Chandra, 2006). The basic configuration of an atmospheric hot-air dryer is an enclosed and heated chamber where food material is placed. It is also equipped with a blower (i.e. fan) and ducts to allow the circulation of hot air around and across the food. The drying process in an atmospheric dryer involves both heating the product and removing water from the product surface (Rahman *et al*., 1999). This technique employs flow of heated air stream (usual operational temperature range between 50 and 100 °C) to supply heat to the food and remove its moisture (Phongsomboon and Intipunya, 2009) but the maintenance of nutritional and commercial quality of such products through this process presents some problems (Argyropoulos *et al*., 2008). Undesirable changes in the color may also lead to a decrease in its quality and marketing value, therefore, the surface color of the dried tomato product is an important criterion. So, the removal of moisture must be accomplished in a manner that will be least detrimental to the product quality. Accordingly, an understanding of the nutritional and color changes of tomato slices during hot air drying is essential for optimization study.

2.4 Factor affecting tomato drying

The kinetics of drying tomato depends on a number factor including product property, pre drying preparation and the drying process condition .It is important to note that the rates of drying also affect the quality of dried product.

2.4.1 Product property

The cellular structure of food is known to affect the kinetics of drying. Tomato consists of a waxy skin layer that protects underlying tissue and permits the exchange of metabolites with the environment. The skin layer of tomatoes is important during drying because the waxes deposited on the surface are believed to be hydrophobic in nature, which represents an efficient barrier to moisture transport. The kinetics of drying fruits (e.g., grapes and prunes) having a waxy skin layer similar to that of tomatoes has been subject of numerous investigation. The drying process of tomatoes could therefore be facilitated by removing the skin layer or cutting the fruit into smaller pieces prior to drying. If tomatoes are dried whole, with their skin intact, it is important to apply pre-treatment (salt and other chemical) prior to drying to improve the water permeability through the skin layer.

2.4.2 Thickness and surface area

The preparation of tomato prior to drying generally affects the drying kinetics. Slicing or dicing tomatoes into smaller pieces facilitate drying process due to the increase in surface area to volume ratio. Obviously, smaller pieces tend to dry faster because the distance that any water molecules within the food matrices must travel to get the surface is reduced. A study conducted by Gupta *et al*. (1984) on sun drying of tomato slice into various sizes found that smaller pieces dried much faster. They reported that drying 1cm slices of tomatoes down to 10% final moisture content took 26 hours while slices 2 cm and 3 cm took 31 and 38 hours respectively. They observed faster drying rates for tomato pulp dried to 10% final moisture content in slab of 15 mm thickness compared to 20 mm slab thickness. Therefore thickness and surface area has impact on drying and it should be minimized to dry on the required time.

2.4.3 Drying condition

2.4.3.1 Temperature

Even if the ideal temperature range for drying a vegetable is between 35^0C and 63^0C the medium range temperature is about 48^0C for most fruit and vegetables. But in any tomato

drying technique, the required duration and temperature for drying the product depends in many parameters such as tomato variety, the soluble solid (^{O}Brix) of the fresh product, the air humidity, the size of the tomato segment, the air temperature, velocity, depth to which the drying tray is packed and the efficiency of the drying system. Since these factors vary, it is impossible to give an exact drying time for any particular food item. According to Correia *et al*. (2015) temperatures below 50^{o}C do not promote sufficient displacement of the water vapor from the material to reach the desired humidity. However Ojiako and Igwe (2008) studied the dehydration of tomato at 30^{o}C and 90^{o}C for 1and 6 hours and reported that the drying at 90^{o}C for 6 hours substantially reduced the moisture content of the product, which seemed to be the appropriate moisture for storage.

In addition, it is widely recognized that the drying process is accelerated at higher temperature. In air-drying, the actual temperature of drying air is important because it determine the amount of water vapor that the air can hold. Elevated temperature would mean an increase in the rate of drying due to higher rates of heat transfer. Also if temperature is increases, the relative humidity of the air at the given moisture content fall, which enhances the drying potential as consequences of higher driving force for external mass transfer. High temperature would also mean that there is greater energy available for the activation of water molecules within the food matrix. Obviously, this causes the water molecule to diffuse more rapidly and subsequently enhances the internal rates of moisture movement.

According to Helmand *et al.*(1997) elevated temperatures improve the drying by affecting both internal and external mechanism of moisture transport. However, for most foodstuff, caution is required because higher temperature may alter the physical and chemical constituents of food products, which affect the quality of the dried product. Increases in temperature generally also mean an increase in energy consumption. Hence, it is paramount to determine the practical temperature limit at which the product can be safely and efficiently dried. A number of studies have been conducted to investigate the effects of temperature on the air drying kinetics of tomatoes. These investigations have found that drying temperature has significant effect on drying kinetics of tomatoes, as has been commonly observed in most biological products. Obviously, these studies have reported

shorter drying time at higher temperatures. Zanoni *et al*.(1999) carried out convective drying studies of fresh tomato halves of Rita cultivar at different temperature (80^0Cand 110^oC) using plot scale cabinet drier. Their work was under taken at 1.5 m/s air flow and results indicated that drying rate increase upon increasing temperature of drying air. It looks 4 hours to reduce the moisture content down to 10% at 110^oC while drying at 80^oC required about 7 hours. In order to reduce the quality loss during drying process using of high temperature and short time is recommended.

2.4.3.2 Relative humidity

Air usually contains some degree of moisture as vapor. The amount of moisture in the air is known to effects of the kinetics of moisture loss during air drying of fruit and vegetables. Relative humidity is the ratio of the actual vapor pressure in the air water mixture to saturation vapor pressure of water at the same temperature. This means that when the relative humidity is 100% the air is fully saturated with water vapor and, consequently a powerless drying agent. Generally, the main influence of relative humidity is limited to the constant rate period of drying and has little impact on the falling rate period of drying (Heldman *et al.*, 1997). Lowering the relative humidity of the drying air enhance the drying process due to the increased difference in moisture vapor pressure between the product surface and the drying of air, which represent the driving force for external mass transfer.

In a thermodynamics sense, decreasing the moisture content of the drying air increases the potential of the drying air to pick up and remove moisture from the product. This is because the reduction of the humidity of the drying air increases the moisture concentration gradient between the product and the drying air. Consequently, this leads to an increase in the driving force for mass transfer from product surface to the air steam. Therefore it is possible to substantially reduce the overall drying time, hence, increasing the product throughput by merely decreasing the moisture content of the drying air. However, very limited information can be found on the effect of relative humidity relevant to the drying process of tomatoes. Price *et al*. (2000) have demonstrated the dramatic effects of relative humidity of the drying air on the drying kinetics of prunes. Their result consistently showed a decrease in drying rate

as the relative humidity condition is increased. So, it is essential to keep low RH in order to accelerate the drying process and for economic aspects also.

2.4.3.3 Air velocity

The velocity at which the drying air passes across the product may influence the drying kinetics. The effects of air velocity mainly impacts on the rate of external mass transfer. It has little effect on drying when the internal diffusion rate is the limiting factor in drying process. Air movement is important particularly during early stage of drying when external mass transfer mechanism predominates. Air is required to transfer heat and to remove moisture from product. Increased air movement over product enhances the evaporation rate as consequence of improved heat and mass transfer. The work of Hawlader *et al*. (1999) has demonstrated the effects of air velocity on drying characteristics tomato slices. He got increase drying rate when air flow was increased from 0.4m/s to 1.8m/s during drying at 80^{o}C. Mariem and Mabrouk (2014) also reported that the increase in temperature and flow rate of the drying air in tomato drying increases the drying potential and consequently decreases the drying time.

However, caution must be taken at high air flow rate in combination with high temperatures may trigger scorching and drying out of the product surface too quickly, making it less permeable to moisture transport. This could result in a well-known phenomenon called case hardening (formation of a hard outer shell), which tend to seal the product surface by preventing diffusion of moisture through the surface layer, thus impeding the drying of the interior part of the product. This means that a very rapid drying may deplete the surface moisture at rate far exceeding the replenishment of moisture from the interior of the food, which creates a dry and hard skin (Hawlader *et al*., 1999).

2.5 Effects of drying on product quality

The quality of dried products is influenced by the particular variety of the raw materials well as its properties (e.g. structure, ripeness), methods of drying, packaging material and storage conditions. Several physical, chemical, biochemical and/or microbiological changes may occur in food during drying and storage, resulting in significant quality losses. These changes

include positive impacts such as reduction of microbial populations, along with loss of nutrient or more visible attributes like color. These effects are a function of time and temperature that the product is exposed to some defined process parameter. According to Hartel *et al*.(1999) also all thermal processes have impact on the product based on the magnitude of temperature and time of processing. Based on many observations and controlled studies, many of the change occurring during processing. However the impact of process on quality will vary with type of process and or the intensity of process.

Drying plays a major role in food manufacturing or food processing activities worldwide. Often one of the last operations in the food processing, it controls to a large extent the quality of the final product. Drying is applied to a wide variety of food products, from cereals to finished goods, from raw materials to by products. The processes used are numerous, according to the type and quantity of product to dry, the amount of water to eliminate, the final desired quality or functionality of the dried product. When drying food, all products will undergo a change that reduces the quality of the product, compared to the fresh raw material. The most noticeable change for the consumers, are the loss of color, taste, aroma, rehydration ability and the less visible, but yet important change, is loss of nutrients. In addition drying has effect on the mechanical and sensory properties of food products, and can be used to create new functionalities (Bonazzi and Bimbenet, 2003, 2008).

To be able to control these quality changes during drying requires knowledge about the adverse effects of process and product conditions. With this knowledge, it is possible to relate the quality of the dried products to the drying conditions by measuring and comparing the effects of different temperatures and duration on the quality degradation reactions.

The main objective of drying is to decrease the water activity (Aw) of various perishable materials to values <0.5, in order to enable their storage at ambient temperature. Water activity is more important to the stability of a food than the total amount of water present, and it makes it possible to develop generalized rules or limits for the stability of foods. For most foods, the critical point below which no micro-organism can grow is in the 0.6–0.7 water activity range. A food product is most stable at its monolayer moisture content, which

varies with the chemical composition and structure. The importance of water activity in controlling the shelf-life of foods is by suppressing the growth of micro-organisms, by reducing the rates of chemical reactions, and by inhibiting enzymatic deterioration (Evangelos *et al*., 2011).

2.5.1 Flavor

There are a number of compositional change that occur during drying of tomatoes which may influence the quality of dried product, including loss and creation of flavor and change in color and nutritional value. This is because of the interactions between water and other components depend on water and solute mobility, which are, therefore, responsible for biochemical reactions, physical transformations and mechanical phenomena during processing, storage and consumption (Le Meste *et al*., 2001). In addition, the physical force that causes the removal of water molecule from food during drying may also cause the removal of the volatile flavor constituents of the food. As a result the dried tomato product have distinctively different flavor to fresh tomatoes. The difference in aroma is primarily due to loss or generation of volatile compound during drying process. Thermal degradation often leads to generation of wide spectrum of flavor compound, depending on the types of reactions. For instance, the breakdown of sugars and carotenoids due to heating creates compounds responsible for cocked aroma. The application of heat may also cause the oxidative degradation of carotenoids in tomatoes, which cause formation of terpenes and their derivative compound. Heating also causes inactivation of lipoxygenase and associated enzyme that are responsible for producing some of the characteristics fresh tomato flavor.

2.5.2 Color

Color is one of the most relevant attributes with respect to the quality of dried foods, because it is part of their visual appearance and most of the time one of the first criteria taken into account by consumers when choosing a new product. The color of tomatoes is mainly determined by carotenoid, lycopene, which is natural pigment that gives tomato and tomato products their characteristic deep-red color. Lycopene has been found to seemingly have beneficial effect on human health (Rao *et al*.,1999). It was reported that high temperature lead to degradation of lycopene, which depends on many factor including processing

condition (temperature, time).The degradation of lycopene during tomato dehydration affects not only color but also final products and the nutritive value which is mainly caused by oxidation and isomerization (Shi *et al*.,1999).

Processing condition such as high temperature, long exposure time and presence of oxygen have been shown to have effect on lycopene degradation. The lycopene content of whole tomato dried to the final moisture content of 3-4% was found to decrease by 4% after drying at 95^0C for 6-10hours, was attributed to heat and oxygen exposure (Shi *et al*.,1999). Lycopene oxidation is reported to be the most important reason for the color loss during storage of tomatoes also (Demirbüker, 2001).

Drying also affects color due to formation of pigment caused by number of reactions. The undesirable brown color of the sample during drying are attribute to enzymatic browning (catalyzed by Poly Phenol Oxidase) and non-enzymatic browning (Maillard and Caramelization reactions) that take place during the process. Various intermediate products (e.g. 5-309 hydroxymethyl-2-furfural) and brown pigments (Melanoidins) are generated and may contribute to the development of new flavors, colors and changes in the nutritional value and antioxidant activity of the products (Valdenegro *et al*.,2013).The Maillard reaction is considered one of the major causes of quality loss (discoloration, off flavors, and nutrients loss) and is a useful indicator of temperature abuse (Arslan, 2011). This reaction accelerates with increasing temperatures (especially above 50°C) and pH values over the range from 4 to 7, which are quite typical in foods (Krokida *et al*., 2000). In addition, the gradual decrease of water activity aids in the progression of Maillard reactions, leading to the formation of colored polymers (Morales *et al*., 2001). Even though it is reported that lycopene is stable during drying (Zanoni*etal*., 1999), however it is not stable during the storage of the dried product.

On the other hand β-Carotene provides not only color, but also antioxidant capacity, pro-vitamin A, and some other health benefits related to its intake. It can be degraded by thermo-oxidation, leading to the formation of low molecular weight colorless products, which generates losses of color and pro-vitamin A levels as well as the development of off-flavors.

In addition further dehydration conditions can cause degradation of carotenoids, not only due to chemical interactions but also to physical damage of tissues. Besides β-carotene is oxidized upon exposure to light and oxygen, and has been described as being labile to different drying techniques (convection, sun, vacuum or freeze-drying (Soria *et al*.,2009). Blanching the product before drying to stop enzymatic activity must be considered for the specific product to be dried (Fellows, 2000).

2.5.3 Nutritional quality

In drying, a food loses its moisture content, which results in increasing the concentration of nutrients in the remaining mass. Proteins and carbohydrates are present in larger amounts per unit weight in dried foods than in their fresh counterpart. Large differences in several reported data on the nutritive value of dried foods are due to wide variations in the preparation procedures, the drying temperature, a time, and the storage conditions (Krokida and Maroulis,1999).

2.5.3.1 Vitamin C

Vitamin C (ascorbic acid) is an important nutrient, and it is often taken as an index of the nutrient quality of processed product. Ascorbic acid is water soluble, and when the water evaporates from the products, it could react with other solutes at higher rate. It can be oxidized to Dehydroascorbic acid under aerobic conditions, followed by hydrolysis and further oxidation. This degradation is influenced by water activity, heat and oxidation. And also, degradation of ascorbic acid has been suggested to be the other major causes of browning. The vitamin C content of tomatoes was found to reduce during drying by number of researchers (Zanoni *et al*.,1999 ; Laveli *et al*.,1999).

In general, vitamin C retention after drying is relatively low, even if quite high contents (in g kg^{-1} of product) can be reported for dry products, due to the evaporation of water and the concentration effect. As a general rule, the longer duration of drying (low temperatures, high relative humidity, thick products), the lower the retention of ascorbic acid (Santos and Silva, 2008). However Freeze-drying provides high retention of vitamin C, due to low temperatures, reduced mobility of reactants, and reduced partial pressure of O_2.

Vitamin C retention is also improved by all drying processes under an inert atmosphere, which reduce the presence of O_2, fast drying, and low oxygen and moisture contents during storage are the factors that prevent further degradation during storage (Fellows, 2000).In addition, to optimize ascorbic acid retention; the product should be dried at a low initial temperature when the moisture content is high since ascorbic acid is most heat sensitive at high moisture contents.

2.5.3.2 Protein, Fat and Carbohydrate

Fruits are generally rich sources of carbohydrates, poor sources of proteins and fats. The biological value of dried proteins varies with the drying procedure. Prolonged exposures to high temperatures can affect the functional properties or render the protein less useful in the diet. Low temperature treatments of protein may in some cases increase the digestibility of protein over the native material. In general, biomaterials and foods form a complex, dehydrated mixture of amorphous compounds. Carbohydrates, proteins and minerals are miscible with water and dehydration may increase the solute concentration (Fellows, 2000).On the other hand rancidity is an important problem in dried foods. The oxidation of fats is greater at higher temperatures than at low temperatures of dehydration. Protection of fats with antioxidants is an effective control.

2.5.3.3 Microbiological quality

During harvesting and subsequent steps involved in processing, food products are prone to different kinds of damage involving mechanical, physical, chemical and microbial damage. Mechanical and physical damage can contribute to enhance the chemical and microbial damages (Rahman, 1999; Mujumdar, 2004). Microbial growth can occur during post harvest processing and storage by the main contaminant such as soil, water, air and animals. The main microorganisms contributing to such damages are bacteria, fungi (molds and yeast), protozoa, however, insects can also contribute to the microbial damage (Mujumdar, 2004). Microbial growth can result into loss of sensory characteristics of the food items (fruits and vegetables) and in many cases the damages food will be of unacceptable quality on various fruits products.

One obvious method of control is the restriction of moisture for growth, since living tissues require moisture. The amount of moisture in food establishes which micro organisms will have an opportunity to grow. Reducing the water activity of a product below 0.85 also inhibits growth but does not result a sterile product. The heat of the drying process reduces or completely overcome the potential of microbial damages (Mujumdar, 2004). Recommendatio ns for the control of micro organisms during processing are often very basic. The highest possible drying temperatures should be used to maximize thermal death even though low drying temperatures are best for maintaining organoleptic characteristics. Pre-treatments like osmotic solution are also useful in controlling microbial growth during dehydration processes. But the most positive control would be to start with high quality foods having low contamination, sterilize the material prior to drying, process in clean area, and store under conditions where the dried foods are protected from infection by dust, insects, rodents and other animals (Woodroof and Luh, 1986).

2.5.4 Physical transformations

In the course of drying different phenomena are linked to water loss and temperature variation with time are observed such as decrease in water activity, glass transition, crystallization, melting of fat, evaporation of volatile components and migration or retention of components. The consequences on product characteristics are complex and interconnected. For example, a decrease in water activity corresponds to a reduction of water availability and mobility in the medium, increasing biological and microbiological stability, which is the main aim. In addition, a decrease in water activity slows down the water transfer, and, therefore the drying rate increasing the time that the product must spend at relatively high temperature during which reactions may develop (Rahman, 2005).

2.5.4.1 Rehydration ratio

Rehydration is a complex process aimed at the restoration of raw material properties when dried material is contacted with water. Dry products are very often used after their rehydration, in different conditions and contexts, involving various mechanisms. For example, for breakfast cereals, crispiness must be preserved for some time, even after adding

milk; in contrast, soups are prepared from powder mixtures which must dissolve quasi-instantaneously in hot water. Several aspects must be taken into account concerning rehydration (Bimbenet *et al*., 2002).

For powders, the dispersion in water depends on the size (agglomeration favors the dispersion), the composition (surface wet ability i.e., composition in fat and non-soluble components), or the sink ability linked with structure (porosity, capillarity), leading to formation of lumps or precipitates. Rehydration will usually not lead to recovery of the initial product, but to a different product. Hence, drying creates irreversible transformations such as protein denaturation (insoluble), modified aroma, color, loss of firmness and shape. In order to compare the rehydration capacities, different criteria and standards, like temperature or stirring, have been defined according to product specificity and final use (Lewicki, 1998; Pisecky, 1997).

In addition, when rehydrating a dried product, it will never regain the same condition as before drying. Because the drying process causes changes in the permeability of the cell walls, loss of osmotic pressure and solute migration. Crystallization of polysaccharides and coagulation of proteins also contribute to irreversible changes of the plant tissue. The less elastic cell walls and the reduced water holding capacity of protein and starch, all decrease the rehydration ratio of the products. If the drying process is optimal, the negative factors regarding rehydration of the cells will be less than with a poor drying technique (Fellows, 2000).

2.6 Factor affecting shelf stability of dried tomato

Shelf stable food is defined as foods that by virtue of their form, formulation, or packaging can be stored for extended periods (months or greater) at ambient temperature without significant deterioration of quality (AGDOHA, 2006). The quality of dried food products especially tomatoes is of utmost importance and should be able to reach a certain level of acceptance in terms of appearance, taste, moisture content, extractible constituents, microbial quality, flavor, nutritive value, texture and degree of contamination (Williams, 1981). However dried vegetables can suffer significant modifications that bring about their

deterioration during storage. The shelf life of dehydrated fruit and vegetable depends on many deleterious reactions, which in turn depends on the specific nature of the food material, nature of packaging material and storage condition. The undesirable changes that occur are due to off flavor, browning, loss of pigment and nutrients. Knowledge of the causes of this reaction is highly necessary to improve the shelf life of the dehydrated products (Mujumdar, 1981).

On the other hand the factor mainly responsible for deterioration is that, moisture content, storage temperature and period, oxygen, and light. Besides methods of drying, additional treatment, storage condition, times required for appearance of the earliest defects, and the states of other factors at times of unacceptability (Mujumdar,1981).

Moisture content is very important parameter influencing stability of dehydrated foods. It has been suggest that the optimal amount of water for long term storage correspond in most dehydrated foods to the Brunauer Emmett-Teller (BET) mono layer value. Items such as freeze dried spinach, cabbage and orange juice were reported to be more stable at zero moisture contents, whereas items like potato and corn had maximum stability at monomolecular moisture contents. The moisture content of the dried tomato product during the drying process for storage also typically reduced to15% (Zanoni *et al*.,1999). It appeared that optimal moisture contents could not be predicted with precision on the basis of the theoretical considerations.

Another important factor affecting storage stability of dehydrated food is temperature and periods of storage. Generally, the storage stability bears an inverse relationship to storage temperature, which affect not only the rate of deterioration (enzyme hydrolysis, lipid oxidation and protein denaturation) but also kind of spoilage mechanism (Mujumdar,1981).

It is well established that elimination of oxygen by packing an inert atmosphere such as nitrogen contributes to extending the storage stability of dehydrated product. Further, since oxidation of lipids and vitamins like ascorbic acids, riboflavin, thiamine and vitamin A and losses of pigments such as carotenoids and chlorophyll are initiated or accelerated by light

and adequate packing also need to be provided to protect such dehydrated foods from light (Mujumdar, 1981).

2.6.1 Packaging material

Even though shelf life of a packaged food is controlled by the physical characteristics of the products such as water activity, pH value, susceptibility to enzymatic or microbial deterioration, mechanism of spoilage, requirement for sensitivity to oxygen, light, carbon dioxide and moisture (Fennema and Tannencbaum, 1985). The success of most preservation methods depends on how well the processed food is protected from adverse environmental conditions, which is mostly accomplished by packaging. Packaging plays an important role in determining the stability of foods by influencing those factors which cause or contribute to food deterioration during storage. But ability of packaging material to retain food sensory characteristics and nutritional properties throughout the storage period cannot be under stressed in the choice of any material to package a type of food (Williams, 1981). Williams (1982) stated that a number of factors determine a good and effective packaging of dried food products. There is a growing pressure in the fruits and vegetables packaging sector to use effective packaging materials with the aim of enhancing the shelf-life. The packaging material must provide a suitable barrier around the food to prevent microorganisms from contaminating the food. Such material must not contain toxic substances that make the food unsafe. Rozis (1997) also noted that the choice of packaging material depends on several factors such as the kind of foodstuff, the storage conditions, the material's protective qualities, the materials availability and cost.

Since, dehydrated tomatoes require very little storage space. Completely dried tomatoes can be stored in sealed plastic jar, polyethylene and airtight jars, or other suitable containers (Tracy *et al*., 2004). Among this polyethylene is one of the most important packaging materials of the present time. Polythene is good material widely used in packaging due to their relatively low cost, good moisture and gas barrier properties, availability. Generally, polyethylenes are characterized by having a low permeability to water vapor, a high permeability to oxygen, carbon dioxide and other gases. They are also good heat sealers

forming a strong seal almost instantly (Famurewa *et al.*,2013).They described either as low density (LDPF) or high density (HDPF) depending on their thickness (Williams, 1981). Sheshma *et al*. (2014) reported that HDPE was found to be a good packaging material to maintain the quality of tomato powder with respect to lycopene degradation, browning reactions and powder was safe for consumption up to 2 months at ambient storage temperature.

Glass jar is one of the oldest packaging materials. It was initially used for packaging wines. The use of glass jar for packaging heat-processed foods began in 1804. Glass jar is a desirable package for foods because it does not react with foods, has excellent barrier properties, transparent, reusable, reasonably strong, easy to open, can be molded into any shape, and usable on many filling machines. However, glass jar is heavy, breakable, and susceptible to sudden temperature shocks (Ojijo *et al*.,2006).

2.6.2 Storage condition

The storage environment is a function of relative humidity and temperature under which the food material is stored. Storages of dried products has significant effect on the quality of the dried product with respect to the length of storage as well as processing parameters because drying of fruit and vegetables causes irreversible structural damage to the cellular structure of foods. Storage condition such as temperature, air humidity and light may deteriorate quality of dried fruit and vegetables during storage. Storage temperature has an important role because this reduces or inhibits the speed of all physicochemical, biochemical and microbiological processes, and thus prolongs storage period. Therefore storage temperature should be below 25°C (and preferably 15°C); lower temperatures (0-10°C) help maintain taste, color and water rehydration ratio and also, to some extent, vitamin C. Generally, food will maintain quality longer at cooler storage temperatures (Sandra *et al*., 2009).

Various studies showed that significant oxidative damage can occur during storage of dried tomatoes. Anguelova *et al*.(2000) detected 30-40% lycopene loss in spray-dried tomato powder stored for 6 weeks at 6^0C in air and in the dark and suggested that degradation

proceeded through isomerization and autoxidation of *all-trans*lycopene. Baloch *et al.* (1997) found that carotenoid loss was above 50% in tomato powder after 20 days of storage at 40^0C in air and in the dark. Zanoni *et al*. (1999) also observed a marked lycopene loss (more than 70%) after 90 days of storage of powdered air dried tomato at 37 ^{0}C in the dark in the presence of air. Sharma and Le Maguer (1996) studied the kinetics of lycopene degradation during storage of tomato pulp solids under various conditions. Lycopene loss was maximum (77.6%) after 60 days of storage at 25^0C in the presence of air and light. Freeze-drying and oven-drying of tomato pulp solids did not cause any loss in lycopene content; however, lycopene loss reached 97% and 79%in freeze-dried and oven-dried samples, respectively, after storage at room temperature in the dark for 4 months.

On the other hand increasing the temperature raises the water mobility inside the powder particle favoring degradative reactions (Rodríguez *et al*., 2009).Vitamin C is an unstable and weak vitamin because of the high reactivity of the enediol structure. Its main degradation route is oxidation to dehydroascorbic acid, which tends to suffer a series of reactions with amino acids and acids deriving into active formation of pigments. However the kinetic loss of vitamin C was lower at 4°C (Cernisev, 2010).

Generally in shelf-life study the degradation reactions are made faster by high temperature, oxygen, light exposure, very low moisture content and water activity (aw). Therefore, storage conditions also need to be optimized to keeping quality. It is important for fruit and vegetables not to be subject to temperatures higher than 30ºC to avoid heavy quality losses.

3. MATERIALS AND METHODS

3.1. Description of the experimental site

The experiment was conducted in post-harvest, plant pathology and Animal nutrition laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in the year 2014-2015. JUCAVM is geographically located at an altitude of 1710ma.s.l. The mean maximum and minimum relative humidity are 91.4% and 39.92% respectively (BPEDORS *et al*., 2000). At the time of investigation the average temperature and relative humidity of the laboratory was 23± 2 °C and 55± 2% RH respectively.

3.2. Sources of raw materials

An improved processing type tomato (variety Cochorro) which is widely grown in Maki area and known for its superior performance was collected from a local farmer in Ziwai (Maki). The tomatoes were freshly hand harvested from the field at their light red maturity stage, transported by car to JUCAVM and ripened to uniform red ripe stage. A total of 160 kg mature tomato fruits were required to complete the experiment in triplicates.

3.3 Sample preparation and drying process

The procedure for the whole study is depicted in Figure 1. Prior to drying, individual tomato fruits were measured by caliper (Fowler, US) and cut into 8mm thickness slices using sharp stainless steel knife (Jayathunge *et al*., 2012). For the sake of keeping uniform drying slices of tomato for each run were placed in single layer on the sample trays. Then the sliced tomato samples were placed inside in the hot air oven (Leicester, LE67 5FT, England) at predetermined temperatures of 70°C, 80°C and 90°C for the duration of 7 and 8 hours which were fixed in preliminary trials. Next dried tomato slices were cooled for about an hour inside desiccators to prevent formation of condensation moisture in a sample to be packaged for both drying study and storage study.

3.4 Packaging

The dried tomato slices were powdered using mortar and pestle in order to make analysis and packaged in glass jar for experiment I (drying study).For the second phase of the study, in addition to glass jar which is odorless, chemically inert, impermeable to gases and vapors, a low density polyethylene bag and plastic jar package with high barrier to water vapor, hot sealing, chemically resistant, inexpensive and lightweight with a wide range of physical and optical properties were used for experiment II (storage study).

3.5 Storage studies (Experiment II)

Based on the findings obtained from experiment one, the study conducted to determine appropriate temperature and duration of drying on physicochemical and sensory quality attributes, accordingly two best treatments were selected (those dried at 90^{o}C for 7 and 8 hours). A sample of 70g was taken from the selected dried tomatoes and packed in different packaging materials and stored under refrigerated and ambient condition for further study. The packaged samples were stored at two conditions; in refrigerate at 4°C (55±5% RH) and at room temperature 23±2°C in dry (55±2% RH) and dark place for three months from February 2015 to April 2015.

Samples were withdrawn at one month interval for analysis that were determined in experiment one (drying study) including microbial count except sensory evaluation. Analyses were done on the first days before storage, First month, Second and Third months of storage period. Samples to be used for analyses on each sampling date were individually packaged.

3.6. Experimental Procedure

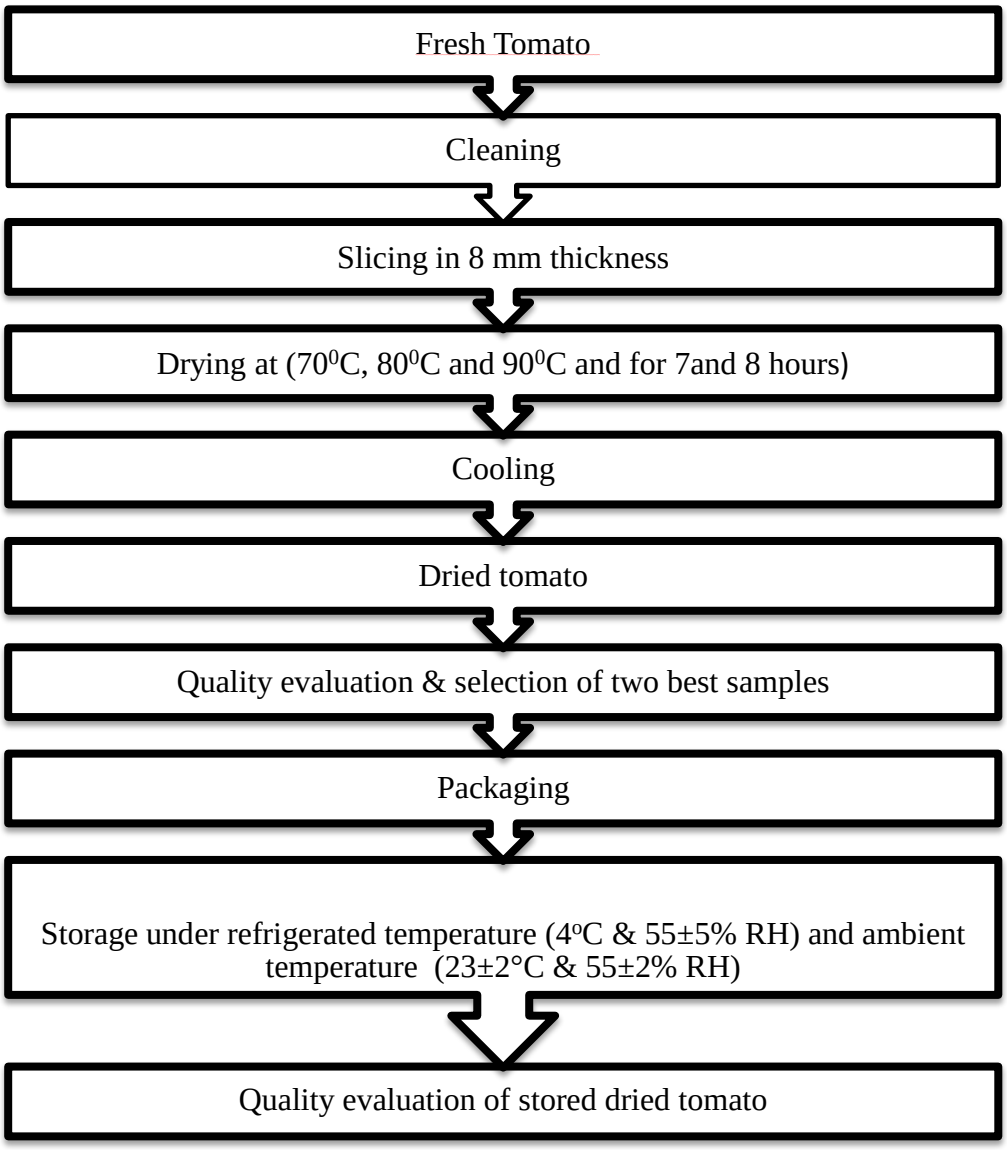


Figure1. Flow chart depicting the process of tomato dehydration, packaging and storage

3.7. Experimental Designs

The present study consisted of two experiments conducted in two phases; Phase I was the drying study which was carried out using a two factor factorial design (3*2); Phase II was the subsequent study built up on the outcome of the physicochemical and sensory analysis of phase I. Then two best treatment samples were selected to design a 2*3*2*3 factorial experiment. In both experiments, treatments were replicated three times.

The first experiment consisted of two factors: Factor A: representing the drying temperature (T) with three levels (70^0C, 80^0C and 90^0C) and Factor B: Time (t) with the two levels (7 and 8 hours). The second experiment involved four factors namely Factor A: Dried tomato with selected two levels (Sample1; Sample2), ; Factor B: packaging materials (P) with three types (Plastic jar, Glass jar, Plastic bags),;Factor C:Storage temperature (SC) with two types (Room temperature, Refrigerated temperature) and Factor D: Storage Period with three levels (1, 2, 3 months). Details of the experimental combinations are presented in Table 1 and Table 2.

Table 1: Experimental plan for experiment I (Drying study)

Durations	Temperature		
	T1	T2	T3
t1	t1×T1	t1×T2	t1×T3
t2	t2×T1	t2×T2	t2×T3

t1 and t2, represent drying durations of 7 and 8 hours respectively.

T1, T2 and T3 represent drying temperatures of 70^0C, 80^0C and 90^0C respectively.

Table 2: Experimental plan for experiment II (Storage study)

Storage temperature		Room temperature (r)			Refrigerate temperature(R)		
Storage period (Months)		1		2	3		
Packaging material		Glass jar	Plastic jar	Plastic bag	Glass jar	Plastic jar	Plastic bag
Dried sample	S1	S1rG	S1rP	S1rB	S1RG	S1RP	S1RB
	S2	S2rG	S2rP	S2rB	S2RG	S2RP	S2RB

S1 and S2, represent dried sample allowed for storage study respectively
G, P, B, represents packaging material (glass jar, plastic jar and polyethylene bag)
r and R, represent room temperature and refrigerate temperature storage respectively

The linear statistical model for the treatment factors is shown below.

Models:

$Y_{ij}= \mu+ T_i+ t_j (Tt)_{ij} +\varepsilon_{ij}$....for experiment one

$Y_{ijk}=.\mu+S_i+P_j+T_k+M_{l+}(SP)_{ij}+(SR)_{jk}+(PT)_{ik+}(SPT)_{ijk}+(S_iM_l)_{il}+(P_jM_{l)jl}+(T_kM_{l)}$
$+(S_iM_lp_j)_{ilj+}(S_iM_lT_K)_{ilk+}(PTM)_{jkl}+(S_ip_jT_KM_{l)ijkl+}\varepsilon_{ijkl}$..... for experiment two

Where
y_{ijk}= the response
μ = is the overall mean effect.
T_i- is the effect of i^{th} level of duration of drying.
t_j - is the effect of j^{th} level of drying temperature.
$(Tt)_{ij}$ -is the interaction between i^{th} level of drying duration , j^{th} level of drying temperature
S_i- is the effect of i^{th} level of dried tomato sample.
P_j - is the effect of j^{th} level of packaging material.
T_k - is the effect of k^{th} level of storage temperature.
M_{l-} is the effect of l^{th} level of storage period.
$(SP)_{ij}$ -is the interaction between i^{th} level of dried tomato sample, j^{th} level of packaging material
$(PT)_{jK}$ -is the interaction between j^{th} level of packaging material and k^{th} level storage temperature
$(ST)_{ik}$ - is the interaction between i^{th} level of dried tomato sample and k^{th} level of storage temperature

$(SPT)_{ijk}$- is the interaction between i^{th} level of dried tomato sample , j^{th} level of packaging material and k^{th} level of storage temperature

$(S_iM_l)_{il\text{-}is}$ is the interaction between i^{th} level of dried tomato sample and l^{th} level of storage period

$(P_jM_{l)jl\text{-}is}$ is the interaction between j^{th} level packaging material and l^{th} level of storage period

$(T_kM_{l)kl}$- is the interaction between k^{th} level of storage temperature and l^{th} level of storage period

$(S_ip_jM_l)_{ijl}$ is the interaction between i^{th} level of dried tomato sample ,j^{th} level of packaging material and l^{th} storage period

$(S_iT_KM_l)_{ilk}$ - is the interaction between i^{th} level of dried tomato sample , and k^{th} level of storage temperature and l^{th} storage period

$(PTM)_{jkl\text{-}}$ is interaction between j^{th} level of packaging material, k^{th} level of storage temperature and l^{th} level of storage period

$(S_ip_jT_KM_{l)ijkl}$ is the interaction between i^{th} level of dried tomato sample, j^{th} level of packaging material and k^{th} level of storage temperature and l^{th}levels of storage period.

ε_{ijkl}-is the error effect

3.8 Data Collected

3.8.1 Chemical parameter

3.8.1.1 Determination of moisture content

Moisture of the samples were determined by air oven (Leicester, LE67 5FT, England) method according to (AOAC, 2011, 925.10). The metal dishes were dried at 130^{o}C for 1hour and placed in desiccators and weighed after cool. 2g of well mixed sample were weighed (*M initial*). Sample contained dish were placed in hot air oven for one hour provided with opening for ventilation of moisture dish and maintained at 130^{o}C. After successful completion of the exposure dish were transferred to desiccators and weigh was taken soon after reached to room temperature (*M dried*). Then, the moisture content was estimated by the following formula:

$$\text{Moisture (\%)} = \frac{M_{\text{initial}} - M_{\text{dried}}}{M_{\text{initial}}} \times 100$$

Where;

$M_{initial}$=Mass of crucible and sample before oven

M_{dried}=Mass of crucibles and sample after oven

3.8.1.2 Determination total of ash content (%)

The ash content was determined by the method as reported in the handbook of AOAC (1984).The samples were weighed (5g) accurately in a previously cleaned and dried weighed crucible (W_2). At first the crucible containing sample was placed in an oven at 105^0C for 4 hours to remove moisture. The moisture free sample was completely charred (free from carbon residues; appears in grayish-white) in a heating mantel followed by heating (ashing) in a muffle furnace (Model SX-5-12, China) at 600^0C for 3 hours. Then it was removed from furnace and cooled in desiccators and weighed (W_3). To ensure complete ashing, the crucible was again heated in a muffle furnace for one hour. Then crucible was removed from the furnace and cooled in desiccators and weighed again.

$$\% \text{ Ash} = \frac{\text{Diffrence in Weight of Ash}}{\text{Weight of sample}} \times 100$$

Where;

Difference in weight of Ash= W_3-W_1

W3=Weight of sample and crucible after muffle furnace

W1=Weight of crucible

3.8.1.3 Determination of Crude Fat (%)

Crude fat was determined by Soxhlet (SHANGHAIINSTRUMENT CO.LTD, 200804026) extraction methods according to AOAC (2011, 2003.06,). About 3g of sample were weighed and put into a thimble. The thimble and contents were place in to a 50 ml beaker and dried in

an oven for 2 hour at 102 ± 2^{o}C.Thimble and contents weight was determined (W1) transfer in to extraction apparatus. The beaker was rinse for several times with the solvent hexane. The sample contained in the thimble was extracted with the solvent hexane in a Soxhlet extraction apparatus for 6-8 hour. Soon after the completion of the extraction, the extract was transferred from the extraction flask into a pre-weighted evaporating small beaker with several rinsing with the solvent. The hexane was evaporated until no odor of its detected. The beaker and its contents were dried in the oven for 30 minutes at 102^{o}C ± 2^{o}C to remove moisture. Then the beaker was removed from the oven and cooled in desiccators. Finally, the beaker and its contents were weighing (W2).

$$\text{Crude fat}(\%) = \frac{\text{W2} - \text{W1}}{\text{Weight of sample}} \times 100$$

Where:

W_1= Weight of extraction flask before extraction

W_2 = Weight of extraction flask after extraction.

3.8.1.4 Determination of Crude Protein (%)

Protein content was determined according to Kjeldahl method of crude protein analysis (AOAC, 2000, 979.09)

Digestion

About 0.3 g of the dried sample was weighed by an analytical balance into the digestion flask (Kjeldahl flask KF250, German). Then the samples was digested by addition of small volume 5ml of concentrated H_2SO_4 (an oxidizing agents which digests the food). About one gram of catalyst mixture was made of K_2SO_4 with anhydrous $CuSO_4$ in the ratio of 10:1 were used. Digestion was converted any nitrogen in the food (other than that which is in the form of nitrates or nitrites) into ammonia and other organic matter to CO_2 and H_2O. In acidic solution, ammonia was not liberated as gas because rather it exists as ammonium sulfate salt.

N (in sample) $\longrightarrow$ $(NH_4)_2\ SO_4$

Distillation

After digestion was complete, the content in the flask was diluted by water and a concentrated NaOH (40%) solution. It was added to make the solution slightly alkaline and to liberate ammonia gas. The ammonia was then distilled into receiving flask that consist a standardized strong acid solution of boric acid (4%) for reaction with ammonia.

Titration

The borate ion was titrated with standard acid (0.1N HCl).

$NH_3 + H_3BO_3$ (boric acid) $\longrightarrow$ $NH_4 + H_2BO_3$ (borate ion)

$H_3BO_3 + H^+ \longrightarrow H_3BO_3$

Then Total nitrogen was calculated as percent by weight as follows

$$\text{Total nitrogen} = \frac{(T - B) \times N \times 14.007 \times 100}{W}$$

Where

T- Volume in ml of the standard acid solution used in the titration for the test material

B-Volume in ml of the standard acid solution used in the titration for the blank determination

N - Normality of standard sulphuric acid

W - Weight in grams of the test material

$$\text{Crude protein } \% = 6.25 * \text{total nitrogen}$$

3.8.1.5 Determination of crude fiber content (%)

The crude fiber content was determined by non-enzymatic gravimetric method (AOAC, 2000, 920.168). About two grams of food sample was placed into 600 ml beaker and 200 ml of 1.25% H_2SO_4 and two grams pre weighed boiling chips were added. Then the beaker was placed on to a digestion apparatus and boiled exactly for 30 min, with regular shaking at 5

min intervals. Next the solution was passed through a screen sieve and the digested sample was decanted. Then the digestion beaker was washed 3 times with 50 ml portion of near boiling point water and each was transferred into the screen for filtration. The residue left on the screen was transferred into 600 ml digestion flask by washing the screen with 200 ml (50mlx4) 1% NaOH. It was then placed on to a digestion apparatus and boiled for 30 min, shaking was done at 5 min interval. The digested sample was filtered in coarse porosity (75µm) crucible in apparatus at a vacuum of about 25mm. The residue was dried at 130^{o}C for 2 hours and cooled in desiccators and weighed (M_1). The dried residue was ignited for 2 hours at 600±15^{o}C until ashing was complete and then cooled inside desiccators and reweighed (M_2).

$$\text{Crude fiber (\%)} = \frac{\text{M1} - \text{M2}}{\text{Weight of sample}} \times 100$$

Where,

M_1 = mass of crucible and residue before ignition

M_2 = mass of crucible and residue after ignition

3.8.1.6 Determination of total carbohydrates (%)

The percentage of total carbohydrate content was determined by the difference method as reported by Onyeike *et al*. (1995). This method involved adding the total values of crude protein, crude fat, crude fiber, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage of carbohydrate constituent of the sample.
Thus,

$$\text{CHO (\%)} = 100 - \%(\text{Moisture} + \text{Ash} + \text{Fat} + \text{Crude Fiber} + \text{Crude Protein})$$

3.8.1.7 Determination of pH

Five grams (5g) of sample was first dissolved in 50ml distilled water and the solution was shaken. Then pH meter was calibrated with two standard buffer solutions at pH 4 and 7. After calibration pH values of the samples solutions were measured using a pH meter (SET/HO11, Mauritius (Ibitoye, 2005).

3.8.1.8 Determination of total soluble solids

Five grams (5g) of sample was dissolved in 50ml distilled water and the solution was shaken. Total soluble solid was measured by hand Refractometer (DR201-95, Germany). By cleaning the slide of the refract meter with distilled water and wiped dry with a clean soft. A smear of the sample was made on the slide of the refract meter and the lid replaced. The reading was taken at the graduated mark which indicates the total soluble solids value of the sample and was recorded in degree Brix (^{0}Brix) (Owoso*et al*., 2000).

3.8.1.9 Determination of titratable acidity

Titratable acidity was determined using (Pearson's, 1981) method. Two gram of ground sample was weighed into a conical flask and 90ml distilled water was added and 10ml of the dissolved sample was taken after filtration. Two drops of phenolphthalein indicator were added to it and this was titrated against 0.1N NaOH.

$$\%\ acid = \frac{(ml\ NaOH)(N\ of\ the\ base\ in\ mol\ per\ liter)(Eq.Wt.\ of\ acid)}{Sample\ volume\ in\ ml} \text{ X } 100$$

Eq.Wt: 0.0064= Citric acid

3.8.1.10 Determination of vitamin-C

The content of vitamin-C in each sample was determined according to Sadasivam and Manickam, (1997). The analyze mixture for vitamin C consisted of 0.1 ml of brominated sample extract, 2.9 ml of distilled water, 1 ml of 2% DNPH reagent and 1-2 drops of thiourea. After incubation at 37ºC for 3 hours, the orange-red zone crystals formed were dissolved by the addition of 7 ml of 80% sulphuric acid and absorbance was read at 540 nm after 30 minutes using UV-Vis spectrophotometer (T80, China)and the Vitamin-C content in the samples was calculated by using Vitamin-C standard curve. Vitamin C concentration was expressed in terms of mg/100g tissue.

3.8.1.11 Determination of β-Carotene and Lycopene content

Beta -carotene and lycopene contents were determined according to the method described by Nagata and Yamashita (1992). The dried methanolic extract (100mg) was vigorously shaken with 10ml of acetone – hexane mixture (4:6) for 1min. The absorbance of the filtrate was measured at wave lengths of 453, 505, 645 and 663nm using UV-Vis spectrophotometer (T80, China). Finally, β- Carotene and Lycopene contents of each sample were calculated according to the following equations:

Lycopene (mg/100ml) = $- 0.0458A_{663} + 0.024A_{645} + 0.372A_{505} + 0.0806A_{453}$…… (1)

β- Carotene (mg/100ml) = $0.216A_{663} – 1.22A_{645} - 0.304A_{505} + 0.452A_{453}$…… (2)

Where A663, A645, A505 and A453 refers to the absorbance at 663, 645, 505 and 453 nm, respectively.

The values are expressed as (mg/100gm) of extract.

3.8.2 Physical parameter

3.8.2.1 Water absorption capacities

The Water absorption capacities were carried out according to (Lewicki, 1998). Two grams (2g) of tomato powder were weighed (initial weight) into 250 ml beakers and submerged in 50 ml distilled water at room temperature for 0.5, 1.0, 1.5, 2.0 hours and the samples were drained by vacuum pump (D-7800, German) until all the water was drained out and the adhered water was absorbed (removed) by tissue paper and finally weight of water absorption capacities of sample were taken (final weight). Finally water absorption capacities were obtained by dividing the rehydrated weight by the initial weight.

$$\text{Water absorption capacities} = \frac{\text{Water absorption capacities}}{\text{Sample weight}}$$

3.8.2.2 Water activity

The water activity of the sample was determined by LabMaster-a_w instrument (Novasina AG, CH-8853 Lachen). A homogenous powdered sample was placed in a sample cup, by completely covering the bottom of the cup. Then, prepared sample were placed in the drawer followed by carefully closing of slide the drawer. In about 10-15 minutes the water activity was measured.

3.8.3 Sensory evaluation

Dried tomato samples were subjected for sensory evaluation in order to assess consumers' reaction with regard to color, flavor, mouth feel, taste, appearances and overall acceptability of the powdered tomato samples (Jayathunge*et al*., 2012). Fifty members of untrained panelists were chosen from students, laboratory technicians and academic staff member of PHM department. All samples were coded and randomly placed and panelists were asked to evaluate the color and flavor, mouth feel, taste, overall acceptability of the dried tomatoes using a five point hedonic scale, where 1= dislike extremely, 2 = dislike moderately, 3 = neither like nor dislike, 4 = like moderately and 5 = like extremely.

3.8.4 Determination of aerobic standard plate count

Nutrient agar medium was used as the growth medium for bacteria. The agar was prepared according to manufacturer's specifications. The standard tenfold serial dilution technique was employed to dilute each sample up to the 10^6 level. Then plates were inoculated with 0.1 ml of volume and then incubated at 37°C for 48 hours.

After incubation, the colonies on each of the plates were counted using colony counter and the colony forming units in the original samples were calculated (Fraizer and Westhoff,1985). Then counts were converted in to microbial load using Eq.3.

Similarly, for fungus count, 0.1ml sample was aseptically surface plated on Potato Dextrose Agar medium (PDA).The plates were incubated at 28ºC for 48 hours as described in Harrigan

and MacCance (1976). Finally, the total counts were presented as colony forming unites per gram (cfu/g).

$$ML = \left(N \ / \ V * R\right)$$

…….……Eq.3

Where, ML = Microbial load

N = Number of colonies

V = Value of Dilution

R = Dilution factor (expressed in cell/ml)

3.9 Statistical Analysis

Initially, all collected data from objective measurements and subjective assessments had their normality, and variance homogeneity tested by distribution graphs and subjected to the Analysis of Variance (ANOVA) using SAS version 9.2 computer software (SAS Institute Inc., 2008). Data were compared on the basis of standard deviation of the mean values. Every significant treatment effect within the evaluated parameters was compared using Tukey at 5% probability level.

4. RESULTS AND DISCUSSION

4.1 Drying Study (Experiment I)

4.1.1 Chemical parameter

The analysis of variance of the results indicated that there is interaction effect between temperature and duration of drying in all parameters during drying study (experiment I). The result of proximate composition for both experiments was calculated by dry basis. Effects of drying temperature and duration of drying on the proximate composition of dried tomato are presented in Table 3 and Table 4. Accordingly the result of the remaining chemical parameter and sensory quality are described below.

4.1.1.1 Moisture (%)

There was significant ($p \leq 0.001$) difference in moisture content between control (fresh) and dried tomato sample (Appendix Table 1). The moisture content of the fresh tomato before drying was determined to be 88% (wet basis). The maximum dry moisture content value (7.87%) was recorded in sample dried at 70^{o}C for 7 hours and minimum value (4.23%) was recorded in sample dried at 90^{o}C for 8 hour (Table 3). The experimental result indicated that as drying temperature and duration of drying increased the moisture contents of dried tomato decreased significantly. This is attributed to the evaporation rate (migration of moisture) which increased with increasing temperature and duration of drying. The reduction of moisture content of the product at studied duration and temperature combination to less than 10 % is desirable and hence contributes for better shelf stability. However there was no statistically significant difference between samples dried at 80^{o}C for 7 hours and 8 hours (Table 3).

The result is in line with the report of Onuegbu *et al*. (2013), who stated that the dried samples were significantly different ($p \leq 0.05$) in moisture content from the fresh samples. Obviously there was very high moisture content (96.26%) in the fresh tomato than the moisture content of (4.24) oven dried samples at 60^{o}C. Similarly Mozumder *et al*.(2012),

reported that there is high moisture content (95% ±1) in fresh tomatoes than in (6.9%) in oven dried samples at 68^{o}C for 27 hours. According to Damodaran *et al*.(2008)water plays an essential role in the chemical and physical processes within foods. One of the importance of decreasing the moisture contents of product is that the microorganisms can no longer grow because many of the organisms found in the fresh material require a specific moisture contents to grow.

4.1.1.2 Ash (%)

Ash is inorganic residue remaining after the water and organic matter have been removed by heating of a given food. It is a measure to indicate the total amount of minerals present within a food. The result of the present study revealed that the ash contents of tomato fruit was affected significantly ($p \leq 0.001$) by interaction between duration and temperature of drying (Appendix Table 1). The maximum ash content was found as 20.86% and 19.94% in sample dried at 70°C for 7 and 8 hours respectively, which is higher than the control (fresh) and other treatment combinations (Table 3).The minimum ash content (8.20%) was found in control (fresh) tomato sample. The result showed that the ash content was increased at low temperature and short duration of drying. This could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Morris *et al*., 2004).

However ash content decreased with increment of duration and temperature (Table 3). Although there was decreasing of ash content observed, it can be seen from the result there was more ash in dried tomato sample than control (fresh) tomato; this implies that there are more combustible materials in dried tomato than control (fresh). But there was no statistically significant difference between samples dried at 90^{o}C for 7 hours and 80^{o}C for 7 and 8 hours.

The result was in line with findings of Onuegbu *et al*. (2013) who reported that the ash content of fresh tomato was lower (0.43%) than those oven dried tomato samples at 60^{o}C. Analogous to this, Idah *et al*. (2014) revealed that ash content decreases with increase in drying temperature because of denaturing of the samples at higher temperatures.

4.1.1.3 Crude Fat (%)

As result illustrates, there was significant ($p \leq 0.001$)difference in crude fat content between dried and control (fresh) tomato samples influenced by interaction effects of duration and temperature of drying (Appendix Table 1).The value ranged between 23.50% and 1.03% which was observed in control samples and in samples dried at 90^{o}C for 8 hours respectively (Table 3). The result showed that as duration and drying temperature increased the fat content decreased. This could be attributed to the oxidation of fat at higher temperature and long duration than at lower temperature for short duration. On the other hand the lowering of fat in dried tomato may have contribution in reducing rancidity of product during storage and cholesterol level in the diet. Results from this study are similar to finding of Famurewa and Raji (2011) who reported that the fat content (1.75%) of fresh tomato samples was higher than (1.25 %) oven dried samples at 50^{o}C.

Table 3: Effects of duration and drying temperature on Moisture, Ash and Fat contents of dried tomato (dry wet basis)

Duration (hours)	Temperature (°C)	Moisture (%)	Ash (%)	Crude fat (%)
Fresh		88.00±0.03^{a}	8.20±1.1^{c}	23.50±0.71^{a}
7	70	7.87±0.13^{a}	20.86±1.1^{a}	2.80±0.71^{b}
	80	5.52±0.13^{c}	18.57±1.1^{ab}	1.79±0.71^{b}
	90	4.82±0.13^{ed}	17.03±1.1^{ab}	1.43±0.71^{b}
8	70	6.83±0.13^{b}	19.94±1.1^{a}	2.14±0.71^{b}
	80	5.29±0.13^{dc}	16.77±1.1^{ab}	1.45±0.71^{b}
	90	4.23±0.13^{e}	13.20±1.1^{cb}	1.03±0.71^{d}
CV (%)		4.20	12.30	8.10

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$.

4.1.1.4 Protein (%)

There was significant ($p \leq 0.001$) difference between dried and control (fresh) samples regarding crude protein content affected by interaction of duration and temperature of drying (Appendix Table 2). The protein content in control (49.97%) samples was higher than

(13.95%) in samples dried at 70^{o}C for 7 hours (Table 4). The result indicated that decreasing of protein content is more in samples dried at low temperature and short time than in sample dried at high temperature and long duration. This shows the high temperature and long duration involved in drying denature the protein contents in dried tomatoes. However, there was no significant difference between the samples dried at 70^{o}C for 8 hours and 80^{o}C and 90^{o}C for 7 hours (Table 4). In accordance with this, Idah *et al*. (2014) stated that as drying temperature increased from 50^{o}C to 70^{o}C, they observed protein contents of dried tomato decreased from 14.68 to 13.97%.

4.1.1.5 Crude Fiber (%)

The fiber content was significantly affected ($p \leq 0.001$) by interaction of duration and temperature of drying (Appendix Table 2). The result revealed that the maximum (9.63%) and the minimum crude fiber content (4.24%) was found in control (fresh) samples and in samples dried at 70°C for 7 hours respectively (Table 4). These indicates that the presence of more crude fiber content in control (fresh) tomato sample than in dried tomato sample. In addition the crude fiber contents of dried tomato decreased as duration and temperature increased (Table 4).This was as a result of high temperature and long duration involved during drying process can disrupt the cellular matrix of the products (Onifade *et al*., 2013). However there was no significant difference between samples dried at 70^{o}C for 7 and 8 hours and also between 90^{o}C for 7 and 8 hours. These result is similar with the findings of Mozumder *et al*.(2012) who stated that crude fiber content of oven dried samples at 68^{o}C for 24±2 hours was (5.9%).

4.1.1.6 Total Carbohydrate (%)

There was significant($p \leq 0.001$) difference in total carbohydrate contents of dried and control tomato samples affected by interaction of duration and temperature of drying (Appendix Table 2).The highest total carbohydrate content (61.15%) was found in samples dried at 90^{o}C for 8 hours while the lowest (8.44%) was found in fresh (control) samples(Table 4). However there was no significant difference between samples dried at 70^{o}C for 7 hours, 80^{o}C for 7 and

8 hours. The result indicated that the total carbohydrate content of dried tomato increased with duration and temperatures of drying. This is expected because carbohydrate content was obtained by difference; since the other proximate composition was slightly degraded with increasing of duration and temperature of drying.

Similar result was observed by Onuegbu *et al*.(2013) who reported that lower total carbohydrate content (0.43%) in control samples than oven dried samples at 60^{o}C and also conforms with observation of Jorge *et al*.(2013) who stated that the carbohydrate content of dried tomato was concentrated on average 15 times, when compared with the fresh tomato fruits. In addition according to David and White Field (2000), dried foods are high in carbohydrates.

Table 4: Interaction effects of duration and temperature on Protein, Fiber, and Carbohydrate contents of dried tomato fruit (dry wet basis)

Duration (hours)	Temperature (°C)	Crude Protein (%)	Crude Fiber (%)	Total Carbohydrate (%)
Fresh		49.97±1.1^{a}	9.63±0.21^{a}	8.44±1.21^{c}
7	70°C	13.95±1.1^{c}	6.65±0.21^{b}	55.73±1.21^{ab}
	80°C	14.90±1.1^{bc}	5.91±0.21^{bc}	58.74±1.21^{ab}
	90°C	16.59±1.1^{bc}	4.71±0.21^{d}	60.1±1.21^{a}
8	70°C	18.50±1.1^{bc}	6.48±0.21^{b}	53.41±1.21^{b}
	80°C	19.54±1.1^{b}	5.22±0.21^{dc}	58.86±1.21^{ab}
	90°C	20.41±1.1^{b}	4.24±0.21^{d}	61.15±1.21^{a}
CV (%)		9.01	6.10	4.15

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$.

4.1.1.7 TSS

TSS content is important criterion in determining the suitability of varieties for processing. From total soluble solid content 50– 65% are sugars, glucose and fructose, and their amount and proportion influence the organoleptic quality of tomatoes (Adedeji *et al*., 2006). The

remaining soluble solids are mainly citric and malic acids, lipids and other components in low concentrations.

The TSS contents of tomato were significantly ($p \leq 0.001$) increased after drying affected by interaction of duration and temperature of drying (Appendix Table 5). The maximum value (10.7) was recorded in samples dried at 70^{o}C for 7 hours and the minimum value (7.3) was recorded in control (fresh) sample (Table 5). However there was no statistically significant difference between samples dried at 70^{o}C for 7 and 8 hours. And also there was no statistically significant difference in TSS between dried samples at 80^{o}C for 7, 8 hours and 90^{o}C for 7 hours (Table 5).The decrease in moisture content in the fruits is usually accompanied by an increased percentage of TSS, since TSS is the major component of dry matter and concentration effects (Malundo *et al*., 1995). On the other hand high TSS is desirable to yield higher recovery of processed products. It also in Conformity with Dereje *et al*. (2009) who indicated that value of TSS contents of tomato significantly increased after drying at 55^{o}C, 65^{o}C and 75^{o}C.

However the total soluble solid contents were reduced at higher temperatures for long duration of drying; this could be due to higher drying temperature and long duration of drying used. In line to this Khazaei *et al*. (2008) reported that the TSS value increased with increasing in drying-air temperature but decreased at 80^{o}C and above. The result is also in agreement with findings of Idah *et al*.(2014) who reported that drying at high temperatures (50°C, 60°C and 70°C) reduces the soluble solids content (31.650%, 30.558% and 29.833%) of the end product.

4.1.1.8 pH

There was significant ($p \leq 0.001$) difference in pH value between dried and control (fresh) sample affected by interaction effect among duration and temperature of drying (Appendix Table 5). The pH of dried tomato was in the range of 4.57-4.31 in control sample and in dried sample at 90^{o}C for 8 hours respectively (Table 5). But there were no statistically significant difference between samples dried at 70^{o}C for 7, 8 hours and 80^{o}C for 7 hours and also between samples dried at 90^{o}C for 7 hours and 80^{o}C for 8 hours.

As the result revealed the pH contents of tomato decreased as temperature and duration of drying increased; this may be due to increasing of titratable acidity. According to Giordano *et al.* (2000), pH below 4.5 is a desirable trait, because it halts proliferation of microorganisms in the final product during industrial processing. According to Campos *et al.* (2006), also appropriate pH value for industrial tomato varies between 4.3 and 4.4.

4.1.1 .9 Titratable acidity

Citric acid is the main acid present in tomato and it may be an important criterion in consumer acceptance of the products because a high value correlates to an acceptable acidic taste. Significant ($p \leq 0.001$) difference was observed in TA content affected by interaction among duration and temperature of drying (Appendix Table 5). The highest value (0.27g/L) was found in sample dried at 90^{o}C for 8 hours and the lowest value (0.17 g/L) was found in the control (fresh) sample (Table 5).The result indicated that titratable acidity was increased with temperatures and duration of drying. During drying, increase in acidity is mainly attributed to the increased moisture loss from the sample and may also due to decreasing of pH content.

These values were in accordance with the results reported by Abdalla *et al*.(2014) who observed the increasing of titratable acidity in oven dried sample at 60ºC, 65 ºC,70 ºC,80 ºC, and 90 ºC for two days and shade dried for four days than fresh tomato sample and Purkayastha *et al*.(2013) also reported that as drying temperature increase the titratable acidity was increased in dried tomato.

Table 5: Interaction effects of temperatures and duration of drying on pH, TSS (^{0}Brix) and (TA) contents of dried tomato fruit (wet basis).

Duration (hour)	Temperature (^{0}C)	pH	TSS (^{0}Brix)	TA(g/L)
Fresh		4.57±0.02^{a}	7.30±0.34^{c}	0.17±0.006^{e}
	70^{0}C	4.53±0.02^{a}	10.7±0.34^{a}	0.20±0.006^{d}
7	80^{0}C	4.45±0.02^{cb}	10.00±0.34^{ab}	0.23±0.006^{cdb}
	90^{0}C	4.36±0.02^{cd}	9.33±0.34^{ab}	0.24±0.006^{cab}
	70^{o}C	4.46±0.02^{cab}	10.16±0.34^{a}	0.21±0.006^{cd}
8	80^{0}C	4.38±0.02^{cd}	9.50±0.34^{ab}	0.26±0.006^{ab}
	90^{0}C	4.31±0.02^{d}	8.50±0.34^{cb}	0.27±0.006^{a}
CV (%)		0.96	6.38	5.10

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$.

4.1.1 .10 Lycopene

The Lycopene content was significantly affected ($p\leq0.001$) by interaction of duration and temperature of drying (Appendix Table 3). The results showed that, lycopene contents ranged from 13.9 mg/100g to 86.3 mg/100g in control (fresh) samples and in samples dried at 90^{o}C for 8 hours respectively (Table 6).However there was no statistically significant difference between samples dried at 90^{o}C, 80^{o}C and 70^{o}C for 8 hours and samples dried at 90^{o}C for 7 hours.

The results indicated that lycopene content increased with temperatures and duration of drying. This may be due to drying increases the lycopene by destructing the tomato cells and breaking the connection between lycopene and matrix, damaging the lycopene-protein complex and releasing free lycopene by *cis*-isomerization (Hadley, 2002; Shi, 2000). Dehghan-Shoar *et al*.(2011) proposed that when lycopene is extracted from its natural form, it bonds strong.

Similar trend of lycopene contents in dried tomatoes has been reported by Abano *et al*.(2011) who dried tomatoes at 50, 60, 70 and 80°C and observed 2.96 mg/100g^{-1} lycopene in fresh tomato and 59.10mg 100 g^{-1} in dried tomato fruit. According to Hadley *et al*. (2002) fruit and vegetable processing, especially the thermal, is negatively reflected on the content of bioactive substances, but carotenoids (lycopene) are quite thermo- stable.

4.1.1.11 β- carotene content

There were significant($p \leq 0.001$) differences in β- carotene content between dried and control (fresh) samples (Appendix Table 3).The maximum β- carotene content was 16.9mg/100g and the minimum was 8 mg/100g in control (fresh) sample and in dried sample at 90^{o}C for 8 hours respectively (Table 6). The findings depicted that there was continuous decrease in of β-carotene with increasing of temperatures and duration of drying. This could be attributed to β-carotenes is more heat and air oxidation sensitive than lycopene (Regier *et al*., 2005).

However there is no statistically significant difference between samples dried at 70^{o}C and 80^{o}C for 7 hours and also between dried sample at 70^{o}C, 80^{o}C, and 90^{o}C for 8 hours (Table 6). Similar findings were reported by Charles *et al*. (2014) who stated that there was sharp decrease in ß-carotene content of tomato samples as boiling or frying time increased and suggested that ß-carotene is a heat labile compound, and could be more available in raw tomato than the processed counterpart. Onuegbu *et al*. (2013) also found decreasing of β-carotene in tomato sample oven dried at 60^{o}C than fresh sample.

4.1.1.12 Vitamin C

The result showed that there was significant ($p \leq 0.001$) difference in vitamin C contents between dried and control (fresh) tomato sample affected by interaction effects of temperature and duration of drying (Appendix Table 3). As a result drying temperature and duration had an adverse effect on vitamin C content of dried tomato samples (Table 6). Samples dried at 90^{o}C for 7 and 8 hours were estimably affected recording an average value of 2.03mg/100g of vitamin C compared to the value recorded in control (fresh) sample (7.03 mg/100g). The lower value of vitamin C or the damage of vitamin during drying was primarily due to heat

(high temperatures and long duration of drying) and might be oxidation and light (Silva *et al*., 2012).

However there was no statistically significant difference between dried sample at 70°C for 7 and 8 hours (Table 6). Similar finding were reported by Charles *et al*. (2014) who reported that Vitamin C progressively decreased as the processing temperature and duration increased and suggested that it does not require excessive heat treatment. The result is also in accordance with the report of Fasuyi (2005) who confirmed that higher ascorbic acid content in fresh leaves is due to absence of heat treatment that does easily degrade this compound. In addition Toor and Savage (2006) also investigated that drying tomatoes at 42^0C during 18 hours led to ascorbic acid losses between 17and 27% according to tomato varieties studied.

Table 6: Interaction effects of temperatures and duration of drying on Lycopene, β-arotene and Vitamin C contents of dried tomato (wet-basis)

Duration (hours)	Temperature (^{0}C)	Lycopene (mg/100g)	β-carotene (mg/100g)	Vitamin C (mg/100g)
Fresh		13.93±2.2^{d}	16.90±0.5^{a}	7.03±0.1^{a}
7	70^{o}C	60.16±2.2^{c}	13.16±0.5^{b}	3.86±0.1^{b}
	80^{o}C	72.33±2.2^{b}	12.56±0.5^{b}	3.16±0.1^{bc}
	90^{o}C	76.66±2.2^{ab}	10.66±0.5^{cb}	2.40±0.1^{de}
8	70^{o}C	76.33±2.2^{ab}	9.73±0.5^{c}	3.70±0.1^{b}
	80^{o}C	83.33±2.2^{a}	9.23±0.5^{c}	2.83±0.1^{dc}
	90^{o}C	86.66±2.2^{a}	8.33±0.5^{c}	2.03±0.1^{e}
CV (%)		5.75	8.72	7.21

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$.

4.1.2 Physical parameter

4.1.2.1 Water absorption capacities

In this study water absorption capacities of dried tomato was evaluated at different times ranging from 30 to 120 min. Significantly ($p \leq 0.001$) difference were observed between dried tomato sample in water absorption capacities as influenced by interaction effects of duration and temperature of drying (Appendix Table 4). The maximum water absorption capacity (3.4) was observed in samples dried at 90^{o}C for 8 hours and minimum (2.4) was observed in samples dried at 70^{o}C for 7 hours (Table 7).

As displayed in Table 7 water absorption capacities of the dried tomato was increased with the duration and temperature of drying; In fact, it is generally accepted that samples dried at high temperatures possess higher rehydration capacity than those dried at low temperatures (Jamradloedluk*et al*., 2007). This can be ascribed to the formation of a more porous structure in the products at high drying temperatures, which facilitates rehydration. It also due to the fact that the rate of the moisture removal at higher drying temperatures is very fast and causes less shrinkage of the dried samples. Similar result were reported by Ahmadzadeh and Ghiafeh (2010) who dried tomato slices at 65±2°C for 6 hours and observed 3.96 rehydration ratios in control sliced sample. According to Krokida & Marinos (2003) the rehydration ratio with the naturally dried samples (without treatment) was the lowest.

4.1.2.2 Water activity (a_w)

There is significant ($p \leq 0.001$) difference in water activity between dried and control (fresh) tomato sample (Appendix Table 4). Water activities of tomatoes were in range of 0.92-0.39 in control (fresh sample) and in dried sample at 90^{o}C for 8 hours respectively (Table 7). However there was no statistically significant difference between dried sample at 90^{0}C for 7 hours, 70^{0}C and 80^{0}C for 8 hours. The result revealed that as temperatures and duration of drying increased water activity decreased. This could be attributed to drying procedure (high temperature and long duration of drying) decreases the water activity of dried product.

Similar observation was reported by Jayathunge *et al*. (2012)reported that water activity of 0.84 for fresh samples higher than 0.61tomato powder dried in air flow dryer at 55^{o}C for 48 hours. Since water activity affects the storage stability of food; some deteriorative process in foods is mediated by water. The samples higher in a_w is more susceptible to the product to microbial spoilage (Owureku *et al*., 2014). The low water activity observed in present study is a good indicator of more shelf stable product. However, the storage conditions also played an important role in this matter.

Table 7: Interaction effects of temperatures and duration of drying on Rehydration ratio and Water activity contents of dried tomato fruit

Duration (hours)	Temperature (^{0}C)	Water absorption capacities	a_W
Fresh			0.92±0.01^{a}
	70^{o}C	2.40±0.1^{d}	0.55±0.01^{b}
	80^{o}C	2.70±0.1^{cd}	0.46±0.01^{c}
7			
	90^{o}C	3±00.1^{cb}	0.44±0.01^{cd}
	70^{o}C	3±00.1^{cb}	0.44±0.01^{cd}
8			
	80^{o}C	3.10±0.1^{ab}	0.43±0.01^{cd}
	90^{o}C	3.60±0.1^{a}	0.39±0.01^{d}
	CV (%)	12.6	4.02

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$.

4.1.3 Sensory acceptability of dried tomatoes

Sensory acceptability is the ultimate measure of product quality and success. Sensory analysis comprises a variety of powerful and sensitive tools to measure human responses to foods and other products.

4.1.3.1 Color

Color is one of the more important quality parameters in dehydrated fruits and vegetables. Indeed, possible color changes would influence the organoleptic properties of dried tomato samples and would limit their potential applications (Garau *et al*., 2007).

The panelist have brief about color of tomato. The color of dried sample should be red, not be burnt or browned color. The result showed that the color acceptability was significantly affected ($p \leq 0.001$) by interaction of duration and temperature of drying (Appendix Table 6). The result indicated that the highest mean score (4.98) was recorded in control (fresh) sample and the lowest mean score were recorded in (2.2) in dried sample at 90°C for 8 hours (Table 8). However no significant difference were identified between samples dried at 70°C for 7 hours and control (fresh) tomato sample. Color of these samples was bright red as a result panelist appreciated the color of this sample and they were followed by sample dried at 80°C for 7 hours.

The results were revealed that color acceptability of tomato decreased as temperature and duration of drying increased. This change can be either due to pigment degradation or browning reaction or both during dehydration (Lopez *et al*.,1997; Shi *et al*.,1999). Similar report was observed by Onuegbu *et al*. (2013) who declared the color quality of fresh tomato was higher than those oven dried tomato samples at 60°C.

4.1.3.2 Flavor

There was very highly significant ($p \leq 0.001$) difference between liking score of flavor of dried and control (fresh) sample affected by interaction effects among duration and temperature of drying (Appendix Table 6). The result indicated that the highest score (4.7) and the lowest score (2.08) was recorded in sample dried at 70°C for 7 hours and in samples dried at 90°C for 8 hours respectively (Table 8).This may be because dried tomatoes have been found to have a distinctive different flavor than fresh tomatoes as a result of heating (Hui and Clark, 2007). But there was no statistically significant difference between sample dried at 90°C and 80°C for 7 and 8 hours and their scores were close to the “neither like nor dislike” level on the 5-point Hedonic scale respectively.

The result showed that flavor acceptability was decreased as temperatures and duration of drying increased (Table 8).The difference in aroma is primarily due to loss and generation of volatile compound during drying process and the decreasing of flavor has been going at high temperature for long duration (Sacilik and Unal, 2005; Fernando *et al*., 2008;Rasouli *et al*., 2011). The drying processes generally alter the flavor characteristics of the product as the heating process transforms and drive away many of the volatile compounds. The result is similar with observation of Puranik *et al*. (2012) who stated that the deterioration in aroma has started just after increasing the temperature from 50°C and the trend was similar up to 75°C in dried garlic and Mitra *et al*. (2011) also reported that the increase in temperature resulted in a slight decrease in flavor content in vacuum dried onion at 50^{o}C -70^{o}C.

4.1.3.3 Taste

Taste scores were significantly ($p \leq 0.001$)affected by interaction between duration and temperatures of drying (Appendix Table 6).The highest score (4.42) rating “like moderately” was observed in sample dried at 70^{o}C for 7 hours and lowest score rating (2.8) was observed in sample dried at 90^{o}C for 8 hours (Table 8). However there is no statistically significant difference between dried sample at 80^{0}C for 8 hours and control sample respectively which were rating “Dislike moderately”.

Even if the taste score of dried sample was improved in present study, as temperature and duration of drying increased the taste acceptability of dried sample was decreased. This could be due to the loss of volatiles compound during the drying process (Kaddumukasa *et al*., 2005).

Table 8: Interaction effects of temperatures and duration of drying on Color, Flavor and Taste quality of dried tomato fruit

Duration (hours)	Temperature (^{0}C)	Color	Flavor	Taste
Fresh		4.98±0.04^{a}	3.37±0.06^{d}	3.19±0.07^{cd}
7	70°C	4.93±0.04^{a}	4.76±0.06^{a}	4.46±0.07^{a}
	80°C	4.26±0.04^{b}	4.08±0.06^{b}	3.50±0.07^{c}
	90°C	2.89±0.04^{e}	2.94±0.06^{e}	2.98±0.07^{ed}
8	70°C	3.79±0.04^{c}	3.70±0.06^{c}	3.98±0.07^{b}
	80°C	3.20±0.04^{d}	2.92±0.06^{e}	3.24±0.07^{cd}
	90°C	2.10±0.04^{f}	2.08±0.06^{f}	2.84±0.07^{e}

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$

4.1.3.4 Mouth feel

Mouth feel scores were significantly ($p\leq0.001$) affected by interaction among duration and temperature of drying (Appendix Table 7). The highest score (4) were recorded in sample dried at 70^{o}C for 7 hours which scored "Like moderately" and the lower score (2.5) recorded in sample dried at 90^{o}C for 8 hours scored "Dislike moderately" (Table 9). However there were no statistically significant differences between dried sample at 70^{o}C for 7 and 8 hours, between control (fresh) and dried sample at 80^{o}C, 90^{o}C for 7 hours, 80^{o}C for 8 hours and panel score rating "Neither like nor dislike" on 5-point hedonic scale. As a result mouth feel acceptability of dried tomato decreased as temperatures and duration of drying increased.

4.1.3.5 Appearance

There was a significant ($p\leq0.001$) difference in appearance quality between dried samples and controls affected by interaction effect of duration and temperature of drying (Appendix Table 7). The maximum scores (4.06) and the minimum scores (2.14) were founded in sample dried at 70^{o}C for 7 hours which was rating 'liked moderately' and the dried sample at 90^{o}C for 8 hours rating 'Disliked moderately ' on 5-point Hedonic scale respectively (Table 9). The result showed that acceptability of appearance of dried tomato samples decrease as temperature and duration of drying increased; this may be due to high temperatures and long

duration of drying that affect appearance quality of dried tomato. Similar results were observed by Puranik *et al*.(2012) who observed very small changes on appearance acceptability at lower temperatures of drying unlike significant changes found at higher temperatures(50^oC-70^oC) in dried garlic.

4.1.3.6. Over all Acceptability

With respect to the overall acceptability of tomato samples there was significant($p \leq 0.001$)difference between dried and control samples as affected by interaction of duration and temperatures of drying (Appendix Table 7). The maximum (4.3) overall acceptances was scored in samples dried at 70^oC for 7 hours which was rating 'liked moderately' and the minimum score (2.1) in samples dried at 90^oC for 8 hour rating 'Disliked moderately' on 5-point Hedonic scale (Table 9).

However there was no statistically significant difference between samples dried at 80^oC for 7 hours and 70^oC for 8 hours and also between control (fresh) and dried samples at 80^oC for 8 hours. Same with other sensory quality observed in present study the overall acceptance also decreased as temperature and duration of drying increased; this may be due to high temperatures and long duration of drying.

Table 9: Interaction effects of temperatures and duration of drying on Mouth feel, Appearance and over all acceptability of tomato fruit

Duration (hours)	Temperature (^0C)	Mouth feel	Appearance	Overall acceptability
Fresh		3.20 ± 0.07^{b}	3.81 ± 0.06^{bc}	3.31 ± 0.06^{c}
	70°C	4.03 ± 0.07^{a}	4.35 ± 0.06^{a}	4.30 ± 0.06^{a}
7	80°C	3.28 ± 0.07^{b}	3.56 ± 0.06^{c}	3.60 ± 0.06^{b}
	90°C	3.05 ± 0.07^{b}	3.07 ± 0.06^{d}	3.13 ± 0.06^{c}
8	70°C	3.78 ± 0.07^{a}	3.86 ± 0.06^{b}	3.71 ± 0.06^{b}
	80°C	2.99 ± 0.07^{b}	2.83 ± 0.06^{d}	3.21 ± 0.06^{c}
	90°C	2.56 ± 0.07^{c}	2.14 ± 0.06^{e}	2.15 ± 0.06^{d}

Values are means± standard error. Values in column with different letters as superscripts are Significantlydifferent at $p<0.05$

4.2 Storage study (Experiment II)

The analysis of variance of the result indicated that the quality parameter of stored tomato powder was significantly affected by main effect, two way interaction and three way interaction among stored sample, packaging material, storage temperature and storage periods. However as described below there was no significant difference observed between interaction of stored sample, packaging material, storage temperature and storage period (all treatment combination). Hence the result are presented and discussed below.

4.2.1 Chemical parameter of stored tomato powder

4.2.1.1 Moisture content (%)

When food product is exposed to an environment above or below their equilibrium point, the protective packages and its barrier level will determine how much the food will be impacted (Esse and Saari, 2004). The analysis showed that there was no significant difference between stored tomato samples in moisture content in first days (Appendix Table 8) while, the storage study revealed that moisture content was affected significantly ($p \leq 0.001$) by main effect of stored sample, packaging material, storage temperature and storage period (Appendix Table 12). However there was non-significant difference in moisture content between interaction effects among stored sample, packaging material, storage temperature and storage period (Appendix Table 12)

As the analysis of variance showed the slight increase in moisture content was observed from first day (4.17%) and (3.91%) to maximum (5.72%) on 3rd months and minimum (4.87%) during 1st month of the storage period respectively (Table 10).This indicated that for the entire storage period of three months, only a slight increase in moisture content occurred.The difference between samples could be attributed to processing variation before storage.

The increasing in moisture content was significantly lower in powder sample packed in Glass jar (5.11%) and in plastic jar (5.22%) packages as compared to Plastic bag (low density polyethylene bag) packages (5.46%). This may be due to glass jar and plastic jar packages had

lower permeability to vapor and O_2 in comparison to plastic bag (low density polyethylene) packages.

With regard to storage temperature, the samples stored at room temperature showed greater increase in moisture content when compared with refrigerated temperature and 3rdmonths of storage period was also significantly higher from the other periods of storage; this may be due to the interaction with temperature, variation of the relative humidity of the surrounding air and the hygroscopic nature of the product.

Even if there were slight increments of moisture content occurred the products can be stored in any one of the packaging materials above three month of storage and because moisture content observed in this study was unfavorable for microbial growth. This finding is in agreement with the work done by Swain *et al*. (2013) who observed the gradually increasing of moisture content in dried sweet pepper during ambient storage for four months of storage period and conclude the products could be stored in any one of the packaging materials up to 45 days. Idah *et al*.(2007) also report that moisture content remained nearly constant for the samples of the products stored in the sealed HDPF(high-density polythene film) storage system throughout the 90 days period of storage and while increased from the initial 4.2% prior to storage to 7.13% after 3 months of storage in open storage system.

4.2.1.2 Crude Protein (%)

Crude protein contents of dried tomato sample showed that significant ($p \leq 0.01$)differences in first days of analysis (Appendix Table 8);this indicate duration of drying and temperature was affect the protein contents of tomato powder. It also decreased significantly ($p \leq 0.01$)in stored tomato powder from 18.26% and 15.93% in first day of analysis to maximum decreasing rate 14.30% in polyethylene bag and 14.36% on 3rd month of storage period respectively (Table 10). Conversely, protein content decreased minimum from 18.26% and 15.93% to 15.45 % at 1st month of storage period, 15.19 % in sample dried at 90^{o}C for 7 hours, 15.23% in glass jar and 15.09% at refrigerated temperature, which was maximum retention of protein content during storage period (Table 10). However there was no statistically significant difference

between glass jar and plastic jar. And also there was no significant difference with regard to interaction effects between treatment combination (stored sample, packaging material, storage temperature and storage period) (Appendix Table 12).

This may be protein is often denatured by drying temperature, storage temperature and storage period. The differences between samples may be due to processing variation before storage. But Glass jar and plastic jar was offer increased stability to heat when compared with polythene bag (Ngoddy and Ihekoronye, 1995) and the permeability of glass jar and plastic jar is lower (Paine and Paine, 1992; Smith and Hull, 2004).

The decreasing of protein in storage temperature and periods may be attributed to Maillard browning that probably occurred during protein hydrolysis (Eze and Akubor, 2012) and According to Paine and Paine (1992), this was possible because of temperature changes in storage environment. This result was in line with the study of Sarker *et al*. (2014) who reported that protein content of tomato powder decreased more in both HDPE and MDPE than LAF pouches during ambient storage for six months of storage period. Famurewa *et al*. (2013) also found significant decreasing of protein in polyethylene than plastic bottle as storage period continued in tomato paste stored in ambient temperature for six week storage period.

Table 10: Main effect of stored sample, packaging material, storage temperature and storage period on moisture and protein content of stored tomato powder.

Treatment	Moisture content (%)		Protein (%)	
Stored Sample		Day I		Day I
S1	5.43±0.03[a]	4.17±0.06[a]	15.19±0.12[a]	18.26±0.3[a]
S2	5.09±0.03[b]	3.91±0.06[b]	14.57±0.12[b]	15.93±0.3[b]
Packaging material				
Plastic Bag	5.46±0.04[a]		14.30±0.15[b]	
Plastic jar	5.22±0.04[b]		15.12±0.15[a]	
Glass jar	5.11±0.04[b]		15.23±0.15[a]	
Storage temp.				
Room temp.	5.08±0.03[a]		14.67±0.12[b]	
Refrigerate temp.	5.05±0.03[b]		15.07±0.12[a]	
Storage period				
1-Month	4.87±0.04[c]		15.45±0.15[a]	
2-Month	5.20±0.04[b]		14.83±0.15[b]	
3-Month	5.72±0.04[a]		14.36±0.15[b]	
CV (%)	4.75	2.91	6.30	3.61

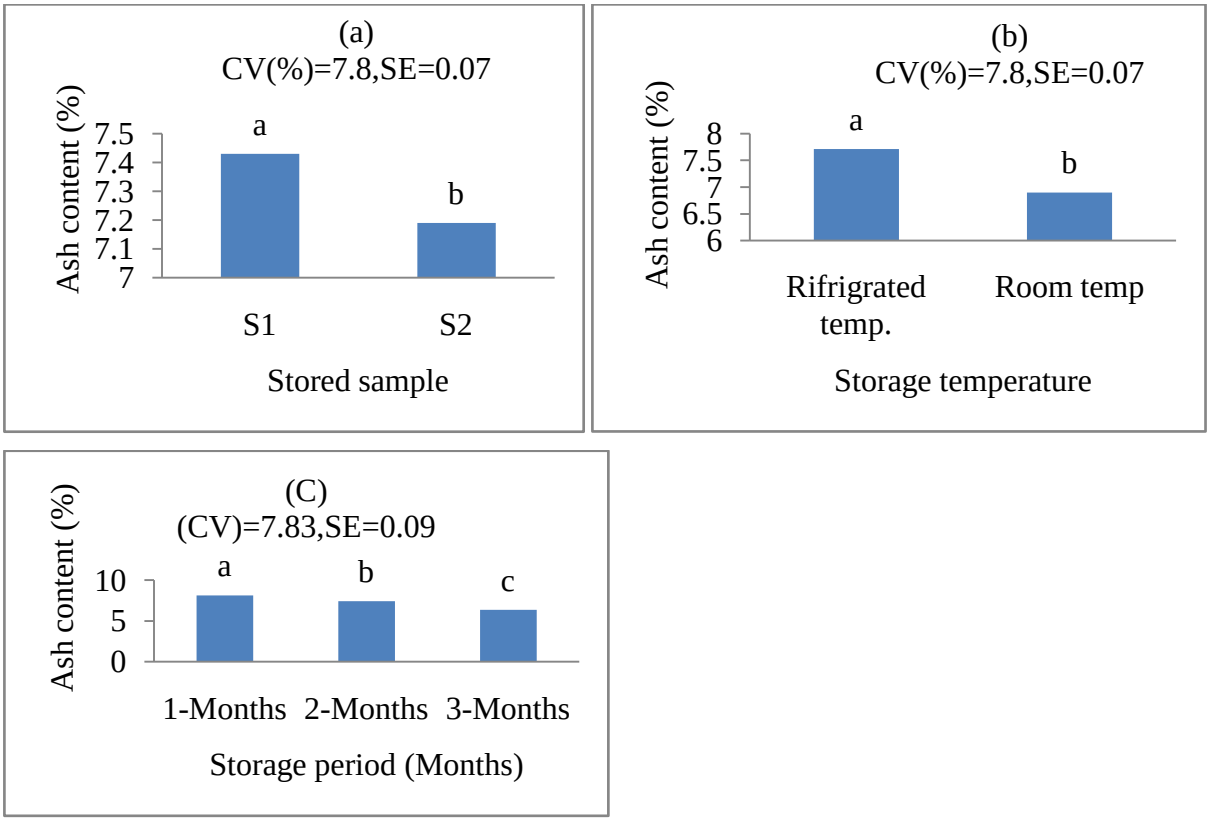
Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$, Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

4.2.1.3 Ash (%)

The result illustrated that there were no significant differences between dried samples in first days of analysis on ash contents; this may be duration of drying may not affect the ash content of dried sample (Appendix Table 8).However the ash content of stored tomato powder significantly ($p\leq0.001$) decreased over the storage period from 12.15% and 11.77% on first day to 8.18% maximum value and (6.34%) to minimum value in 1st and 3rdmonth of storage period respectively (Figure 2). And also ash content was significantly ($p\leq0.001$) affected by storage temperature with decreasing rate from 12.15% and 11.77% to 7.71% in refrigerated temperature, and 6.90% at room temperature storage condition respectively (Fig-2). There is also significant difference between the stored samples. This may be due to processing variation. These changes were not expected since ash is stable to heat, air and storage

conditions; it might be due to some microorganisms exposed to be present during storage. Although there was no significant difference between main effects packaging material and as well as interactions of treatment combinations (Appendix Table12).

These observations agree with the findings of Ibironke and Rotimi (2013) who found the minimal decreasing of ash contents in tomato powder dried at 75^{o}C for 20 hours and stored at room and fridge temperature storage condition. In contrary to this Sarker *et al.* (2014) reported the increasing of ash content in stored tomato powder packed in HDPE, MDPE pouches, LAF pouches and stored in ambient temperature for six months of storage period. Famurewa *et al*. (2013) also reported that significant increase in percentage ash content as storage continued in tomato paste stored in polyethylene and bottle for six week storage period.



Values in column with different letter superscripts are significantly different at p<0.05, standard error (SE), Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

Figure 2.a) Effects of stored sample on ash content b) Effect of storage condition on ash contents b) Effects of storage period on ash content of stored tomato powder

4.2.1.4 Crude Fat (%)

There were significant differences ($p \leq 0.01$) in crude fat content during first days of analysis (Appendix Table 8). The result of analysis of variances of stored tomato powder also showed that the stored tomato powder was decreased significantly ($p \leq 0.05$) from 3.24% in sample dried 90^{o}C for 7 hours and 2.70% in sample dried 90^{o}C for 8 hours in first days of analysis to maximum decreasing 1.74% and minimum 1.05% in sample dried at 90^{o}C for 7 and in sample dried at 90^{o}C for 8 hours in 1st and 3rd months of storage period respectively (Table 11).There was also two way interaction effect in fat contents observed between packaging material and stored sample with 1.54% maximum and 1.21% minimum in dried sample at 90^{o}C for 7 hours packed in glass jar and in dried sample at 90^{o}C for 8 hours packed in plastic bag (low density polyethylene).

In addition two way interaction effect was also found between storage period and storage temperature significantly ($p \leq 0.01$) with 1.70 % maximum and 1.08% minimum in 1stmonths in sample stored at refrigerated temperature and 3rd months of storage period in sample stored in room temperature respectively. However there is no significant difference founded between interaction effects of stored sample, packaging material, storage temperature and storage period (Appendix Table 13). From the packaging material the higher decreasing is observed in both sample (sample dried at 90^{o}C for 7 and 8 hours) which were packed in plastic bag (low density polyethylene) (Table 11). This may be attributed to higher permeability of plastic bag (low density polyethylene) than glass jar and plastic jar and the difference between two samples are due to processing variation before storage.

The degradation rate of crude fat in stored tomato powder was also higher in 3rd months of storage period in stored sample at room temperature storage condition; this may be oxidation of crude fat during storage period. Similar observation was reported by Sarker *et al.* (2014) who found crude fat content of tomato powder stored at room temperature was 2.1% maximum and 1.58% minimum in packed sample HDPE, MDPE pouches, LAF after storage for six month in ambient storage. Eze and Akubor (2012) also reported that decreasing of crude fat content of samples subjected to different storage conditions observed higher value

for stored sample in dark cool place than stored sample in over a hearth for eight weeks storage in okra vegetables.

Table 11: Interaction effects of stored sample with storage period, packaging material and storage condition on Fat contents stored tomato powder

Treatment combinations	Fat (%)	Day I
Stored Sample*Storage period		
S1*1-Month	1.74±0.01[a]	3.24±0.09[a]
S2*1-Month	1.57±0.01[b]	2.7±0.09[b]
S1*2-Month	1.47±0.01[c]	
S2 *2- Month	1.24±0.01[d]	
S1*3-Month	1.16±0.01[e]	
S2 * 3-Month	1.05±0.01[f]	
Stored sample*packaging material		
S1 * Glass jar	1.54±0.01[a]	
S1* Plastic jar	1.47±0.01[b]	
S1* Plastic bag	1.37±0.01[c]	
S2 * Glass jar	1.32±0.01[c]	
S2 * Plastic jar	1.31±0.01[c]	
S2 * Plastic bag	1.24±0.01[d]	
Storage temp.*Storage period		
Refrigerated temp. * 1-Month	1.70±0.01[a]	
Room temp. *1-Month	1.62±0.01[b]	
Refrigerated temp. * 2-Month	1.44±0.01[c]	
Room temp. * 2-Month	1.27±0.01[d]	
Refrigerated temp. * 3-Month	1.13±0.01[e]	
Room temp. * 3-Month	1.08±0.01[e]	
CV (%)	4.86	5.44

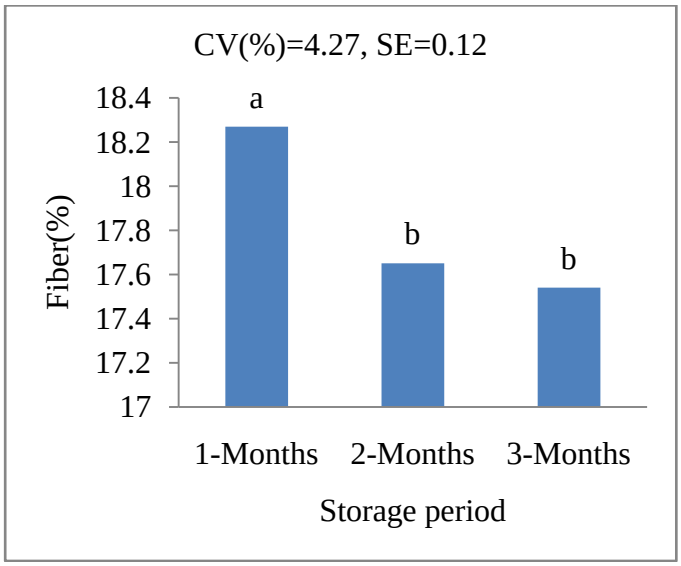
Values are means± standard error. Values in column with different letters as superscripts significantly different at $p<0.05$,Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

4.2.1.5 Crude Fiber (%)

There was no significant difference between dried samples in first days of analysis; this indicate temperature and duration of drying was not affect the fiber content of dried tomato (Appendix Table 9).While as displayed in the Figure-3 the changes in crude fiber content of the samples subjected for three months of storage period were significantly ($p\leq0.001$) affected by main effects storage period (Appendix Table 13). Slight decreasing of crude fiber in the

storage period were observed when compare with the initial values before storage which ranged from 18.27%,18.18% to 18.27% in first months, 17.65% in second months, 17.54% in third months of storage period respectively (Figure-3).

These slight changes may be due to variation in processing condition. However crude fiber was not significantly affected by main effect of packaging material, duration of drying (processing variation) as well as storage temperature and their interaction (Appendix Table 13). This is attributed to the fact that fiber content is stable macromolecular compounds to conditions of low water activity (Sudha *et al*., 2007).This result was in line with the findings of Eze and Akubor (2012) who reported that crude fiber content of the samples subjected to different storage conditions were not significant in stored sample in dark cool place and stored over a hearth for eight weeks okra vegetables.



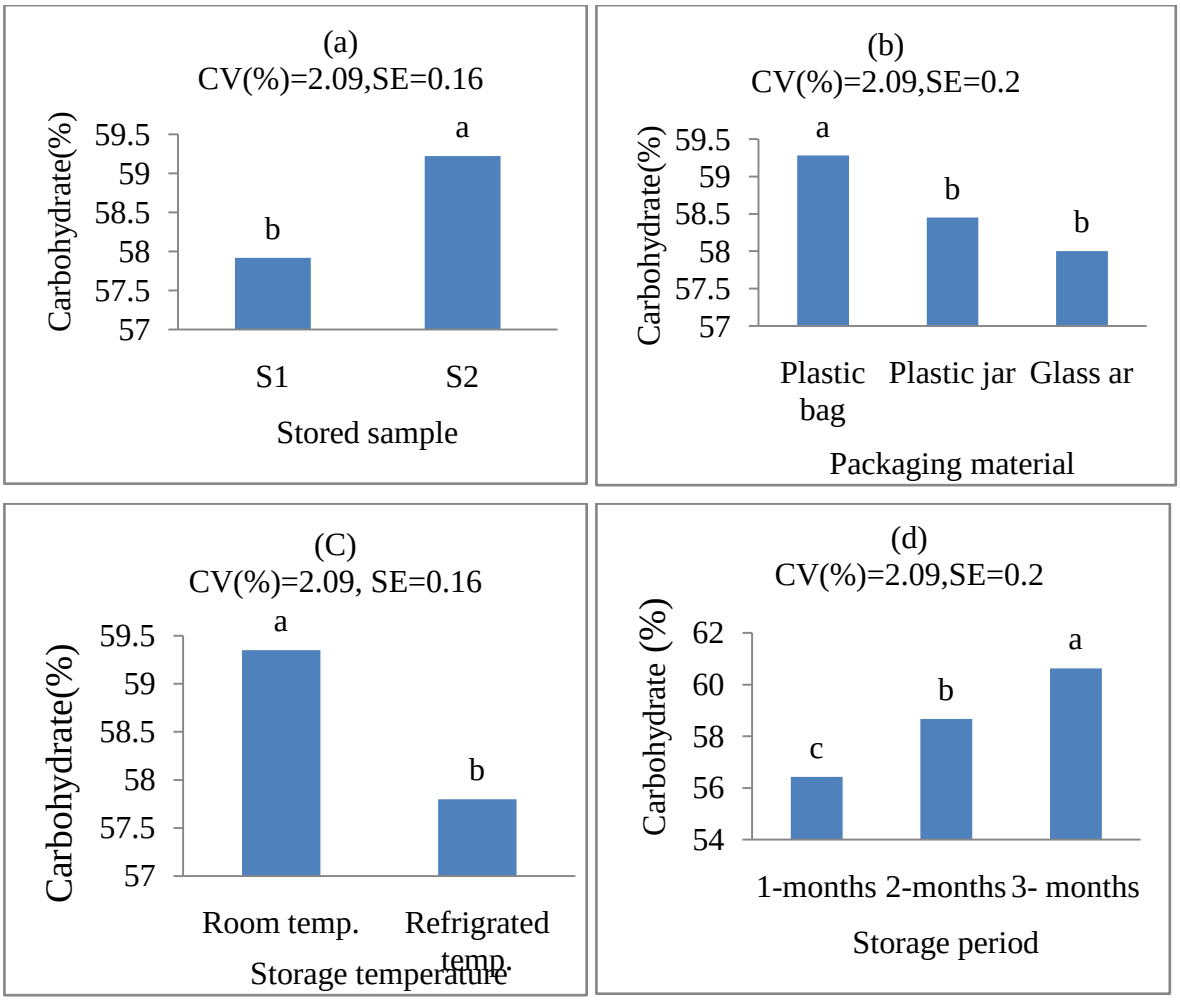
Values in column with different letters as superscripts are significantly different at p<0.05, standard error (SE)

Figure 3: Effects of storage period on crude fiber contents of stored tomato powder

4.2.1.6 Total Carbohydrate (%)

There was no significant difference in total carbohydrate contents of dried sample before storage (in first days of analysis) (Appendix Table 9). But as displayed in Figure-4 there were significantly ($p \leq 0.001$) affected by main effects of stored sample, packaging material, storage temperature and storage period. However no significant difference was founded between

interaction effects of treatment combination (dried sample, packaging material, storage temperature and storage period) (Appendix Table 13). The total carbohydrate contents of stored tomato powder increased from 48.07%, 48.99 % in first days of analysis to maximum 60.62% in 3-month and minimum 56.43% in 1-months storage period respectively (Figure 4). The result showed that the total carbohydrate was increased with storage period increased. The increased of total carbohydrate value with increasing of storage period could be due to changes that occurred on other proximate compositions during drying and storage since carbohydrate was obtained by difference. Analogues to this Eze and Akubor (2012) reported that increasing of total carbohydrate content of samples subjected to different storage conditions in sample stored in dark cool place and stored over a hearth for eight weeks okra vegetables.



Values in column with different letters as superscripts are significantly different at $p<0.05$,Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2),SE (standard error)

Figure 4 :a) Effects of storage on Total carbohydrate content of stored sample b) Effects packaging material on Total carbohydrate c) Effects of storage condition on Total carbohydrate d) Effects storage period on Total carbohydrate of stored tomato powder

4.2.1.7 TSS

In first days of analysis there was no significant difference on TSS contents of dried tomato samples (90^oC for 7 and 8 hours) (Appendix Table 11). However there are significant ($p \leq 0.05$) difference as affected by two way interaction of storage condition with storage period and the main effects of packaging material in the total soluble solid (TSS) contents of stored tomato powder (Appendix Table 16) The total soluble solid contents of stored tomato powder were found decreased with storage periods increased (Table 12).

It was observed that 9 and 8.8 °Brix in first days of analysis to maximum 7.4 and minimum 6.2 was observed in 1^{st} month in refrigerated temperature and in 3^{rd} months of storage at room temperature storage condition respectively. This could be attributed to the higher storage temperature of the room temperature could have led to increase in rate of spoilage and also the solids are probably broken down during long storage time. But there were no significant differences between the storage temperatures in 1^{st} month of storage period.

Regarding to packaging material the greater rates of decreasing 6.7 was observed in the sample packed in plastic bag (low density polyethylene) than 7.1 glass jar and plastic jar this may be higher permeability of plastic bag than glass jar and plastic jar. However there were no significant interaction effects among the treatments on total soluble solid contents of stored tomato powder (Appendix Table 16). This observations was agree with the findings of Ibironke and Rotimi (2013), who stated that minimal decreasing of TSS in powder stored at room and fridge storage temperature.

4.2.1.8 Titratable Acidity (TA)

There is significant ($p \leq 0.05$) difference in titratable acidity of dried tomato sample in first days of analysis (Appendix Table 11). The result of the analysis of variance of stored tomato powder showed that titratable acidity was significantly ($p \leq 0.01$) af fected by two ways interaction among stored sample and storage period and main effects of packaging material

and storage temperature exhibited a gradual increase throughout the storage period (Table 12). However, the rise in acidity was higher from the first days of analysis 0.23 and 0.25 g/L which was observed in sample dried at 90°C for 7 and 8 hours to 0.39 in both sample (dried at 90^{o}C for 8 and 0.38 in sample dried at 90^{o}C for 7 hours) and on the 1^{st} months of storage period, followed by 0.37 at room temperature, and 0.36 in glass jar packaging material, while least increase was 0.32, 0.29 occurred in both samples dried (at 90^{0}C for 7 and 8 hours) in the 2^{nd} months of storage, 0.32 in refrigerated temperature and also 0.33 in plastic bag packaging material respectively (Table 12). While non-significant was founded between interaction effects of stored sample, packaging material, storage temperature and storage period (Appendix Table 16).

Increase in titratable acidity of tomato powder may be due to acids produced by *Baciluscoagulans*, *Clostridium butyricum* and as a result of phenolic compounds produced by *Bacillus coagulans*. It may also be due to oxidation of alcohol and aldehyde during processing and is influenced by storage temperature (Gould, 1992). Slight increasing observed in 2^{nd} month of storage period probably due to the effect of organisms responsible for the spoilage, some of which can release basic substances into the samples. Similar observation was reported by Sarker *et al.* (2014) and Safdar *et al*.(2010) who observe the increasing acidity content of stored tomato powder packed in different packaging material and who observe the decreasing of pH contents of tomato paste during storage at 25^{o}C, 6^{o}C and -10^{o}C respectively.

Table12: Interaction effects of storage period with storage temperature and main effects of packaging material on total soluble solid and interaction effect among stored sample and storage period on titratable acidity contents of stored tomato powder (wet-basis)

Treatment	TSS(°Brix)	Treatment	Titratable acidity(g/L)	
Storage period*Storage temp.		Stored sample*Storage period		Day I
1st Month * refrigerated temp.	7.40±0.09[a]	S1 * 1-months	0.38±0.003 [a]	0.23±0.006[b]
1st Month * Room temp.	7.40±0.09[a]	S2 * 1-months	0.39±0.003 [a]	0.25±0.006[a]
2nd Month * refrigerated temp.	7.30±0.09[a]	S1*2-months	0.29±0.003 [d]	
2nd Month *Room temp.	6.80±0.09[b]	S2 * 2-months	0.32±0.003 [d]	
3rd Month * refrigerated temp.	6.40±0.09[bc]	S1* 3-months	0.34±0.003 [c]	
3rd Month * Room temp.	6.20±0.09[c]	S2 *3-months	0.35±0.003 [b]	
Packaging material		Storage temp.		
Glass jar	7.00±0.6[a]	Room temp.	0.37±0.001[a]	
Plastic jar	7.00±0.6[ab]	Refrigerate temp.	0.32±0.001[b]	
Plastic bag	6.70±0.6[b]	Packaging material		
		Glass jar	0.36±0.002[a]	
		Plastic jar	0.34±0.002[b]	
		Plastic bag	0.33±0.002[c]	
CV (%)	5.6		3.9	

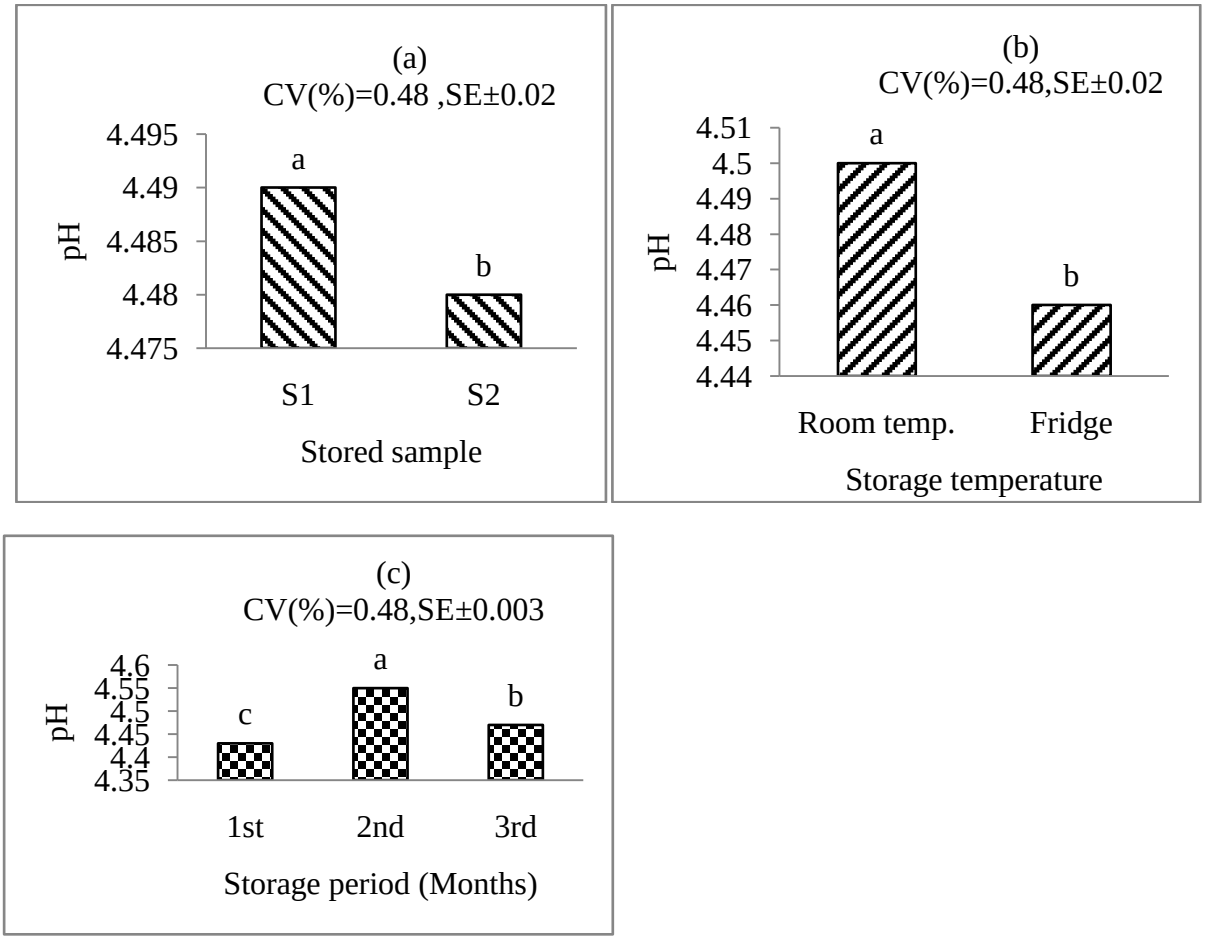
Values in column with different letters as superscripts are significantly different at $p<0.05$
Sample dried at 90°C for 7 hours (S1), Sample dried at 90°C for 8 hours (S2)

4.2.1.9 pH

There was no significance difference in pH contents in first days of analysis on pH value of dried tomato (Appendix Table 11). While during storage significantly ($p \leq 0.01$) affected by main effects of stored sample, storage temperature and storage period (Appendix Table 16).

At the result shows it decreased from 4.53 in first days to maximum 4.49, 4.48 in both stored sample (at 90^{o}C at 7and 8 hours) but minimum 4.46, 4.43 was founded in refrigerated temperature and 1^{st} months of storage period respectively (Figure 5). However the slight increasing was founded in 2^{nd} months of storage period; this may be following the decreasing of acidity in this month. Although there were no interactions effects of treatment combination on pH contents of stored tomato powder (Appendix Table 16)

Regarding to storage condition temperature influences the decrease in pH; however this value will prevent the growth of the microorganisms. Codex (2007) recommends pH of less than 4.6. The present study was agreed with the result reported by Safdar *et al*. (2010) and Sarker *et al.* (2014) who observed that decreasing of pH contents of tomato paste during storage at 25^{o}C, 6^{o}C and -10^{o}C and in stored tomato powder packed in different packaging materials respectively.



Values in column with different letters as superscripts are significantly different at $p<0.05$, standard error (SE)

Figure 5: a) Effects of storage on pH of stored sample b) Effects of storage condition pH c) Effects of storage period on pH contents of stored tomato powder

4.2.1.10 Lycopene

Tomato is considered a single most important source of lycopene (Lumpkin, 2005) therefore retention of this constituent in storage was studied. There is significant ($p\leq0.001$) difference between dried samples (90^{o}C for 7 hours and 8 hours) in first days of analysis (Appendix Table 10). There is also significant ($p\leq0.001$) difference between two way interactions effect of stored sample and storage temperature, stored sample with storage period and also the main effects of packaging material during three months of storage period. However, the interaction

effect among types of stored sample, packaging material, storage temperature and storage period was not-significant (Appendix Table14).

As the result illustrate in both of stored samples (dried at 90^{o}C for 7 and 8 hours) there was a progressive loss of lycopene throughout storage period with a different rate of degradation. The decreasing rate was significantly higher during storage period followed by packaging material and at room temperature than refrigerated temperature. It decreased from 26 mg/100 g, 16.6 mg/100 g in first days to maximum 21.7 mg/100 g and minimum 8.27 mg/100 g observed in 1–month of storage period in sample dried at 90^{o}C for 8 hours and in plastic bag (low density polyethylene) in the sample dried at 90^{o}C for 7 hours respectively. In case of storage temperature in both sample (dried at 90^{o}C for 7 and 8 hours) it decreased from 26.6 mg/100 g, 16.7 mg/100 g to maximum 15.89 mg/100 g in refrigerated temperature and minimum 9.93 mg/100 g, at room temperature storage respectively (Table 13).

Even if lycopene is considered relatively stable during food processing; storage of tomato product may contribute to lycopene loss. This is because of carotenoid are highly unsaturated, they are particularly susceptible to oxidation, physical and chemical factors known to degrade carotenoids include elevated temperature, exposure to light, oxygen, and extremes in pH. Water activity is another very important factor in the storage of the dehydrated food products. According to finding reported by Zanoni *et al*. (2003) and Abushita *et al*.(2000) very low moisture content or very low water activity seems to favor oxidative degradation in tomato products.

This observation was agreed with the report of Neena *et al*.(2013) who observed that about 60 and 30 percent of the lycopene was degraded at 45°C and 6°C after 6 week and conclude that several lycopene degradation products were tentatively identified in the drying and stored powder. Sheshma *et al*. (2014) also reported the slight decreasing of lycopene content during storage of tomato powder packed in HDPE at room temperature (35±2^{0}C) in 40 days of storage period

Table 13: Interaction effects among stored sample and storage period, stored sample with storage condition and main effects packaging material on lycopene contents of stored tomato powder (wet basis)

Treatment Combinations	lycopene (mg/100g)		Day I
Stored sample*Storage Period			
S1 * 1-Month	13.70±0.26^{b}	S1	16.60±0.51^{b}
S1 * 2-Month	9.02±0.26^{cd}	S2	26±0.51^{a}
S1 * 3-Month	8.27 ±0.26^{d}		
S2 * 1-Month	21.70±0.26^{a}		
S2 * 2-Month	13.70±0.26^{b}		
S2 * 3-Month	10.50±0.26^{c}		
Stored sample*Storage Condition			
S2 *Refrigerated temp.	15.89±0.21^{a}		
S2 *Room temp.	14.46±0.21^{b}		
S1* Refrigerated temp.	10.30±0.21^{c}		
S1*Room temp.	9.93±0.21^{c}		
Packaging material			
Glass jar	13.02±0.18^{a}		
Plastic jar	12.75±0.18^{ba}		
Plastic bag	12.19±0.18^{b}		
CV (%)	8.86		4.2

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$, Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

4.2.1.11 β-carotene

There were highly significant ($p\leq0.01$) differences between dried sample (90^{o}C for 7 and 8 hours) in first days of analysis (Appendix Table 10).As presented in Table 14 there was also very highly significant ($p\leq0.001$) difference in decreasing rates of β-carotene content between main effects of both sample (90^{o}C for 7 and 8 hours), packaging, storage temperature and storage period (Appendix Table 14). The β-carotene content of stored tomato powder in first day was 5.18 mg/100gand 4.11 mg/100gdecreased to maximum 2.49 mg/100gin dried sample at 90^{o}C for 7 and minimum 2.35mg/100gin low density polyethylene (plastic bag) packaging material in three months of storage period. This may be because of β-carotene are heat and oxidation sensitive during processing and storage.

In packaging material the maximum retention 2.46 mg/100gis founded in sample packed in glass jar. This may be attributed to poor gas and oxygen barrier property as well as proper controlling of temperature and storage environment or humidity of plastic bag when compare with glass jar and plastic jar (Dutta *et al*., 2007). On the other hand maximum 2.49 mg/100gretention were observed in sample stored in refrigerated temperature and minimum retention 2.34 mg/100gwas founded at room temperature condition. This may be due to the fluctuation of temperature in room temperature storage than refrigerated temperature storage. However there were no significant between difference between interaction effects of stored sample, packaging material, storage period and storage temperature on β-carotene contents of stored tomato powder (Appendix Table 14).

The result indicated that with increasing of storage period β-carotenes content was decreased. This loss of β-carotene could be due to non-oxidative changes (cis–trans isomerization, poxide formation, or heat degradation of tissues) or oxidative changes on exposure to light, oxygen and storage temperature (Aruna *et al*., 1999). Similarly Aruna and Poonam (2013) reported that decreasing of β-carotene at room (28-35°C) temperature, fridge (4-10°C) temperature and found that maximum β-carotene retention in salsa packed in glass jars stored at refrigeration temperature followed by glass jars stored at room temperature for two months of storage periods.

Table 14: Main effects of stored sample, packaging material and storage temperature on ßeta-carotene contents of stored tomato powder (wet-basis)

Sample	ß-carotene (mg/100g)	First day
Dried Sample		
S1	2.49±0.01[a]	5.11[a]
S2	2.34±0.01[b]	4.11[b]
Packaging material		
Glass jar	2.46±0.02[a]	
Plastic jar	2.42±0.02[ab]	
Plastic bag	2.42±0.02[b]	
Storage temp.		
Refrigerated temp.	2.49±0.01[a]	
Room tem	2.34±0.01[b]	
Storage period		
1-Months	2.72±0.02[a]	
2-Months	2.44±0.02[b]	
3-Months	2.08±0.02[c]	
CV %	5.6	5.8

Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$, Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

4.2.1.12 Vitamin-C

Vitamin-C is an unstable compound under undesirable conditions and it decomposes easily (Lee and Coates, 1999). It is the most labile of the nutrients, so its deprivation is used as an indicator of quality (Smith and Hui, 2004). There were significant ($p\leq0.001$) differences between dried sample (90^{o}C for 7 and 8 hours) in first days of analysis (Appendix Table 10). This may be due to processing variation.

Changes in vitamin C content during storage were significant ($p\leq0.05$) difference affected by three way interaction effects among stored sample, packaging material and storage period (Appendix Table 15). As a result vitamin C content of tomato powder was decreased from 8.4 mg/100g and 5.45 mg/100g in first days to maximum decreasing 0.92 mg/100g in sample dried at 90^{o}C for 8 hours packed in plastic bag (low density polyethylene) in 3rdmonths of storage period and minimum decreasing 4.64 mg/100g in sample dried at 90^{o}C for 8 hours packed in glass jar packaging material in 1st months of storage period respectively (Table 15).

There was also significant ($p \leq 0.01$) difference between storage temperature with maximum loss 2.52 mg/100g at room temperature and minimum losses 2.94 mg/100g was observed in refrigerated temperature storage respectively (Table 15). The result showed that there was decreasing of vitamin C with duration of drying and storage period as well as in storage temperature. As a result the degradation rate of ascorbic acid content was high in both samples which were stored in plastic bag in all of storage period. While degradation rate was lower in glass jar and plastic jar with value 4.64 and 4.49mg/100g after storage; this may be due to poor oxygen and CO_2 barrier property of plastic bag (low density polyethylene) than glass jar and plastic jar. However there were no interaction effects in all of treatment combination (among stored sample, packaging material, storage temperature and storage period) on vitamin C contents of stored tomato powder (Appendix Table 15).

In regard to storage temperature the degradation was high at room temperature than at refrigerated storage condition; this may be due to oxidation, especially at higher storage temperature. In line to this Dewanto *et al*. (2002) and Safdar *et al.* (2010) reported that the losses of ascorbic acid during thermal processing and storage probably attributed to oxidation of ascorbic acid to dehydro ascorbic acid followed by hydrolysis of the latter in 2,3-diketogluconic acid which then undergoes polymerization to other nutritional inactive products.

Similarly Charles *et al*. (2014) reported that Vitamin C progressively decreased as the processing times increased and suggested that it does not require excessive heat treatment. Ibironke and Rotimi, (2013) observed that the decreasing of vitamin C in powder stored at room and fridge storage temperature and conclude the higher temperature at which the samples were prepared is probably responsible for this. Hossain and Gottschalk (2009) also reported that ascorbic acid was degraded rapidly in room environment than that of cool chamber and the sample with lower final moisture content might be lost because of more oxidation in the drying chamber in five months of storage.

Table 15: Interaction effects between stored sample, packaging material and storage period on vitamin contents of stored tomato powder (wet-basis)

Treatment combinations	Vitamin-C (mg/100g)	Day I
Sample* Packaging material*Storage period		
S1* Glass jar *1-Months	4.64±0.07^{a}	8.41±0.19^{a}
S1*Plastic jar *1-Months	4.49±0.07^{a}	4.78±0.19^{b}
S1*Plastic bag *1-Months	4.09±0.07^{cb}	
S2 * Glass jar * 1-Months	4.36±0.07^{cab}	
S2 * Plastic jar * 1-Months	4.36±0.07^{ab}	
S2 * Plastic bag * 1-Months	3.98±0.07^{c}	
S1 * Glass jar * 2-Months	3.08±0.07^{d}	
S1* Plastic jar *2-Months	2.95±0.07^{de}	
S1* Plastic bag * 2-Months	2.49±0.07^{f}	
S2 *Glass jar * 2-Months	2.69±0.07^{fe}	
S2 * Plastic jar * 2-Months	2.55±0.07^{f}	
S2 * Plastic bag * 2-Months	1.79±0.07^{g}	
S1* Glass jar *3-Months	1.79±0.07^{g}	
S1* Plastic jar * 3-Months	1.57±0.07^{gh}	
S1* Plastic bag * 3-Months	1.34±0.07^{ih}	
S2 * Glass jar *3-Months	1.08±0.07^{ij}	
S2 * Plastic jar *3-Months	0.96±0.07^{ij}	
S2 * Plastic bag * 3-Months	0.92±0.07^{j}	
Storage temp.		
Refrigerate Temp.	2.94±0.02^{a}	
Room temp	2.52±0.02^{b}	
CV (%)	6.6	5.1

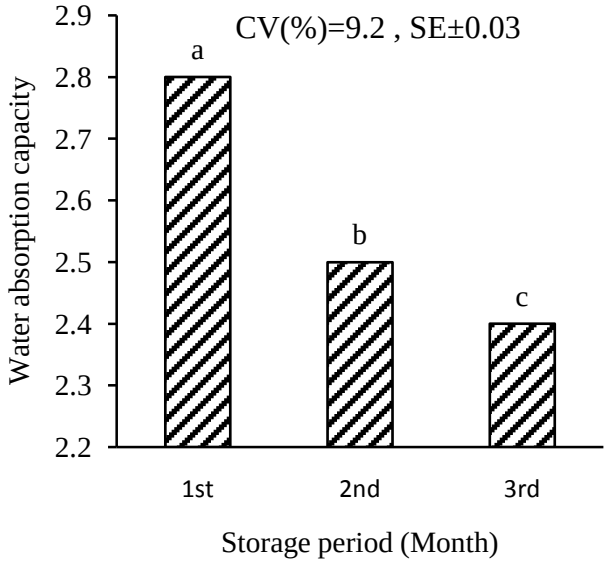
Values are means± standard error. Values in column with different letters as superscripts are significantly different at $p<0.05$, Sample dried at 90^{o}C for 7 hours (S1), Sample dried at 90^{o}C for 8 hours (S2)

4.2.3 Physical parameter

4.2.3.1 Water absorption capacities

Water absorption capacities result indicated that there was none significant difference between dried tomato samples in first days of analysis (Appendix Table 9).While in stored tomato powder it was significantly ($p \leq 0.001$) affected by main effects of storage period (Appendix Table 15). As a result, water absorption capacities of powder decreased slightly from the mean value of 4.1 and 3.96 on the first day to maximum 2.83 and minimum 2.44 which were observed on 1st and 3rd month of storage period respectively (Figure 6). In addition, there were no significance differences among interactions of stored sample, packaging material, storage temperature and storage periods (Appendix Table 15).

These slight reductions in water absorption capacities could be attributed to adsorption of moisture content during storage of the dried product, structural and chemical change during storage. Analogous to this Hossain and Gottschalk (2009) reported that rehydration ratio decreased linearly with the storage duration in dried tomato sample stored at room and in cool chamber storage condition for five months of storage periods.



Values in column with different letter superscripts are significantly different at $p<0.05$, standard error (SE)

Figure 6: Effects of storage period on rehydration quality of stored tomato powder

4.2.3.2 Water activity

In first days of analysis there was no significant difference on water activity between dried tomato samples (Appendix Table 9).While it was observed that Aw was significantly ($p \leq 0.001$) affected by main effects of packaging material, storage temperature and storage periods. However there is no significant between interaction of dried sample, packaging material, storage temperature and storage material (Appendix Table 15).

As the result revealed that the slight decreasing in water activity was founded from 0.45 in first day to maximum decreasing rate 0.37 in glass jar, in 1^{st} months, and minimum decreasing 0.39, in 2^{nd} months of storage period and at room temperature storage respectively. This may be due to Millard reaction. On the other hand slight increasing of water activity from 0.45 in first day to 0.41 in polyethylene (plastic bag) packed sample and 0.42 in 3^{rd} month's storage period was observed (Table 16). Similar to moisture content Aw also increased slightly due to the high rate of migration of water vapor from the storage environment to packaging material, high permeability of plastic bag and also following of increasing of moisture content with storage period.

The result indicated that for the entire storage period, only a slight increase in water activity was found. Therefore, the products could be safely stored for three months of storage period after which increase in its value may result into attack by microorganism. This finding was in agreement with the work done by Swain *et al*. (2013) who observed the slight increasing of water activity in dried sweet pepper during ambient storage for four months of storage period and conclude the products could be stored up to 60 days of storage period. Jayathunge*et al*. (2012) also reported that the increasing of water activity in tomato powder packed Polypropylene (PP), Polystyrene (PS) and Polyvinyl chloride (PVC) than triple laminated Aluminium foil for six months of storage at 31±2^{o}C and 65±5% RH and conclude PP, PS and PVC were found unsuitable for storage of dehydrated tomato powder as the moisture content and water activity increased.

Table 16: Effects of storage condition, packaging material and storage period on water activity of stored tomato powder

Treatment	Water activity (aw)
Storage temp.	
Room temp.	0.39±0.004[a]
Refrigerated temp	0.38±0.004[b]
Packaging material	
Glass jar	0.37±0.005[b]
Plastic jar	0.38±0.005[b]
Plastic bag	0.41±0.005[a]
Storage period	
1- Months	0.37±0.005[b]
2- Months	0.37±0.005[b]
3- Months	0.42±0.005[a]
CV (%)	8.02

Values in column with different letters as superscripts are significantly different at $p<0.05$

4.2.4 Microbial Load

Microbiological quality is a common criterion used to determine the acceptability and shelf life of dehydrated products. It can reduce or completely overcome the potential of microbial growth by drying (Mujumdar, 2004). But drying is not lethal to all microbes. The load of microbial in dried foods depends on handling quality of utensils used during the processing period, storage conditions and the moisture level in the product (Jay, 2000; Jangam and Mujumdar, 2010).

The microbial load obtained in first day was 0.33,0.00 cfu/g in samples dried at 90^{o}C for 7and 8 hours at $x10^{-4}$ and $x10^{-6}$ respectively (Table 17).It is clear that the total viable bacterial count increased slightly with the increase of storage period. As a result the load increased maximum to 6.33 in 90 days at $x10^{-4}$ in both sample packed plastic bag (low density polyethylene) and plastic jar stored at room temperature storage and minimum 5 in 90 days in sample dried at 90°C for 7 hours which packed in plastic bag and stored at room temperature storage condition at 10^{-6} in three months of storage period respectively and also the microbial population does not contain fungi (yeast/mould). The result showed that there is low microbial load in both sample which stored in glass jar when compared with plastic bag and

plastic jar (Table 17).This may be permeability of plastic bag and plastic jar than glass jar packaging material.

These low bacterial counts of stored tomato powder seemed to be due to lower pH, water activity, and moisture content at which the growth of microorganisms was not possible and it should be remembered that the samples were produced in laboratory conditions which were presumably cleaner. Moreover all packaging materials and storage condition were able to maintain the moisture content below 10 %, which is the alarm water content suggested for storage stability of dehydrated foods (Jay, 2000).

Similarly Famurewa *et al*. (2013) reported that maximum (12 $x10^{-3}$ cfu/g) and (3 $x10^{-3}$cfu/g) minimum microbial load of tomato paste packed in polyethylene and plastic bottle and does not contain fungi (yeast/mould).Neena *et al.* (2013) also reported that oven dried tomato sample resulted in lower bacterial population and observed higher population in the three months storage.

Table 17: Interaction effects of sample, packaging material, and storage temperature and storage days on microbial quality of stored tomato powder

Sample*****Packaging material*****Storage temp.*****Storage days				Total plate count (TPC) CFU/g	
				$x10^{-4}$	$x10^{-6}$
S1	-	-	1^{st}	0.33^{a}	0.00^{a}
S2	-	-	1^{st}	0.00^{a}	0.00^{a}
S1	Glass jar	Room temp.	15^{th}	1.33^{lmnk}	1^{hjik}
S1	Plastic jar	Room temp.	15^{th}	1.66^{lmjnk}	1^{hjik}
S1	Plastic bag	Room temp.	15^{th}	2.33^{limjhk}	1.66^{hjifg}
S2	Glass jar	Room temp.	15^{th}	1^{lmn}	0^{k}
S2	Plastic jar	Room temp.	15^{th}	1.66^{lmjnk}	0^{k}
S2	Plastic bag	Room temp.	15^{th}	2.33^{limjhk}	1.66^{hjifg}
S1	Glass jar	Refrigerate temp	15^{th}	0.33^{n}	0^{k}
S1	Plastic bag	Refrigerate temp	15^{th}	1^{lmn}	0.66^{jik}
S1	Plastic bag	Refrigerate temp	15^{th}	0.66^{mn}	1.33^{hjikg}
S2	Glass jar	Refrigerate temp	15^{th}	0.33^{n}	0^{k}
S2	Plastic jar	Refrigerate temp	15^{th}	1^{lmn}	0^{k}
S2	Plastic bag	Refrigerate temp	15^{th}	1.33^{lmnk}	0.33^{jk}
S1	Glass jar	Room temp.	30^{th}	2.66^{ligjhk}	1^{hjik}

S1	Plastic jar	Room temp.	30th	2.66ligjhk	1hjik
S1	Plastic bag	Room temp.	30th	2.66ligjhk	1.33hjikg
S2	Glass jar	Room temp.	30th	2limjnk	1hjik
S2	Plastic jar	Room temp.	30th	2limjnk	1hjik
S2	Plastic bag	Room temp.	30th	2.33limjhk	2.33hedfg
S1	Glass jar	Refrigerate temp	30th	1.33lmnk	1kijh
S1	Plastic jar	Refrigerate temp	30th	2limjnk	1kijh
S1	Plastic bag	Refrigerate temp	30th	2.66ligjhk	1.33hjikg
S2	Glass jar	Refrigerate temp	30th	1lmn	0.66jik
S2	Plastic jar	Refrigerate temp	30th	1lmn	1.33hjikg
S2	Plastic bag	Refrigerate temp	30th	2limjnk	1.33hjikg
S1	Glass jar	Room temp.	45th	2.66ligjhk	2.6cedfg
S1	Plastic jar	Room temp.	45th	3figjhk	2heifg
S1	Plastic bag	Room temp.	45th	3.33figjhe	3cedf
S2	Glass jar	Room temp.	45th	3figjhk	1.66hjifg
S2	Plastic jar	Room temp.	45th	3figjhk	2heifg
S2	Plastic bag	Room temp.	45th	3.33figjhe	2.33hedfg
S1	Glass jar	Refrigerate temp	45th	2.33limjhk	1hjik
S1	Plastic bag	Refrigerate temp	45th	2.33limjhk	1.66hjifg
S1	Plastic bag	Refrigerate temp	45th	3figjhe	2heifg
S2	Glass jar	Refrigerate temp	45th	2.33limjhk	1hjik
S2	Plastic jar	Refrigerate temp	45th	2.66ligjhk	1hjik
S2	Plastic bag	Refrigerate temp	45th	3figjhk	2heifg
S1	Glass jar	Room temp.	60th	4.33fcgdbe	3cedf
S1	Plastic jar	Room temp.	60th	4.66fcadbe	3cedf
S1	Plastic bag	Room temp.	60th	4.66fcadbe	3.6cadb
S2	Glass jar	Room temp.	60th	4fcgdhe	3cedf
S2	Plastic jar	Room temp.	60th	4fcgdhe	3.33cedb
S2	Plastic bag	Room temp.	60th	4.66fcadbe	3.6cadb
S1	Glass jar	Refrigerate temp	60th	3.66figdhe	2.33hedfg
S1	Plastic jar	Refrigerate temp	60th	4fcgdhe	2.33hedfg
S1	Plastic bag	Refrigerate temp	60th	4.33fcgdbe	3cedf
S2	Glass jar	Refrigerate temp	60th	2.66ligjhk	2.6cedfg
S2	Plastic jar	Refrigerate temp	60th	3.33figjhe	3cedf
S2	Plastic bag	Refrigerate temp	60th	4fcgdhe	3cedf
S1	Glass jar	Room temp.	75th	4.66fcadbe	3cedf
S1	Plastic jar	Room temp.	75th	5.33cadb	3.33cedb
S1	Plastic bag	Room temp.	75th	5.66cab	4ab
S2	Glass jar	Room temp.	75th	4.66fcadbe	2cedf
S2	Plastic jar	Room temp.	75th	4.66fcadbe	3.66cadb
S2	Plastic bag	Room temp.	75th	5cadbe	3.6cadb
S1	Glass jar	Refrigerate temp	75th	4fcgdhe	3cedf
S1	Plastic jar	Refrigerate temp	75th	4.66fcadbe	2cedf
S1	Plastic bag	Refrigerate temp	75th	5cadbe	3.6cadb
S2	Glass jar	Refrigerate temp	75th	3.66figdhi	2.6cedfg
S2	Plastic jar	Refrigerate temp	75th	4fcgdhe	3.66cadb

S2	plastic bag	Refrigerate temp	75^{th}	5.66^{cab}	3.66^{cadb}
S1	Glass jar	Room temp.	90^{th}	5.6^{cab}	4^{cab}
S1	Plastic jar	Room temp.	90^{th}	6.33^{a}	4^{cab}
S1	Plastic bag	Room temp.	90^{th}	5.6^{cab}	5^{a}
S2	Glass jar	Room temp.	90^{th}	5^{cadbe}	4^{cab}
S2	Plastic jar	Room temp.	90^{th}	5.33^{cadb}	4^{cab}
S2	Plastic bag	Room temp.	90^{th}	6.33^{a}	4.6^{ab}
S1	Glass jar	Refrigerate temp	90^{th}	4.66^{fcadbe}	3.33^{cedb}
S1	Plastic jar	Refrigerate temp	90^{th}	5^{cadbe}	3.33^{cedb}
S1	Plastic bag	Refrigerate temp	90^{th}	6^{a}	4^{cab}
S2	Glass jar	Refrigerate temp	90^{th}	4.66^{fcadbe}	3^{cedf}
S2	Plastic jar	Refrigerate temp	90^{th}	5^{cadbe}	4^{cab}
S2	Plastic bag	Refrigerate temp	90^{th}	5.66^{cab}	4^{cab}
p-value				<.0001	<.0001

Values in column with different letters as superscripts are significantly different at $p<0.05$, Sample dried at $90^{o}C$ for 7 hours (S1), Sample dried at $90^{o}C$ for 8 hours (S2)

5. SUMMARY AND CONCLUSION

In developing countries such as Ethiopia, tomato is a seasonal product. In addition, it is highly perishable and records huge losses during the period of maximum production. On the other hand, now a day in Ethiopia many agro- processing industries are emerging in an alarming rate due to the current opportunity. However they process limited amounts of crops. So in order to make it available on the market as long as possible after harvest, the preservation technology is needed. One of the most important methods of reducing tomato losses is drying which is a common form of food preservation. It reduces the weight of the product; by this minimize the costs of storage space and transportation. Taking into consideration the importance of drying, especially for developing countries, several studies have already been carried out on various products to optimize one or more parameters. But in Ethiopia there is no published study on drying of tomato.

The study showed that it is possible to reduce post harvest loss and extend shelf life of tomato with minimum loss by drying process. The results indicated that both duration of drying and temperature had great influence on the physicochemical and sensory acceptability of tomatoes. As drying time and temperature increased, moisture, fat, water activity, pH, Vitamin C, β-carotene and color content decreased while carbohydrate, protein, lycopene ,titratable acidity and rehydration ratio increased: this may be concentration of nutrient as moisture content removed. But fiber, TSS, ash, and some sensory quality increase at 70^{o}C and 80^{o}C for 7 and 8 hours duration and declined at 90^{o}C for 7 and 8 hours: this could be attributed to denature the quality of dried tomato. There is also significant difference between dried and the control tomato sample (fresh) this may be because thermal processing especially drying may concentrate the nutritional value of tomatoes. On the other hand reduction in the moisture content and water activity in this study decreased the perishability and microbial loads of this product; by this it can extend the shelf life, thereby making them available year around as well reduce cost of storage and transportation.

In addition the decrease in fat content can minimize the rancidity of the product during storage. Generally from drying study (experiment I) physicochemical and sensory quality of

dried tomato showed that drying of tomato slices at 90°C for 7 and 8 hours can help in providing acceptable quality which is a major criterion in dried products as opposed to lower drying temperatures and control (fresh tomato).

Storage study (experiment II) also indicated that there is slight decreasing of lycopene, pH, TSS, fat, protein, ash, fiber, rehydration ratio and increasing of moisture content, TA, Carbohydrate, and microbial load. This is due to the interaction with temperature, variation of the relative humidity of the surrounding air and the hygroscopic nature of the product. The low bacterial counts and the absence of fungi in stored tomato powder seemed to be due to low pH, water activity, and moisture content. Furthermore, vitamin C content of stored tomato powder was decreased more in 3-months of storage period in plastic bag (low density polyethylene bag) and the decreasing rate of lycopene content was also higher in plastic bag (low density polyethylene) packaging material. But the degradation rate was lower in glass jar and plastic jar for both vitamin C and lycopene. Finally, to retain quality, drying for 7 hours is recommandable.

Even if slight increasing of moisture content occurred during storage the products could be stored in any one of the packaging materials up to three month of storage because the moisture content of the product was unfavorable for microbial growth. To ensure the maximum hygienic quality and minimum loss on physicochemical quality of dried tomato might be stored for maximum three months in glass jar and plastic jar at refrigerate temperature could retain than plastic bag (low density polyethylene) packaging material and store at room temperature storage. The result showed that dried tomato could contribute the daily intake of nutrition especially proximate composition superior than fresh tomato. Generally drying can reduce the post harvest losses of tomatoes and extend shelf life with minimum degradation on quality.

6. FUTURE LINE OF WORK

Due to limited access to variety, drying facilities and budget, it was difficult to run the study involving different varieties, different drying methods and for extended storage period beyond three months. Therefore, it is suggested that additional study be carried out to investigate the shelf life and other quality attributes of different tomato varieties dried using different methods of drying. Moreover, it is also essential to investigate the extent of energy consumption during oven drying

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APPENDICES

Analysis of variance of physicochemical quality of dried tomatoes

AppendixTable1.Mean Square value for moisture, ash and Fat content affected by interaction effects of temperature and duration of drying

		Mean square value		
Source of variation	DF	Moisture	Ash	Fat
Duration (hrs)	2	1.71125000***	127.4572127***	1.95089206**
Temp.(ºC)	3	12.56631667***	105.7341603***	2.34300397***
Duration*Temp.	6	5.46850333***	57.5577635***	1.30933810***
Error	14	0.05869444	4.0553143	0.02238571
CV(%)		4.20	12.30	8.12

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant.

Appendix Table 2.Mean Square value for Protein, fiber and carbohydrate content affected by interaction effects of temperature and duration of drying

Source of variation	DF	Mean Square value		
		Protein	Fiber	Carbohydrate content
Duration (hrs)	2	1413.801740***	21.97537937***	3118.156051***
Temp.(ºC)	3	919.534447***	18.71789365***	2113.846836***
Duration *Temp.	6	473.971987***	9.53999683***	1059.424032***
Error	14	3.92692	0.13981429	4.416624
CV (%)		9.01	6.10	4.15

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant.

Appendix Table 3.Mean Square value for lycopene, βet-acarotene and Vitamin-C content of tomato affected by interaction effects of temperature and duration of drying

Sources of variation	DF	Mean Square value		
		lycopene	βeta-carotene	Vitamin-C
Duration (hrs)	2	5284.96921 ***	71.4628571***	21.10349206***
Temp.(°C)	3	3481.66929***	37.8835714***	16.39825397***
Duration *Temp.	6	1861.64714***	26.0276190***	8.26746032***
Error	14	14.87190	3.1161905	0.06666667
CV (%)		5.7	8.7	7.2

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant.

Appendix Table 4.Mean Square value for water absorption capacity and water activity content of tomato affected by interaction effects of temperature and duration of drying

Source of variation	DF	Means Square value	
		Water absorption capacity	aw
Duration	2	177.4464683***	0.28969206***
temp	3	98.6017312***	0.19335952***
time*temp	5	1.87468472***	0.10052698***
Error	66	0.14488649	0.00043810 14
CV (%)		12.6	4

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant.

Appendix Table 5: Mean Square value for pH, Total soluble solid and Titratable content of tomato affected by interaction effects of temperature and duration of drying

		Mean Square		
Source of variation	DF	pH	TSS	TA
Duration	2	0.04325714***	8.27682540***	0.00682540 ***
Temp. (°C)	3	0.04708810***	7.24492063***	0.00644286***
Duration*Temp	6	0.02728571***	3.92968254***	0.00364921***
Error	14	0.00181905	0.35666667	0.00014286
CV(%)		0.96	6.3	5.1

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant.

Analysis of variance of sensory quality of dried tomatoes

Appendix Table 6: Mean Square value for Color, Flavor and Taste quality of tomatoaffected by interaction effects of temperature and duration of drying

		Mean Square value		
Source of Variation	DF	Color	Flavor	Taste
Duration	1	241.6825397***	238.1877778***	19.6544444***
Temp. (°C)	2	264.5653968***	224.5633333***	133.3633333***
Duration*Temp	6	169.241587***	115.1819048***	50.5076190***
Error	1043	0.306973	0.679764	0.956561

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant.

Appendix Table 7: Mean Square value for Mouth feel, Appearance and Overall acceptance quality of tomato affected by interaction effects of temperature and duration of drying

Mean Square value				
Source of Variation	DF	Mouth feel	Appearance	Overall acceptance
Duration	1	26.6944444***	74.5358730***	48.12285714***
Temp.(°C)	2	96.0677778***	125.7220635***	93.8841270 ***
Duration*Temp.	6	37.0342857***	83.4326984 ***	65.2165079 ***
Error	1043	0.867498***	0.732790	0.643164

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant.

Analysis of variance of physicochemical quality of dried tomatoes powder in first days of analysis

Appendix Table 8: Mean Square value for Moisture, Ash, Fat and Protein contents of tomato affected by drying process in first days of analysis

Mean Square value					
Source of variation	DF	Moisture	Ash	Fat	Protein
Sample	1	0.10140000^{ns}	0.21660000*	0.43201667**	8.09681667**
Error	4	0.01385000	0.35208333	0.02616667	0.38236667
CV (%)		2.91	4.95	5.44	3.61

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant, ns=none significance.

Appendix Table 9: Mean Square value for Fiber, Carbohydrate, Water activity and water absorption capacity of tomato affected by drying process in first days of analysis

		Mean Square value			
Source of variation	DF	Fiber	Carbohydrate	Aw	Water absorption capacity
Sample	1	0.01306667^{ns}	1.27881667^{ns}	0.00015000^{ns}	0.02666667^{ns}
Error	4	0.16693333	0.94456667	0.0002833 3	0.01666667
CV (%)		2.24	2.00	3.72	3.2

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance.

Appendix Table 10: Mean Square value for Lycopene, βeta-carotene and Vitamin-C contents of tomato affected by drying process in first days of analysis

Mean Square value				
Source of variation	DF	Lycopene	βeta-carotene	Vitamin-C
Sample	1	131.6016667***	1.70666667***	19.80166667***
Error	4	0.8016667	0.07398333	0.11748333
CV (%)		4.2	5.84	5.1

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance.

Appendix Table 11: Mean Square value for pH, TSS and Titratable acidity contents of tomato affected by drying process in first days of analysis

		Mean Square value		
Source of variation	DF	pH	TSS	Titratable acidity
Sample	1	0.00166667^{ns}	0.04166667^{ns}	0.00106667*
Error	4	0.00166667	0.29166667	0.00011667
CV (%)		0.9	6	4.56

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance

Analysis of variance of physicochemical quality of stored tomatoes powder

Appendix Table12.Mean Square value for Moisture, Ash and Protein content affected by Main effects of stored sample, packaging material, storage condition and storage period in stored tomato powder

Mean Square value				
Source of variation	DF	Moisture	Ash	Protein
Stored sample	1	3.06030000***	1.44675926**	10.39120370***
Packaging	2	1.18960833***	0.70002593^{ns}	9.16148426***
Storage temperature.	1	4.89814815***	17.7147000***	4.75440370 *
Storage period	2	6.66787778***	30.6067592***	10.69206759 ***
Sample*Packaging	2	0.17538611^{ns}	0.03334815^{ns}	0.88754537^{ns}
Sample*Storage temp.	1	0.03929259^{ns}	0.02083333^{ns}	2.23603333^{ns}
Packaging*Storage temp.	2	0.04919537^{ns}	0.15631111^{ns}	0.11609537^{ns}
Sample*Packaging*Storage temp.	2	0.04803981^{ns}	0.04541111^{ns}	0.20437500^{ns}
Sample*storage period	2	0.08234444^{ns}	0.57240370^{ns}	0.95327870^{ns}
Packaging*storage period	4	0.01567778^{ns}	0.09040509^{ns}	0.38563981^{ns}
Sample*Packaging*storage period	4	0.01722222^{ns}	0.07091343	0.06619537^{ns}
Storage temp.*storage period	2	0.04815926^{ns}	0.31221111^{ns}	1.14279537^{ns}
Sample*Storage temp.*storage period	2	0.04588148^{ns}	0.11410000^{ns}	0.17970278^{ns}
Packaging*storage temp.*storage period	4	0.03624815^{ns}	0.05268472^{ns}	0.62467870^{ns}
Sample*Packaging*Storage temp.*storage period	4	0.01433704^{ns}	0.00674861^{ns}	0.02446944^{ns}
Error	72	0.06276944	0.3023259	0.3286722
CV (%)		4.75	7.8	6.30

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance.

Appendix Table13.Mean Square value for fat content affected by two way interaction of stored ample with storage period ,stored sample with packaging material, and storage condition with storage period, main effects of storage period affect fiber content, main effects of stored sample, packaging material, storage condition and storage period on carbohydrate contents of stored tomato powder

		Mean Square		
Source of variation	DF	Fat	Fiber	Carbohydrate
Sample	1	0.76844537***	1.54083333^{ns}	45.5780148***
Packaging	2	0.15471944***	0.71558148^{ns}	15.1730343***
Storage temp.	1	0.25911204 ***	1.83561481^{ns}	64.7125926***
Storage period	2	2.72663611***	5.47709537***	158.5935454***
Sample*Packaging	2	0.01637870*	0.34724444^{ns}	0.7049009^{ns}
Sample*Storage temp.	1	0.00033426^{ns}	0.18750000^{ns}	1.9093481^{ns}
Packaging*Storage temp.	2	0.00711759^{ns}	0.81847778^{ns}	1.2555620^{ns}
Sample*Packaging*Storage temp.	2	0.01256204^{ns}	0.85060370^{ns}	0.2303065^{ns}
Sample* storage period	2	0.02750093**	0.39565833^{ns}	0.8621287^{ns}
Packaging* storage period	4	0.00280556^{ns}	0.34852870^{ns}	0.4987162^{ns}
Sample*Packaging* storage period	4	0.00298426^{ns}	0.08470278^{ns}	0.1315606^{ns}
Storage temp.*storage period	2	0.03120093**	0.21411204^{ns}	1.6332676^{ns}
Sample*Storage temp. *storage period	2	0.00428426^{ns}	0.29940833^{ns}	1.9812509^{ns}
Packaging*Storage temp.*storage period	4	0.00688981^{ns}	0.40689259^{ns}	0.1658662^{ns}
Sample*Packaging*Storage temp.*storage period	4	0.00162037^{ns}	0.21426111^{ns}	0.2483884^{ns}
Error	72	0.00449074	0.58063426	1.5098120
CV (%)		4.86	4.27	2.09

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance.

Appendix Table14.Mean Square value for Lycopene affected by two way interaction of stored sample with storage period ,stored sample with storage condition, and main effects of packaging material and main effects of stored sample, packaging material, storage condition and storage period on βeta- carotene of stored tomato powder

Mean Square value			
Source of variation	DF	βeta- carotene	Lycopene
Sample	1	0.59704537***	687.507408***
Packaging	2	0.12613611***	6.461337**
Storage temp.	1	0.63020833***	22.477156***
Storage period	2	3.73460278***	662.253490***
Sample*Packaging	2	0.01384537^{ns}	1.068311^{ns}
Sample * Storage temp.	1	0.02644537^{ns}	7.150779**
packaging* Storage temp.	2	0.00545278^{ns}	0.344193^{ns}
Sample * Packaging * Storage temp.	2	0.01529537^{ns}	0.135848^{ns}
Sample*storage period	2	0.00116759^{ns}	108.271636*
packaging* storage period	4	0.01438056^{ns}	0.664476^{ns}
Sample* packaging * storage period	4	0.01071759^{ns}	0.496181^{ns}
Storage temp. * storage period	2	0.03500278^{ns}	1.081456^{ns}
Sample*storage temp.*storage period	2	0.00208981^{ns}	0.362184^{ns}
Packaging* storage temp. * storage period	4	0.00168889^{ns}	0.141134^{ns}
Sample*storage temp.*storage period			
Sample* packaging *storage temp.*storage period	4	0.00371481^{ns}	0.073570^{ns}
Error	72	0.01892222	1.260856
CV (%)		5.69	8.86

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance

Appendix Table15.Mean Square value for water absorption capacity affected by storage period, water activity affected by main effects of packaging material and main effects of storage condition and storage period and Vitamin-C affected by three way interaction effects of stored sample with packaging material with storage period in stored tomato powder

Mean Square value				
Source	DF	Water absorption capacity	aw	Vitamin c
Sample	1	0.19580625^{ns}	0.00311481^{ns}	4.6916676***
Packaging	2	0.07250903^{ns}	0.01293981***	2.5030778***
Storage temp.	1	0.20778403^{ns}	0.00507037**	0.3082676***
Storage period	2	2.09320903***	0.02536759***	83.9517528***
Sample * Packaging	2	0.02625208^{ns}	0.00044537^{ns}	0.0161037^{ns}
Sample * Storage temp.	1	0.03641736^{ns}	0.00062593^{ns}	0.0046676^{ns}
Packaging * Storage temp.	2	0.00158403^{ns}	0.00058426^{ns}	0.0060593^{ns}
Sample* Packaging *Storage temp.	2	0.16418819^{ns}	0.00006759^{ns}	0.0032926^{ns}
Sample *storage period	2	0.06283958^{ns}	0.00042870^{ns}	0.4214065^{ns}
Packaging * storage period	4	0.01742778^{ns}	0.00031343^{ns}	0.2094972***
Sample *packaging* storage period	4	0.03204792^{ns}	0.00053843^{ns}	0.0867176*
Storage* storage period	2	0.05182569^{ns}	0.00007315^{ns}	0.0434620^{ns}
Sample*storage temp.* storage period	2	0.05562569^{ns}	0.00061204^{ns}	0.0049343^{ns}
Packing*Storage temp.*storage period	4	0.06324444^{ns}	0.00030787^{ns}	0.0190787^{ns}
Sample*packaging*Storage temp.*Storage period	4	0.00202153^{ns}	0.00063287^{ns}	0.0051009^{ns}
Error	108	0.05766273	0.0009861172	0.0334398^{ns}
CV(%)		9.23	8.02	6.6

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant ******= highly significant, *******= Very highly significant, ns=none significance.

Appendix Table16.Mean Square value for TSS affected by two way interaction of storage period with storage condition and by main effects of packaging material, Titratable acidity affected by two way interaction between stored sample and storage period and main effects of packaging material and storage condition and pH affected by main effects of stored sample ,storage condition and storage period in stored tomato powder

		Mean Square value		
Source of variation	DF	TSS	Titratable acidity	pH
Sample	1	0.18750000^{ns}	0.01060093***	0.00428148**
Packaging	2	0.93787037***	0.00526759***	0.00103333^{ns}
Storage temp.	1	1.89342593***	0.04522315***	0.04813333***
Storage period	2	11.05120370***	0.06679537***	0.13721944***
Sample*Packaging	2	0.02527778^{ns}	0.00020093^{ns}	0.00018148^{ns}
Sample*Storage temp.	1	0.26009259^{ns}	0.00000093^{ns}	0.00003333^{ns}
Packaging*Storage con	2	0.03731481^{ns}	0.00008426^{ns}	0.00034444ns
Sample*Packaging*Storage temp.	2	0.01398148^{ns}	0.00028426^{ns}	0.00014444^{ns}
Sample*storage period	2	0.22027778^{ns}	0.00094537**	0.00002870^{ns}
Packaging* storage period	4	0.18425926^{ns}	0.00009537^{ns}	0.00034861^{ns}
Sampler*packaging*storage period	4	0.10055556^{ns}	0.00002870^{ns}	0.00006620^{ns}
Storage temp.* storage period	2	0.59453704**	0.00025093^{ns}	0.00058611^{ns}
Sample*Storage temp.* storage period	2	0.18175926^{ns}	0.00020093^{ns}	0.00002500^{ns}
Packaging*Storage temp.* storage period	4	0.17009259^{ns}	0.00004537^{ns}	0.00017639^{ns}
Sample*packing*Storage temp. *storage period	4	0.13231481^{ns}	0.00016759^{ns}	0.00019028^{ns}
Error	72	0.15555556	0.00018981	0.00047778
CV (%)		5.66	3.39	0.48

DF= Degree of freedom, CV= Coefficient of variance, *****= Significant **= highly significant, ***= Very highly significant, ns=none significance.

I. Sensory evaluation questioner form

Ballot for tomato powder hedonic taste using a five point scale

Please look at and taste each sample of tomato powder in order from left to right as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase of category which is listed below and mark your choice with the number that corresponds to your preference on each parameter.

1. Dislike Very Much
2. Dislike
3. Neither Like or Dislike
4. Like
5. Like Very Much

Sample code	Color	Flavor	Taste	Mouth feel	Appearance	Overall acceptability

Thank you so Much

II, Vitamin-C standard curve