EFFECT OF DRYING TEMPRATURE, VARIETIES AND STORAGE PERIOD ON PHYSICOCHEMICAL QUALITY, FUNCTIONAL PROPERTIES AND SENSORY ACCEPTABILITY OF DRIED ONION POWDER

M.Sc THESIS RESEARCH

BY

MEHABA SEIFU

February 16, 2016

Jimma, Ethiopia

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Thesis Submitted to the School of Graduate Studies, Jimma University College of Agriculture and Veterinary Medicine, in Partial Fulfillment of the Requirements for the Degree of Master of Science in Post-Harvest Management (perishable crops)

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MEHABA SEIFU

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DEDICATION

This thesis manuscript is dedicated to my beloved family for all the sacrifices, wishes and praiseworthy to my success in all my life.

STATEMENT OF THE AUTHOR

I declare that this thesis, submitted in partial fulfillment of the requirement for M.Sc. degree in Post-Harvest Management (specialization of perishable crops) at Jimma University, is my own original work and has not been submitted to any institution anywhere for the award of any academic degree or diploma. This thesis can be deposited in the university library to be made available to readers or borrowers come to pass under the rules of the university library. Brief quotation from this thesis is allowed without special permission, provided that accurate acknowledgement of the source is made. In all other instances, however, permission must be obtained from the author.

Name: Mehaba Seifu Shifa

Signature: _________________

Date of submission:-____________

BIOGRAPHICAL SKETCH

The author, Mehaba Seifu Shifa, was born on March 10, 1992 at *Agena* town, *Guragea* Zone of South Nations Nationalities and Peoples Regional State. She attended her elementary education at welkite Selam Ber School and secondary education at Agena Secondary and preparatory school. After the completion of her preparatory education, she joined Jimma University College of Agriculture and veterinary medicine in 2011 and graduated with BSc Degree in Post-Harvest Management in June, 2013. After graduation, immediately she was joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a Master of Science degree in Post-Harvest Management (perishable crops).

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LIST OF ABBRIVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
a_w	Water activity
Cfu	Colony forming unit
CIA	Central Intelligence Agency
DNPH	Dinitrophenyl hydrazine
EPHI	Ethiopian Public Health Institute
FAO	Food and Agriculture Organization
GPCS	Gamma-L-glutamyl-trans-S-1-propenyl-L-cysteine sulfoxide
LSD	Least significant difference
NEB	Non-enzymatic browning
PDA	Potato Dextrose Agar
PHL	Post harvest losses
RH	Relative humidity
TSS	Total Soluble Solids

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EFFECT OF DRYING TEMPRATURE, VARIETIES AND STORAGE PERIOD ON PHYSICOCHEMICAL QUALITY, FUNCTIONAL PROPERTIES AND SENSORY ACCEPTABILITY OF DRIED ONION POWDER

ABSTRACT

In Ethiopia, onion is one of the most important vegetables produced mainly as a source of cash income and for flavoring the local stew 'wot'. The excess production of onion results in a glut in the market and reduction in onion prices. Moreover, marketing of fresh onion during the harvesting season is a great problem because of its shorter postharvest shelf life as well as lack of appropriate processing and preservation techniques, its postharvest lose is significant. Therefore, this study was initiated to investigate the impact of temperature and storage period on quality and storage stability of different oven dried onion varieties. Three different onion varieties were procured from Zeway (Sweet carolin, Bombay red and Qellafo) and subjected to five levels of drying temperature (50, 60, 70, 80 and 90^oC) in CRD. For quality evaluation, physical and functional parameter (colour, rehydration ratio, shrinkage ratio, bulk density and water activity), chemical parameter (total soluble solid, titratable acidity, pH, vitamin C, pyruvic acid, moisture, ash and fiber) and sensory quality were analysed. The result indicated that the values of total colour change and functional prosperities increased with increment of drying temperature. Chemical quality such as vitamin C and pyruvic acid were highly degraded at high oven drying temperature. Qellafo onion variety dried at 50^oC had higher vitamin C, pyruvic acid and fiber. From sensory quality, the maximum average of overall acceptability was recorded from Qellafo onion variety dried at 50^oC followed by Bombay Red onion variety. Storage stability study of onion powder was performed for a period up to 90 days. For this purpose, based on analyzed physicochemical and sensory quality; three temperatures were selected (50, 60 and 70^oC). The results showed that total color change, water activity, moisture content, titratable acidity and total plate count increased with increasing of storage period; whereas, vitamin C and pyruvic acid decreased during storage period. Generally the best quality of onion powder obtained at 50^oC though microbial loads were higher after storage. In general, the present finding showed that the best quality of onion powder was obtained from Qellafo onion variety dried at 50^oC. Furthermore, the best microbial quality of onion powder was obtained at 70^oC. Therefore, further research should be done using different packaging materials and storage condition to give conclusive recommendation about quality profile of the studied onion varieties under different drying temperature along with best shelf life.

Key word: *onion, oven drying, variety, quality, shelf life, onion powder*

1. INTRODUCTION

1.1. Background

Onion (*Allium cepa L.*) is considered as the second most important horticultural crops in the world and has always been most widely traded among vegetables (Griffiths *et al.*, 2002). It is one of the world's oldest cultivated plants, which belongs to the family *Liliaceae*. It is a natural part of the daily diet for most of the population and a crop of great economic importance in all over the world (Mogren *et al.*, 2007). In Ethiopia, it is the most essential vegetable crop used as a spice and important ingredient in food due to its nutritive value, aroma, flavor and pungency. It is produced by smallholder farmers mainly as a source of cash income and for flavoring the local stew ‘wot’ and it is believed to be more intensively consumed than any other vegetable crops (Lemma and Shemelis, 2003). It is also used for domestic consumption, export market, and industrial processing. It’s used in the formulation of meat products, gravies, canned foods, sausage and seasonings, soups, dry soup mixes, cheeses, crackers and other snacks and special food products (Prasad, 1994). Nutritionally, fresh onions contain about 868 g kg^{-1} moisture, 116 g kg^{-1}carbohydrates, 12 g kg^{-1} proteins, 2-5 g kg^{-1} calcium, 0.5 g kg^{-1} phosphorus and traces of iron, thiamine, riboflavin and ascorbic acid (Kaymak-Ertekin and Gedik, 2005). Not only the onion gives an excellent taste to dishes, but also is associated with imparting a number of health benefits to its users. As numerous health benefits have been attributed to onions, it has been used traditionally as medicine (Rubatzky and Yamaguchi, 1997). It can protect against cancer, fight fungi and bacteria, promote cardiovascular health, reduce high blood pressure and insulin resistance, aid in weight loss, possess antioxidant activity, fight chronic bronchitis, infections, fever, etc. (Ismail *et al.*, 2003).

The postharvest losses (PHL) of this crop are quite serious in our country due to lack of appropriate processing and preservation techniques. Preservation of onion is essential for keeping them for a long time without further deterioration in the quality of the product (Brewster, 1997). Several process 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. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply (Gallali *et al.*, 2000). Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality maintenance, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind. Drying involves the application of heat to vaporize moisture and some mean of removing water vapor after its separation from the food products (Krokida and Marinos-Kouris, 2003). The removal of moisture prevents the growth and reproduction of microorganisms like bacteria, yeasts and molds causing decay and minimizes many of the moisture mediated deteriorative reactions. It brings about substantial reduction in weight and volume, minimizing packaging, storage, and transportation costs and enables storability of the product under ambient temperatures (Rangana *et al.,* 2000).

Moisture content of a product is important for inducing microbial spoilage and, hence, affects the shelf life of dehydrated product. Besides, the activities of enzymes and vitamins in foods are also governed by water activity which influences the colour, taste, and aroma of food materials (Marty-Audouin *et al.,* 1992). Temperature and pH, along with several other factors, can influence the occurrence of organisms in a product and their growth rate. Moisture content also strongly influences the colour of the product by affecting non-enzymatic browning (NEB) of the product (Driscoll and Madamba, 1994). An exponential relationship between the browning rate and moisture content is reported, and it is specified that the water activity of 0.6-0.7 is the most vulnerable range to promote browning in the case of dehydrated onion (Rapusas and Driscoll, 1995). Onions were dried from initial moisture content of more 82 per cent to 8 per cent or less sufficient for storage and processing (Sagar, 2001). Pre treating the vegetables can decrease the browning during processing and storage, and lower the losses of flavour and of vitamins. Most commonly used pre treating methods adopted for vegetables are sulphiting and dipping into salt (NaCl) solutions. Sulphur is used as a reducing agent that reacts with and traps electrophiles and other intermediates in the Millard reaction, NaCl retards oxidative and enzymatic browning, penetrates fast into the tissue, hinders shrinkage and prevents poly phenol oxidase activity (Karathanos *et al.,* 1995).

1.2. Statement of the Problem

During peak harvesting seasons, the loss is high and the products are sold at low price because of lack of means to preserve and store the products. Marketing of fresh onion during the season is a great problem because of its shorter postharvest shelf life. FAO (2011) report indicated that, there is a high postharvest loss of onion that is estimated to about 30-35% due to lack of proper postharvest handling. In addition, non-availability of onion during off-season creates major problem in the market and causes price fluctuations, which directly affects the consumer. Furthermore, fresh onion products also create problems during transportation and storage because of their bulk volume. Therefore, development of low cost preservation methods to produce shelf-stable and convenience products is the prime requirements of present competitive market. In this perspective, drying is the best technique because it reduces wastage, reduces volume, minimizes transportation and packaging cost and increase the availability of powdered onion throughout the year as an ingredient in food processing industries. The dried onion powder can also be used as substitute of raw onion to develop new food recipe (Jayathunge *et al*., 2012). Furthermore, farmer will be benefited to maximize their yield and production. Traditionally, our family dry onion by storing the product under direct sun light and this method of drying causes loss of quality because of contamination, damage by different insect pests, slow or intermittent drying and no protection from rain or dew that wets the product, encourages mould growth, low and variable quality of products due to over- or under-drying and direct exposure to sunlight reduces the quality (color and vitamin content) of the product. Other drying techniques that are used to dry onion with fewer losses of quality and the storage condition used to extend the shelf life of the dried onion by maintaining its quality for a long period should be applied. However, little research has been done in Ethiopia to appraise proper postharvest handling practices in onion storage. Therefore this study is aimed to reduce losses, promote value addition, and extend the shelf life of onion with desired degree of quality using proper drying technique.

1.3. Objectives of the study

1.3.1. General objective

To determine the optimum temperature level for convective oven drying of different onion varieties and assess the storage stability of dehydrated onion powder under ambient condition.

1.3.2. Specific objectives

I. To assess the physicochemical quality of three varieties of onions dried under different oven drying temperatures
II. To assess the shelf life stability of dried onions during storage under ambient condition
III. To study microbial quality of dehydrated onion during storage

2. LITERATURE REVIEW

2.1. Production of Onion

2.1.1. World Production

Alliums belong to the family Alliaceae and are thought to have originated in central Asia. The bulb onions (*Allium cepa* L.) are the second most important horticultural crop after tomatoes and are consumed worldwide for their unique flavor and health related properties (Grffiths *et al.*, 2002). According to FAO (2013), the world production of onion is 64.48 million tons from 3.45 million ha area. The production of this vegetable in 2007 was around 68 million tons. Onions are important crops in the tropics, which account for nearly 30% of total global production. Although some tropical countries are net importers, export potential of onions is developing in several tropical regions partly because if dried and packed properly, the bulbs can be transported for considerable distances without deteriorating (FAOSTAT, 2013).

Table 1. Top five onion producing countries

Country	Onion production in metric tones
China	20,567,295
India	12.156.200
United States of America	3,602,090
Turkey	1,859,442
Russian Federation	1,857,110

Sources: FAOSTAT (2014)

2.1.2. Onion Production in Ethiopia

In Ethiopia, onion is grown widely in rift valley and lake regions of the country (Lema and Shimeles, 2003. Farmers, private growers and some larger state enterprises in many parts of Ethiopia cultivate onions. Areas with good soil and weather conditions for the cultivation of onions are Awash valley, Lake region and areas close to the Sudan border (Desalenge and Aklilu, 2003).The production of onions in Ethiopia in 2011 was estimated to 236,922 tons (FAOSTAT, 2013). The two cities Meki and Zeway are located in the fertile Lake region; this area is known as the onion belt of Ethiopia. Of the 46,600 inhabitants in Meki, 11,320 are farmers working with onion cultivation in an area of 5,650 ha. Of the 56,100 inhabitants in Zeway, 7,700 are farmers in an onion cultivation area of 11,500 ha. The onion production is estimated to be 135,600 tons/year in Meki and 34,766 tons/year in Ziway (Meki and Zeway agricultural office, 2014). The onion crops have contributed to Ethiopian economy by exports of bulbs and cut flowers (Desalenge and Aklilu, 2003).

2.2. Uses of Onion

2.2.1. Medicinal benefit of onion

Onions have been used in many medicinal practices. Similar to garlic, they contain sulfur compounds such as allyl propyl disulphide that contribute to onions pungent odor. Onions have been shown to improve cardiovascular health. Studies in China which compared the health of two similar villages, one who grew onions and the other who did not, showed that the village who grew and consumed onions had a lower death rate due to cardiovascular disease in comparison to the village who did not consume onions. This is due to the sulfur compounds, chromium and vitamin B6, all of which are known to decrease the homo cysteine levels which is a known factor in heart attack, stroke and heart disease patients. Similarly atherosclerosis, cardiovascular disease, heart attack and stroke are all associated with platelet aggregation and the clogging of arteries and veins that these compounds can help mitigate. Due to the presence of these compounds, onions have been shown to control hyperglycemia and hyperlipemia as well (Block, 1978).

2.2.2. Nutritional benefit of onion

It has moderate amounts of protein, fat, fiber and good amounts of calcium, phosphorous and potassium, vitamin C and B6. It has both glucose (reducing sugar) and sucrose (non-reducing sugar). The pungent taste of onion is due to volatile oil Allyl-propyl-disulphide present in it. Onions contain significant amount of a flavonoid called quercetin. Although quercetin is available in tea and apples, earlier research proved that absorption of quercetin from onions is twice that from tea and more than three times that from apples (Singh, 2005).

2.3. Post harvest handling of onion

2.3.1. Harvesting of onion

Harvest of onions is at optimum maturity. Maturity is best determined by pinching the neck of the growing onion. Necks of immature onions are stiff, whereas necks of mature onions are soft and limber. Carefully examine onions for softness in the neck and large bulb size to indicate time to harvest. Late varieties are highly susceptible to warm weather bacterial diseases and may require harvest before optimum maturity to prevent widespread infection with bacterial diseases. Manual harvesting is the most common practice in most developing countries. This is normally carried out by levering the bulbs with a fork to loosen them and pulling the tops by hand. In developed countries, especially in large scale farms, mechanical harvesting is commonly used. The harvesting techniques adopted are influenced by weather condition at harvest time. In areas where warm, dry weather occurs reliably, the curing and bagging of the crop can be done in the field. In wetter, temperate regions, mechanical harvesting and artificial heating and ventilation for drying are essential for reliable production of high quality bulbs on a large scale (KTBL, 1993).

2.3.2. Curing of Onion

Onions are cured to remove excess moisture from the outer layers of the bulb prior to storage in order to extend their shelf life. The dried skin provides a surface barrier to water loss and microbial infection, thereby preserving the main edible tissue in a fresh state. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the crop to ripen before fresh consumption or long-term storage. Drying reduces bulb weight and since they are sold mostly on a weight basis, achieving the desired level of dehydration is critical. Weight losses of 3-5% are normal under ambient drying conditions and up to 10 % with artificial drying (Opara and Geyer, 1999).

In traditional small-scale operations, onion drying is carried out in the field in a process commonly called ‘windrowing’. It involves harvesting the mature bulbs and laying them on their sides (in windrows) on the surface of the soil to dry for 1 or 2 weeks. In hot tropical climates, the bulbs should be windrowed in such a way to reduce the exposed surface to minimize damage due to direct exposure to the sun. In wet weather, the bulbs can take longer time to dry and may develop higher levels of rots during storage. The side of the bulb in contact with wet soil or moisture may also develop brown strains or pixels, which reduce the appearance quality and value. Obviously, successful windrowing is weather dependent and therefore cannot be relied upon for large scale commercial onion production business. Bulbs harvested for storage require in total 14-20 days of ripening or drying before being stored. Harvested onions may also be placed in trays, which are then stacked at the side of the field to dry. In some tropical regions, the bulbs are tied together in groups by plaiting the tops, which are then hung over poles in sheds to dry naturally. Harvested bulbs can also be taken straight from the field and dried artificially either in a store, shed, barns, or in a purpose-built drier. This method is commonly used when crops are stored in bulk but it can also be applied to bags, boxed or bins. Under this method, bulbs are laid on racks and heated air is rapidly passed across the surface of the bulbs night and day (Brice *et al.,* 1997).

2.3.3. Storage of Onion

High quality onions should have mature bulbs with good firmness and compactness of fleshy scales. Bulbs should have well shaped thin necks and no soft or moldy spots. Bulbs should be free of mechanical or insect damage, decay, sunscald injury, greening of fleshy scales, sprouting, bruising, doubles and abnormally large necks. For long term storage, onions should be harvested when 50 to 80% of the tops have fallen over and the bulbs are mature with a thin neck. Bulbs harvested when the neck is completely dry have a shorter storage life. Onions intended for storage must be dried well and cured in the field, in sheds, or in storage, to promote drying of the neck and outer bulb scales. Field-cured onions must be protected from the sun to prevent sunscald injury. Bulbs can be covered with cloth bags or arranged in the field with tops of one row of bulbs cover the next row of bulbs (Cantwell, 2004).

The optimum storage temperature for onions is 32°F at 65 to 75% RH. Humidity below 65% cause shriveling and loss of moisture, and consequently quality is reduced. Humidity has little effect on sprouting so if storage at a higher humidity is required in order to store the onions with other crops this should not have a detrimental effect on sprouting. But high humidity can promote root growth (Brice *et al*., 1997) causing some loss in quality and weight. There is also the problem that onions can taint other crops if stored alongside them. High temperatures induce sprouting, high RH induce root growth, while high temperatures and RH increases decay and loss of quality. Mild or sweet onions have a shorter storage period than pungent types and can be kept in refrigerated rooms or common storage. Onions are often stored in common storage, using cool ambient air to maintain low temperatures and RH. Storage periods are shorter in common storage than refrigerated storage, however, because of losses due to sprouting and decay. Onions in cold storage should be kept in crates and containers with good ventilation. Storage in sacks is limited because of insufficient air movement (Frazier *et al.*, 2004).

It is important that onions dried with warm air should be cooled to ambient temperatures (around 15°C) before going into store to avoid condensation, especially where cool storage is to be used. The produce should be inspected before entering the store or clamp. Any damaged or diseased bulbs should be removed. It is also preferable to top onions at this stage, this may be practical by hand with a small amount of onions or mechanical toppers are available for larger quantities. They may also be graded. Smaller onions tend to store better than large ones (Tolhurst, 1997).

2.4. Preservation of onion

2.4.1. Pickled Onion

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

2.4.2. Dehydrated Onion

Cured or dried onion has 4 to 5% moisture to allow good storage and acceptable quality. The product is processed to make powder, granules, flakes or slices, then used for the formulation of sausages, meat products, many kinds of soups and sauces as well as dressings (ADOGA ,2005).
Dehydrated onion, recently, has become standard ingredient in a vast range of processed foodstuff. They are being increasingly used as they retain their culinary quality and palatability, and economically feasible in storage space and transport cost. Besides, there is optimum utilization of the product during the glut season, and saving of packaging material and tinplate. Dehydrated onion is used extensively in overseas countries, unlike Ethiopia, as a condiment. Dried onions are used in all sorts of industrial food products, especially in instant foods which

have a very short preparation time (between 5 and 15 minutes). Production of dried onion via osmotic dehydration/drying is relatively small scale, as other horticultural crops, but this produce has become a standard ingredient in processed foods in which raw onion can be used. It is used as seasoning in production of catsup, many sauces, meat casseroles, as well as cold cuts, sausages, potato chips, crackers and other snack items. Restaurants, canteens and cafeteria use dehydrated onion because of its convenience in storage, preparation and use (Kaymak *et al*, 2005).

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

Processed and value added products are gaining importance in the worldwide markets. According to Singh *et al.* (2006) onion has 6% share in the overall production of vegetables in India and about 93% of the total export of fresh vegetables from India. Onion is mainly exported in the form of dehydrated onion, canned onion and onion pickle. Free water is removed from the vegetables during the drying process so that microorganisms do not survive and reproduce. Simultaneously, the solids such as sugar and organic acids are concentrated there by exerting osmotic pressure to further inhibit the microorganisms. Drying process involves the application of heat to vaporize water and removal of moist air from the dryer Onions are generally dried from an initial moisture content of about 86% to 8% or less for efficient storage and processing. Dehydrated onions in the form of flakes or powder are in extensive demand in several parts of the world, for example UK, Japan, Russia, Germany, Netherlands and Spain (Sarsavadia *et al.*, 1999).

Drying of onion is aimed at producing a concentrated product, which when adequately packaged has a long shelf life, after which the onion can be simply reconstituted without substantial loss of flavor, taste, color, aroma and pungency. Several types of dryers and drying methods, each better suited for a particular situation are commercially used to remove moisture from a wide variety of food products including fruits and vegetables. Factors, on which the selection of a particular dryer or drying method depends, include the form of raw material and its properties, desired physical form and characteristics of the product, necessary operating conditions and operating costs. The most commonly adopted drying practices for onion are sun drying, solar drying, oven drying, green house drying and infrared drying (Kaymak-Ertekin and Gedik, 2005).

2.4.2.1. Fundamentals and purpose of drying

Drying is one of the oldest known food preservation techniques. The primary objective of drying is to extend the shelf-life of foods by reducing their water content. This prevents food from microbiological spoilage as well as from the occurrence of chemical reactions such as enzymatic and non-enzymatic browning. In addition to preservation, drying is also used to reduce the cost or difficulty of packaging, handling, storage and transportation, by converting the raw food into a dry product (Karel and Lund, 2003).

The terms “drying” and “dehydration” both refer to the simultaneous application of heat and removal of water by evaporation from a wet material (Brennan *et al.,* 2006). Therefore, they are used interchangeably in the literature: However, Barbosa-Canavos and Vegamercado point out the difference between drying and dehydration. According to them, dehydrated food products are those with no more than 2.5% water (dry basis) while dried food products have more than 2.5% water. The major dried food products include fruits and vegetables, herbs, pasta, dairy products (milk, whey), meat, soluble coffee and tea, breakfast cereals and grains such as rice and wheat (Heldman and Hartel, 1997).

2.4.2.2. Drying process

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 the food’s surroundings to its surface by way of radiation, convection or conduction. In the common case of air drying convection is the predominant mechanism (Brennan *et al.*, 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 (Karel and Lund, 2003). 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 the existing concentration and/or water vapor pressure, and temperature gradients, respectively (Al-Duri and Mcintyre, 1992).

Transport phenomena thus involve both external and internal resistance to heat and/or mass transfer. The factors that slow the rate of these processes determine the drying rate (Ramaswamy and Marcotte, 2006). In other words, the resistance mechanisms 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. 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. The reason for this is that within the food, heat is usually transported more easily than moisture and thus the temperature gradients inside the food can be assumed to be flat (no resistance to internal heat transfer), especially when compared to the steep moisture content gradient (Karel and Lund, 2003). In addition, it is known that heat transfer within the food may be limited by the thermal conductivity of the product as its water evaporates (Geankoplis, 2003).

In conjunction 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. Brennan attributes 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 and velocity, and exposed surface area all influence the resistance to external heat and mass transfer whereas the internal mass transfer is 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 enough 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 insufficient water at the surface, resistance to internal mass transfer governs the process. Most foods therefore switch from an external drying process during the initial stages to an internal drying process as the product dries out (Karel and Lund, 2003). In addition, the drying rate in the food sample, which decreases from the very beginning of the process (at a constant temperature), may also indicate that the internal resistance to mass transfer controls the drying (Márquez, 2006).

2.4.2.3. Factors affect drying process

a) **Drying temperature**

One of the key factors affecting the rate of moisture removal is the drying temperature. The greater the temperature difference between the drying air and the food, the greater will be the heat transfer into the food. This results in a higher driving force (water vapour pressure gradient and/or water concentration gradient between the food surface and the drying air) for moisture removal, which shortens the overall drying time. Increased air temperature improves drying by affecting both external (constant rate period) and internal processes (falling rate periods). However, extremely high temperatures may cause quality loss, especially regarding colour. A practical limit must therefore be found for each food product to maintain maximum product quality (Vega *et al.,* 2007).

b) **Relative Humidity**

The amount of moisture in the air, as measured by the vapour pressure or relative humidity, influences the rate of moisture removal from the sample through its effect on external mass transfer. This suggests that relative humidity exerts more influence on drying in the constant-rate period than in the falling-rate period, where internal mass transfer is the controlling mechanism. The effect of relative humidity on external mass transfer is as follows: an increase in the relative humidity of the air decreases the water vapour pressure or water concentration gradient between the food surface and its surrounding air and thus reduces the rate of external mass transfer. Conversely, adecrease in the relative humidity of the drying air increases this gradient between the food surface and its surrounding air and hence enhances the rate of external mass transfer (Heldman and Hartel, 1997).

c) Air Velocity

The velocity at which the drying air blows across the food surface affects the rate of moisture removal through its impact on external mass transfer. Increasing the air velocity will take more moisture away from the drying surface of the food, preventing the moisture from creating saturated conditions there. This also shortens the duration of the constant rate period although it does not have a significant effect on the falling rate period. Several researchers have studied the effects of air velocity on the drying rate of different food samples (Márquez, 2006). In these studies, it is revealed that the air velocity, like air humidity, does not influence the drying rate as much as the drying temperature. Furthermore, in some other studies a critical air velocity value above which the drying rate dependence on air velocity becomes negligible has been defined (Kaymak, 2002).

d) Thickness and surface area of the food

The distance that water molecules have to migrate within a food before evaporating from its surface determines how fast that food can dry. In the constant-rate period, smaller pieces have a larger surface area available for evaporation relative to their volume, whereas in the falling-rate period, smaller thickness means a shorter distance for moisture migration to the surface. Thus slicing or dicing into smaller pieces with high surface area will generally facilitate drying (Fellows, 2000).

e) Composition and structure of the food

The rate of moisture removal from food depends on the composition and structural properties of the particular food material. For example, high concentrations of solutes such as sugars, salts, gums, starches, etc. interact with water molecules in the food and inhibit their mobility. As a result, viscosity in the food increases, water activity decreases and drying slows down. Moisture migration within a food product may also occur in different directions depending on the orientation of the food microstructure such as fibers and protein strands. Fibers in celery and protein strands in meat, for example, allow more rapid drying along the length than across the cell structure. Similarly, moisture is removed more easily from intercellular spaces than from within the cells since there is an additional resistance to water migration across the cell boundary. Blanching and/or reduction in sample size can increase the rate of moisture removal by weakening this resistance. However, such pre-treatments may also result in severe cell rupture and this kind of damage to the cell may adversely affect the texture of the rehydrated product. In addition, the loss of cellular structure, pore formation and shrinkage of the product, which are micro structural changes that occur during the drying of food materials, strongly affect the rate of drying (Tang *et al.*, 2000).

2.4.2.4. Changes occurring during drying

The quality of dried onion is influenced by the particular variety of the raw material as well as its properties, methods of drying and storage conditions. Several physical, chemical, biochemical and/or microbiological changes may occur in onion during drying and storage, resulting in significant quality losses. Such changes that reduce the quality of the final dried onion as listed in Table 2 are functions of temperature, moisture content and time. 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 onion to the drying conditions by measuring and comparing the effects of different temperatures and moisture content on the quality degradation reactions (Ramaswamy and Marcotte, 2006).

a) Shrinkage Ratio

Loss of water during a drying process originates a reduction in the size of the cellular tissue, which is usually referred as shrinkage phenomenon. The shrinkage could be very intensive, depending on the drying method applied (Lozano *et al.*, 2004) and on drying conditions. Shrinkage ratio affects mass and heat transfer parameters and it is a relevant factor to be accounted for establishing drying models. Madamba *et al.* (2004) reported pioneer studies of shrinkage at microscopic level, related to dehydration processes of onion, carrots, potatoes and several fruits. Shrinkage is expressed on the basis of the ratio between the bulk volume of the product and the initial bulk volume (Hernandez *et al.,* 2005).

b) Bulk density

Bulk density is defined as the particle mass divided by the particle volume, including the volume of all pores. During drying and as food loses water, the bulk density increases. This tendency was observed by several authors (Lozano *et al.*,2000; Madamba *et al.*, 2004; Krokida and Maroulis, 1997) dealing with drying of carrot, sweet potato and garlic.

c) Vitamin C

Vitamin C (ascorbic acid) is an important nutrient, and it is often taken as an index of the nutrient quality of processes. Ascorbic acid of onion can be oxidized to dehydro ascorbic acid under aerobic conditions, followed by hydrolysis and further oxidation. This degradation is influenced by water activity and temperature. In general, vitamin C retention after drying is relatively low, due to the evaporation of water and the concentration effect (Santos and Silva, 2008).

d) Pyruvic acid of onion

Drying is affect pyruvic acid content of onion. The pyruvic acid contents of the onion powder decreased with increases in drying temperature. Compared to fresh onion slices, the pyruvic acid content in the dried onion slices decreased by 22–25%, resulting in what may be considered an acceptable concentration, considering even greater losses during hot-air drying. Drying 2-mm-thick onion slices at temperatures of 80^{o}C resulted in 65% loss in the pungent pyruvic acid component (Adam *et al.*, 2000). The loss of pyruvic acid may be attributed to the damage to the cell structure of the onion slices and to subsequent losses of allinase at elevated temperatures. Similar observations were reported by Adam *et al.* (2000) and Sharma and Prasad (2001).

Table 2. Effect of drying on the quality of food products

Physical	Chemical	Biochemical Nutritional
Shrinkage	Non-enzymatic browning reactions	Vitamin loss
Migration of solids/case Hardening	Enzymatic browning reactions	Protein loss
Loss in colour	Decrease and loss in flavour and aroma	
	Formation of new flavour and aroma	
	Oxidation reactions (vitamins, lipids)	
	Denaturation of proteins	

Source: Ramaswamy and Marcotte (2006)

If dried food is safe in terms of microbial count, which is achieved by lowering the moisture content of the sample to fewer than 15% (wb), then the quality depends mostly on appetizing appearance factors such as colour, flavour and aroma, texture or rehydration ability and nutritional value. However, among these sensorial characteristics of food, colour is probably the most important criterion for consumer purchasing decisions since it is the first and most direct visual sign of product quality at the point of sale (Krokida and Maroulis, 2000). Rehydration ability is also important, especially if the product is first going to be consumed upon rehydration (Karel and Lund, 2003). In general, from the consumer's point of view, severe browning and poor rehydration ability indicate reduced quality. One of the key aims of drying technology is to minimize these product changes, while optimizing the process and taking into account the cost (Heldman and Hartel, 1997). In the following subsection, the major product quality changes and their effects on the degradation of food are hence reviewed in more detail.

e) Browning Reactions

Browning reactions decrease nutritional value and solubility, create off-flavors, and induce textural alterations in the food. Such reactions are classified into enzymatic and non-enzymatic reactions (Krokida and Maroulis, 2000). Enzymatic browning occurs in fruits and vegetables such as bananas, pears, mushrooms and potatoes, often upon bruising during handling or when sliced under the presence of air, as well as during the drying process. Protective measures against discoloration by enzymatic browning reactions include the inactivation of enzymes by blanching or heat treatments at temperatures of around 70 to 75°C, the use of reductive agents such as sulphur dioxide or ascorbic acid, and the removal of available oxygen (Hutchings, 1999).

In the case of a thermally stabilized product, in which enzymatic activity has been almost completely destroyed by heat, particular attention should be paid to non-enzymatic browning reactions. The most common types of non-enzymatic browning during drying are Millard reactions in which carbonyl groups of reducing sugars, aldehydes and ketones interact with amino compounds such as amino acids, peptides and proteins. These reactions result in brown pigments, known as melanoidins, causing the main discoloration problem in dried products such as white dried soups, tomato soup and other dried fruit and vegetables (Kaymak-Ertekin and Gedik, 2005).

The Millard reaction rate depends on several factors including temperature, the types of the reactant sugars and amines, moisture content and pH. It has been reported in the literature that when a certain intermediate moisture range is reached in the course of the drying process, the Millard reaction rate starts to increase, and later, at low-moisture ranges, it peaks at a maximum value. That is, the last drying period is associated with high browning. This may be explained by the fact that at this stage, less evaporative cooling takes place, which leads to an increase in sample temperature. Reducing the air temperature during the last drying period is therefore advisable. In this way, the product will not experience unnecessary heat when it is within its critical moisture content range (Ramaswamy and Marcotte, 2006).

2.5. Shelf Life of Dried Onion

The color and flavor of dried onion are the most important quality attributes. The browning reaction and pyruvate loss are generally considered as dominant factors in quality deterioration during drying and storage of dried onion. Many standards state that the dehydrated onion shall have the characteristic color and marked pungent flavor of the variety used, and it shall be free from discoloration. Not much research has been done on changes of color of onion during dehydration and storage. Shannon *et al.* (1967) have shown that pink to red water-soluble pigments can be formed during processing of onion. An enzyme reaction was the essential step in the formation of these pigments. Enzymatic activity of the tissue during drying is great importance since onion is not blanched before dehydration and the fresh cut tissue is exposed to moderately hot air for a relatively long time. The strong effect of storage temperature on browning of dried onion was also shown by Peleg *et al.* (1970). Little browning occurred at15^{o}C but higher storage temperatures markedly increased browning. The type of flexible package did not affect browning as measured by the absorbance of extracts. A Hunterlab Tristimulus colorimeter revealed a decrease in lightness, increase in red, and a most pronounced increase in yellowness of dried onion during storage. Discoloration was the main sign of deterioration of dried onion during 3months of storage at room temperature (Singh and Kumar, 1984). Changes of color were dependent on the variety processed, and in some cases the reflectance dropped by as much as 50% during storage. The influence of onion variety on color stability of dried product was reported by Kalra *et al*. (1986). During 6 months of storage at room temperature, color scores evaluated by a panel dropped 12 to 45%depending on the variety. Sharma and Nath (1991) measured onion color by optical density of a methanolic extract. The onions became darker upon drying, and the increase in optical density was as high as 2 fold. Studies conducted by Raina *et al.* (1988) have shown that most of the varieties studied turned brown during 6months' storage of dehydrated samples. The degree of browning depends on the temperature of the air and pre-treatment applied before dehydration. Garlic slices showed the least degree of browning at 55^{o}C, whereas drying at 85^{o}C showed the highest browning reaction (Kim *et al.*, 1992).

3. MATERIALS AND METHODS

3.1. Description of the Experimental Site

The experiment was conducted in different laboratories of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in 2015. JUCAVM is geographically located at an altitude of 1710m.a.s.l. Ambient temperature and relative humidity at JUCAVM was 23^{o}C±2 and 22^{o}C±2.

3.2. Raw Materials

Fresh onion varieties were widely grown in Zeway. In this study, Sweet Carolin, Bombay Red and Qellafo onion varieties were procured from local farmer in a town of Zeway. The variety of onion was selected based on the availability of the products and highly production and the same ecological area. Also they are matured and harvested within three months. Demand of those onion varieties were higher compare to the other. During transportation the fresh onion varieties were packed by three different woody boxes for three different onion varieties then transported from zeway to Addis Ababa and Addis Ababa to Jimma by Vehicle. Then the fresh onion was directly stored in post harvest laboratory at normal temperature until drying was finished.

3.3. Sample Preparation and Osmotic pretreatment

Before drying, onion was peeled and the root was cut with a sharp stainless steel knife. Onions were cut into slices of 5 mm thickness (Mitra *et al*., 2011). Onion slices were osmotically treated by immersing in aqueous solution of 5% w/v of sodium chloride for 30 minute at room temperature (Jayeeta *et al.,* 2015). Fifty kilograms of onions from each variety and a total of 150 kilograms of onion were used and the experiment was carried out in three replicates.

3.4. Drying Process

Osmotically treated onion slices were placed inside in hot air oven (Model: Leicester, LE67 5FT, England) at a specific temperatures of 50, 60, 70, 80 and 90^{0}C until a constant mass was achieved. The dried onion was cooled after drying in desiccators to prevent formation of condensation moisture in a sample. The dried onion slices were ground in to powder. Then the onion powder was packaged in high density polyethylene bags for phase one experiment (drying study). After phase one experiment, plastic bottle was used for phase two experiment (storage study).

3.5. Storage Study

The storage study was done after analysis of phase one experiment (drying study) based on analyzed physicochemical and sensory quality; three temperatures (50, 60 and 70^{o}C) were selected. Based on shelf life determination parameter, seven parameters (water activity, moisture content, titratable acidity, pH, vitamin C, pyruvic acid and color) were selected out of the total parameters studied during drying study. Then samples of approximately 50g of onion powder were packed in plastic bottle and stored for further analysis. Finally, packaged samples were stored at room temperature 26±3°C (42±5% RH) for three months. Analyses were done on day one and 30, 60 and 90 days of storage period. Samples were withdrawn at every 30 days interval for the analysis of selected parameters and microbial analysis.

3.6. Experimental Design

The experiment was carried out in the two phases. Phase one experiment was carried out in two factors factorial experiment (3x5) using CRD arrangement, with three replications. Temperature was first factor at five levels (50, 60, 70, 80 and 90^{0}C). Variety as second factor had three levels (Sweet Carolin, Bombay Red and Qellafo). There were 15 treatments combinations and 45 experimental units (Table 3). Phase two experiment was carried out to investigate the impact of storage time on quality of dehydrated onion varieties for storage period of one to three months (Table 4).

Table 3. Treatment combinations of phase I experiment (drying study)

Variety	Temperature	Treatment Combination
V1	T1	V1T1
	T2	V1T2
	T3	V1T3
	T4	V1T4
	T5	V1T5
V2	T1	V2T1
	T2	V2T2
	T3	V2T3
	T4	V2T4
	T5	V2T5
V3	T1	V3T1
	T2	V3T2
	T3	V3T3
	T4	V3T4
	T5	V3T5

Where V1=Sweet Carolin, V2=Bombay Red, V3=Qellafo onion varieties, T1=50^{0}C, T2=60^{0}C, T3=70^{0}C, T4=80^{0}C, T5=90^{0}C

Table 4.Treatment combinations of phase II experiment (storage study)

Variety	Temperature	Duration	Treatment Combination
V1	T1	D1	V1T1D1
		D30	V1T1D30
		D60	V1T1D60
		D90	V1T1D90
	T2	D1	V1T2D1
		D30	V1T2D30
		D60	V1T2D60
		D90	V1T2D90
	T3	D1	V1T3D1
		D30	V1T3D30
		D60	V1T3D60
		D90	V1T3D90
V2	T1	D1	V2T1D1
		D30	V2T1D30
		D60	V2T1D60
		D90	V2T1D90
	T2	D1	V2T2D1
		D30	V2T2D30
		D60	V2T2D60
		D90	V2T2D90
	T3	D1	V2T3D1
		D30	V2T330
		D60	V2T3D60
		D90	V2T3D90
V3	T1	D1	V3T1D1
		D30	V3T1D30
		D60	V3T1D60
		D90	V3T1D90
	T2	D1	V3T2D1
		D30	V3T2D30
		D60	V3T2D60
		D90	V3T2D90
	T3	D1	V3T3D1
		D30	V3T3D30
		D60	V3T3D60
		D90	V3T3D90

Where V1=Sweet Carolin, V2=Bombay Red, V3=Qellafo onion varieties, T1=50^{0}C, T2=60^{0}C, T3=70^{0}C, T4=80^{0}C, T5=90^{0}C; D=day

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

Models:

$Y_{ijk} = \mu + T_i + V_j + Ck + (TV)_{ij} + \varepsilon_{ijk}$....For Phase I experiment (quality analysis)

$Y_{ijk} = \mu + T_i + V_j + Sk + (TV)_{ij} + (TS)_{ik} + (VS)_{jk} + (TVS)_{ijk} + \varepsilon_{ijk}$..... For Phase II (shelf life study)

y_{ijk} = the response
μ = overall mean effect.
T_i =effect of i^{th} level of drying temperature.
V_j =effect of j^{th} level of onion varieties.
Ck =k^{th} level of control.
$(TV)_{ij}$=interaction between i^{th} level of drying temperature, j^{th} level of onion varieties
S_k=effect of k^{th} level of onion powder storage.
$(TS)_{ik}$ =interaction between i^{th} level of drying temperature, k^{th} level of storage duration.
$(VS)_{jk}$ =interaction between j^{th} level of onion variety, k^{th} level of storage duration
$(TVS)_{ijk}$=interaction between i^{th} level of drying temperature, j^{th} level of onion Varieties and k^{th} level of onion powder storage period.
ε_{ijk}= error effect

3.7. Experimental Procedure

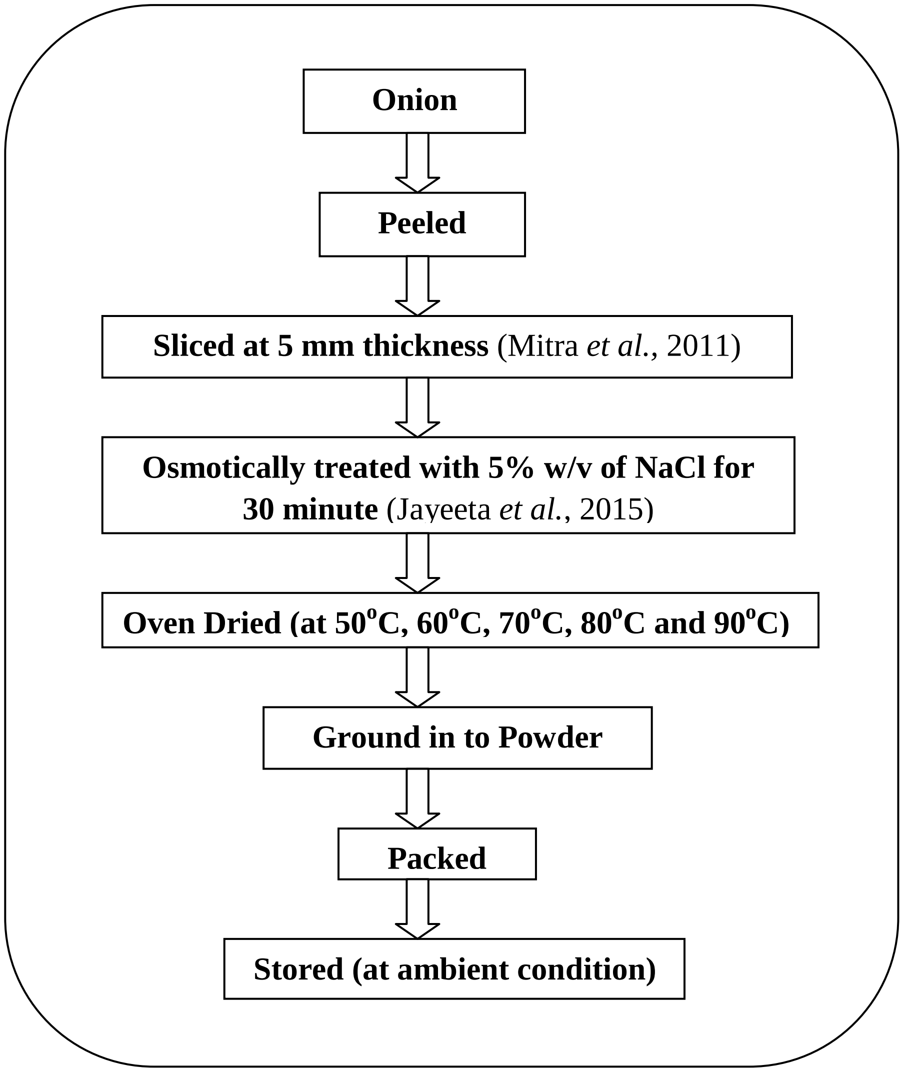

Figure 1. Flow sheet showing drying procedure of onion

3.8. Data Collected for Quality Assessment

Different response variables such as physical, functional, chemical and sensory quality evaluation of onion powder were collected. The separate analysis and determination procedures for every parameter are described below.

3.8.1. Determination of Physical and functional properties

3.8.1.1. Color

The total color change of each sample was measured using color chromameter (Model: Accu-probe HH06M, America). Color measurements recorded using Hunter L*, a* and b* scale (Hassani and Sharifi, 2012). The "L*" coordinate was a measure of lightness (white – black) and ranges from no reflection (L=0) to perfect diffused reflection (L=100), "a*" scale ranges from negative values for green to positive values for red and "b*" scale ranges from negative values for blue to positive values for yellow. Total color change (ΔE) was calculated in order to evaluate the change in color of dried onion samples using Eq.1.

$$\Delta E=((L_0-L^*)^2+(a_0-a^*)^2+(b_0-b^*)^2)^{1/2} \qquad \text{Eq.1}$$

Where, ΔE = total color change, L_0, a_0, b_0 are colour parameters of fresh onion varieties, L^*, a^*, b^* colour parameters of dried onion powder.

3.8.1.2. Water absorption capacity

Water absorption capacity was determined using the method of Sathe and Salunkhe (1981). About 10 mL of distilled water was added to 1.0 g of onion powder in a test tube. Then it was centrifuged at 4000 rpm for 30 min. Then removed and measured the supernatant. Then, the amount of water absorption capacity was calculated by the equation presented below:

$$\text{Water absorption capacity} = \text{initial volume of water} - \text{final volume of water} \qquad \text{Eq.2}$$

3.8.1.3. Bulk density

Bulk density was determined by the method of (Goula & Adamopoulos, 2005). About 50 gram onion powder was placed in to 100 ml measuring cylinder. The cylinder was tapped several times on laboratory bench to content volume. The volume of sample was recorded. The bulk density was calculated by;-

$$\text{Bulke density} = \frac{\text{weight of sample}}{\text{volume of sample after tapping}} \qquad \text{Eq.3}$$

3.8.1.4. Shrinkage ratio

Shrinkage is usually expressed by the volume ratio of onion slice before and after drying. Shrinkage ratio was calculated at each instant of the drying according to the following formula (Dissa *et al.*, 2010).

$$S = \frac{(Vi - Vf) * 100}{Vi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 4$$

Where, S (%) is shrinkage, Vf is the apparent volume of the sample after drying, cm^3 and Vi is the apparent volume of the raw sample, cm^3.

3.8.1.5. Water activity (a_w)

The water activity of the sample was determined by LabMaster-a_w instrument (Novasina AG, CH-8853 lachen, Switzerland). A homogenous powder sample was placed in a sample cup, completely covering the bottom of the cup. The sample of flour was half filled in the cup because of the overfilled cups might contaminate the sensors in the sensor chamber. The sample drawer knob turned to the OPEN/LOAD position and pull the drawer open. Then, prepared sample was placed in the drawer followed by carefully closing of slide the drawer. Prior to starting cycle reading, the sample drawer knob was turned to the READ position to seal the sample cup with the chamber. In about 8-10 minutes, the first water activity was measured (ADOGA, 2005).

3.8.2. Determination of Chemical analysis

3.8.2.1. pH

The pH value of each sample was determined using digital pH meter in AOAC (2011) official method 981.12. About 5 grams of samples was diluted with 50 ml of distilled water. The pH meter was then calibrated using pH 4 and 7 buffer solutions. The electrode of the pH meter was then washed with distilled water, blotted with tissue paper and dipped into each of beaker containing liquid samples to measure the pH value.

3.8.2.2. Titratable acidity

Titratable acidity was determined using conventional titration method. About 5 gram of the sample was weighed into a conical flask and 90ml of the distilled water were added and 10ml were taken from dissolved sample after the sample was filter and titrated with 0.1N NaOH in the presence of 3-4 drops phenolphthalein indicator (Akhtar *et al*., 2010). Titratable acidity results were expressed as percentage Glutamic acid, which is the main organic acid in onion bulb (Beatriz *et al.*, 2008). Finally, titratable acidity was calculates as:

$$\%\,Titratable\ Acidity\ = \frac{Titre\ \times MNaoH\ \times F \times 100}{0.1 \times Weight\ of\ sample} \qquad \text{Eq.5}$$

3.8.2.3. Total soluble solids (TSS)

The glass slide of the refractometer (Model DR201-95, Germany) was cleaned with water and wiped dry with a clean napkin. A smear of the sample was made on the slide of the refractometer and the lid replaced. The reading was taken at the graduated mark. This reading indicates the total soluble solids value of the sample and was recorded in degree brix (^{0}brix) (Owoso *et al.*, 2000).

3.8.2.4. Vitamin C

The determination of vitamin C was determined according to Sadasivam and Manickam (2005). 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 h, the orange-red osazone crystals formed were dissolved by the addition of 7 ml of 80% sulphuric acid and absorbance was read at 540 nm after 30 minutes UV-Vis spectrophotometer (T80,China) and the vitamin C content in the samples was calculated by using ascorbic acid standard curve(R^2 = 0.974) (Appendix: 12). Vitamin C concentration was expressed in terms of mg/100g tissue.

3.8.2.5. Pyruvic acid

Total pyruvate was measured according to Crowther *et al*. (2005). About 1 gram of onion powder was homogenized with 15 ml of phosphate buffer using homogenizer (PLTYRON® 2500E, Switzerland). Then centrifuged at 4000 rpm for 30 min. Taking 1 ml of the supernatant into test tube and the volume was made 2 ml with phosphate buffer. After addition of 0.5 ml of 2, 4 dinitrophenyl hydrazine (DNPH) solution, it was incubated at 37°C for 30 min. Then 5 ml of NaOH solution was added to the tube and incubated for additional 10 min at 25°C. Eventually the absorbance was recorded at 515 nm using spectrophotometer (T80, China). Pyruvate concentrations (µmol/g) in onion were determined from the standard curve (R^2 = 0.986) (Appendix: 13).

3.8.2.6. Ash content

The ash content of each sample was determined AOAC (2011), method 923.03. The empty clean porcelain crucible with its lid was placed in the muffle furnace (Model SX-5-12, China) for 30 min and then transferred into desiccators for cooling. The mass of dried porcelain dish was measured (*M1*) by analytical balance (Model:ABJ220-4M, WB1151070, Australia). About 2 gram of each powder sample was weighed (*M2*) into dried crucible and transferred the crucibles into a muffle furnace and set the temperature at 550°C for 8 hrs. The samples were removed from the furnace and placed in the desiccators followed by the mass determination (*M3*). Then ash content was calculated using equation Eq.4 below.

$$\text{Ash}(\%) = \frac{(M3 - M1)}{(\text{M2-M1})} * 100 \quad \text{……Eq.6}$$

Where:-
M1 =Mass of the crucible
M2 = Mass of onion powder sample and crucible, and
M3 = Mass of ash and crucible

3.8.2.7. Moisture content

The moisture contents of each sample was determined by hot air oven dry method according to AOAC (2011) 925.09. About 2 gram (*Mi*) of each sample was transferred to the petri-dish and then the petri-dish was placed in the oven at 105°C for 6 hours dried in the hot air oven (Model:

Leicester, LE67 5FT, England),cooled in desiccators and reweighed(*Md*) (Olusola and Sarah, 2014). Then moisture content was calculated as percent loss in weight using the equation Eq.7.

$$\text{Moisture (\%)} = \frac{Mi - Md}{\text{Mi}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{Eq.7}$$

Where:-M_i=intial mass and M_d= dried mass

3.8.2.8. Crude fiber

The crude fiber was determined by the non-enzymatic gravimetric (AOAC, 2011, method 920.168). Well defatted 2 g of onion powder sample were place into 600 ml beaker and 200 ml of 1.25% H_2SO_4 and 2 g pre weighed boiling chips was added. Then the beaker was place on digestion apparatus and was boil exactly for 30 min, while shaking at 5 min intervals. The solution was passed through screen sieve and the digested sample were decant. 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 digestion apparatus and boiled for 30 min, while shaking 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 hrs and cooled in desiccators and weighed (M_1). The dried residue was igniting for 2 hrs at 600±15^{o}C until ashing was complete and then cooled in desiccators and were reweighed (M_2).

$$\text{Crude fiber (\%)} = \frac{M1 - M2}{\text{weight of sample}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{Eq.8}$$

Where,
M_1 = mass of crucible and residue before ignition, M_2 = mass of crucible and residue after ignition

3.8.3. Sensory analysis

Onion powder has spice in nature. Spice is not recommended for direct consumption. Therefore sample was rehydrated with distilled water. Each rehydrated onion powder was coded with three digits and presented for consumer sensory evaluation. The 5-point hedonic scale having a scoring range described in Kolapo *et al.* (2008) where 5= Like extremely, 4=Like moderately, 3= neither like nor dislike, 2=Dislike moderately and 1=Dislike extremely were used to determine sensory properties of the sample. Sensory evaluation was carried out based on the sensory parameter of color, aroma, taste and overall acceptability. A total 50 consumer and panelists (Lawless and Heymann, 1998) were randomly selected from JUCAVM staff, students and other people and informed about the sensory parameters and test procedures before the test. Each sample was put at a reasonable distance between the judges to reduce halo effect. The rehydrated sample of each treatment was served in randomly coded white dish and arranged in randomly order. After tasting each coded sample instructed to panelists that they have to rinse their mouths before moving to the next sample. Then the scores of all judges for each sample were summed up and divided by the number of panelists to find the mean value.

3.8.4. Determination of microbial quality and shelf life of onion powder

Determination of microbial quality and shelf life studies were conducted for the selected best treatment combination from drying study. About 28 grams of Nutrient agar in deionized one litter water was prepared to determine bacteria and also about 39 g of Potato dextrose agar (PDA) powder in deionized one litter water was prepared to determine fungus according to manufacturer’s specification. About 1 gram of best treatment combination of onion powder was weighed aseptically into 10 ml of sterile distilled water in a test-tube. From this 1 milliliter was serially transferred into series of sterile test tubes containing 9 milliliters sterilized deionized water using a sterile pipette and shaken vigorously by using vortex mixer (Cyclone, England). Serial dilution was continued until 10^{-5}dilution (Bridson, 2006).From serial diluted samples of 0.1 milliliter were taken and inoculated on nutrient agar (NA)and Potato dextrose agar **(**PDA) media plate using spread plating technique and incubated(Heraeus,Germany) at 37°C for 24 hrs for bacteria and 25°C for 72 hrs for fungus (Akujobi and Njoku, 2010). After incubation, colonies on medium were counted using colony counter until no change in colony numbers were observed. The microbial quality obtained from colony forming units per milliliter (cfu/ml) in the original samples was converted to microbial load using Eq.9 (Fraizer and Westhoff, 2004).

$$ML = \left(\frac{N}{V} * R\right) \quad \text{Eq.9}$$

Where:-
ML = Microbial load, N = Number of colonies, V = Volume of dilution, R = Dilution factor

3.9. Statistical Analysis

The collected data were statistically analyzed and evaluated using analysis of variance (ANOVA) using SAS Version 9.2 Software (SAS Institute, 2008) after the required check for fulfillment of assumptions. Every significant treatment effect was compared using the least significant difference Test (LSD) at 5% probability level.

4. RESULTS AND DISCUSSIONS

4.1. Effect of Oven Drying Temperature and Variety on Onion Powder Quality

The drying process of onion was performed up to reaching the constant mass. The sample dried at 90˚C enjoyed the shortest drying time. It took 2 hours and 30 minutes. This is due to the fact that at higher drying air temperatures the water vapor pressure within the onion slices initiating easier moisture movement within the tissue and diffusion to the drying air. Drying at 50^{o}C temperature took longer time (7 hours and 30 minutes) and drying at 60^{o}C, 70^{o}C and 80^{o}C temperature required 6 hours, 5 hours and 4 hours for drying, respectively. Similar observations have been reported for drying of apple and onion slices (Goyal *et al.,* 2008; Sarsavadia *et al.*, 1999).

4.1.1. Effect of oven drying temperature and variety on physical and functional properties of onion powder

4.1.1.1. Color of onion powder

Color is among the most prominent quality features of dried vegetables, and alters during drying and long storage as a consequence of some chemical and biochemical reactions. The criterion for judgment about optimal conditions of drying onion was evaluation of lightness and darkness (L), redness and greenness (a), yellowness and blueness (b) values during this process. Mean color values of fresh and dried onion chromatic parameters are shown in Table 5. Comparing colorimetry results about parameters of L*, a*, and b* suggested that these indices reduce significantly with increase in drying temperature. Table 5 indicated reduction of average lightness changes (L*) during drying period of three onion varieties with the five temperatures. The L values of fresh onion varieties were 57.21, 61.27 and 78.64 for Bombay Red, Qellafo and Sweet Carolin onion variety respectively. L value of Qellafo and Bombay Red onion varieties were statistically ($P>0.05$) the same. Among dried treatment, the highest mean of L* value (50.68) was observed from Sweet Carolin onion variety dried at 50^{o}C. On the other hand, the lowest L* value (35.86) was recorded from Qellafo onion variety dried at 90^{o}C.

The mean of variation of a* parameter measured during drying of onion varieties showed that by increasing temperature, a* is reduced. The fresh onion variety had 12.37, 12.34 and 11.01 for Bombay Red, Qellafo and Sweet Carolin onion varieties respectively. After drying, the highest a* value (11.02) was observed from Sweet Carolin onion variety dried at 50^{o}C. It was statistically (P>0.05) the same with fresh onion varieties. On the other hand, the minimum average of a* value (2.30) was recorded from Qellafo onion variety dried at 90^{o}C, and also, decreased b* value with rising temperature. Those 56.16, 58.68 and 68.63 were b* value which were recorded for fresh onion varieties (Bombay Red, Sweet Carolin and Qellafo) respectively. From dried onion powder Bombay Red onion variety dried at 50^{o}C scored the highest b* value (48.49); however, the lowest (28.27) was registered from Sweet Carolin onion variety dried at 90^{o}C. Color changes at 90°C were higher for all onion varieties and more than that of other temperatures. Moreover, dehydrated onions become darker probably because of an extensive Millard reaction (Vega-Gálvez *et al.*, 2009). These chemical reactions are consequences of reducing sugars in the material being dehydrated (Perera, 2005). Some non-enzymatic causes of browning in foods include the Millard reaction, auto-oxidation reactions involving phenolic compounds, and the formation of iron-phenol complexes (López-Nicolás *et al.*, 2010).

This result is in line with Mehmet *et al*. (2001) who reported that the behavior of the *L** coordinate, which represents lightness, was 66.95 in the fresh leeks and 60.57 in the dried leeks. Also result was similar with the finding of Vega-Gálvez *et al.* (2009) who reported that at 90 ºC, parameters a* and b* showed a decrease to 43% in its value as compared with fresh samples; this generates brown products caused by non-enzymatic reactions in the case of using 90°C for drying onion, an effective control is required during process, in order to prevent browning and decline of marketability of dried onion. With respect to color maintenance, the temperature of 50°C is more preferable than others.

The ΔE color index is an important factor in the study of quality preservation while drying the product. This index determines that how much the color of product has been changed. Variance of analysis disclosed that temperature influence on the index of ΔE was significant and that increment in temperature caused the ΔE rise. The highest ΔE (51.58) was recorded from Sweet Carolin onion variety dried at 90^{o}C. But in fact it didn't exhibit any significant (P>0.05) difference with treatment of 80°C on the same onion variety (Table 5). On the other hand, the least changes in onion color (12.92) occurred from Bombay Red onion variety dried at 50°C but, at 60°C the slightest changes were observed, that was to say there was no significant ($P>0.05$) difference between them. This result supported by Mehmet *et al*. (2001) who reported that ΔE increased during drying mainly due to the effect of temperature on heat-sensitive compounds, such as carbohydrates, proteins, vitamins, which cause color degradation in fresh foods in addition to browning reactions and pigment destruction with drying processes.

Table 5. Interaction effect of oven drying temperature and onion varieties on color of onion powder

Factors		Color			
Variety	Temperature(°C)	L*	a*	b*	ΔE
Sweet Carolin	Fresh	78.64^{a}	11.01^{ab}	58.68^{b}	_
	50	50.68^{c}	11.02^{ab}	37.98^{ghi}	35.33^{de}
	60	48.41^{cde}	9.83^{bc}	33.87^{jkl}	39.54^{bcde}
	70	42.79^{efgh}	8.37^{cde}	31.98^{klm}	45.19^{ab}
	80	38.33^{hi}	8.30^{cde}	30.29^{lm}	49.92^{a}
	90	37.97^{hi}	6.35^{efg}	28.27^{m}	51.58^{a}
Bombay Red	Fresh	57.21^{b}	12.37^{a}	56.16^{b}	_
	50	49.56^{cd}	8.48^{cd}	48.49^{c}	12.92^{i}
	60	47.40^{cdef}	7.39^{def}	45.97^{cd}	16.27^{hi}
	70	44.33^{defg}	6.32^{efg}	43.66^{de}	19.51^{ghi}
	80	41.63^{fghi}	5.27^{fgh}	42.22^{ef}	22.78^{gh}
	90	39.08^{hig}	4.70^{ghi}	39.99^{efgh}	26.29^{fg}
Qellafo	Fresh	61.27^{b}	12.34^{a}	68.63^{a}	_
	50	44.38^{defg}	5.54^{fgh}	42.47^{def}	32.73^{ef}
	60	42.86^{efgh}	5.06^{gh}	41.17^{efg}	34.72^{de}
	70	40.91^{ghi}	3.83^{hij}	39.64^{fgh}	37.27^{cde}
	80	38.89^{ghi}	2.73^{ij}	36.55^{hij}	41.26^{bcd}
	90	35.86^{i}	2.30^{j}	34.90^{ijk}	44.43^{abc}
Cv (%)		7.71	17.56	5.31	13.43
LSD(0.05)		5.96	2.12	3.71	7.61

Values with in a column with different letter superscripts are significantly different at P<0.05.

4.1.1.2. Water absorption capacity of onion powder

The water absorption capacity was used as a quality characteristic of powdered product. It is a complicated process intended at the restoration of raw material properties. ANOVA result showed that a highly significant effect (P<0.05) of temperature and onion varieties on water absorption capacity of onion powders. But there was no interaction effect between oven temperature and onion cultivars. Table 6 showed that higher drying temperatures lead to products with higher Water absorption capacity. Maximum average water absorption capacity (2.15) was observed from sample dried at 90˚C as compared to those dried at lower temperatures but, there was no significant effect at 80˚C (2.02). Whereas, the minimum average water absorption capacity (1.47) was registered from sample dried at 50˚C but there was no significant effect at 60˚C (1.61). This reduction was because of the samples which were dried at lower temperatures needed more time to achieve their equilibrium moisture contents than those dried at higher temperatures. Thus the samples suffered more structural damage at higher temperatures. As a result, the reconstitution capability of the sample undergoing high temperature drying was higher than those went through low temperature drying (Krokida and Marinos, 2003). This result was in agreement with Abasi *et al*. (2009) who reported that rehydration ratio of onion slice which was dried at temperature from 60^oC to 90^oC was significantly increased with increment of drying temperature. Also the result was in line with the work of Mitra *et al.* (2011) who reported that the rehydration ratio can be maximized by drying at higher temperature. Also Table 6 shows that Onion varieties were highly significant ($P<0.01$) effect on water absorption capacity of onion powder. The highest water absorption capacity (2.26) was recorded from Qellafo onion variety whereas the lowest water absorption capacity (1.36) was observed from Sweet Carolin onion variety.

4.1.1.3. Shrinkage ratio of dried onion

Shrinkage ratio determined from dried onion slice. Significant changes in respect of shrinkage ratio during oven drying were obtained due to variation in the level of temperature among variety; however, there was no interaction effect between temperature and onion varieties. Results in Table 6 indicated that the shrinkage ratio was gradually increased with rising of temperature during drying period. The maximum average shrinkage ratio (53.5) was observed from the sample dried at 90^oC and the minimum average shrinkage ratio (33.72) was recorded from sample dried at 50^oC, at the same time as no significant ($P>0.05$) difference with 60^oC. The reason of this reduction was might be due to that samples dried at higher temperatures suffer more shrinkage than those undergoing drying at lower temperatures. Since, higher temperature could contribute to the increased heat transferred to the food material which results in decreasing moisture content of the sample. Therefore, contractile stresses occur in the cellular structure of the food material which intensifies shrinkage. This result was in support of Abasi *et al*. (2009) who reported that shrinkage ratio of onion slice dried at temperature of 60^{o}C to 90^{o}C was significantly increased with increment of drying temperature. Onion varieties were also affected the shrinkage ratio of onion powder. Among three onion varieties Sweet Carolin onion variety had the highest shrinkage ratio (44.18) but statistically no significant difference with Bombay Red. The lowest shrinkage ratio was registered from Qellafo (40.28).

4.1.1.4. Bulk density of onion powder

Bulk density is among the basic parameters measured in powdered product. This is one of particular importance in industry with regard to transport, storage and packaging, because increase in density results in reduction of product volume. The influence of temperature on bulk density was significant (Table 6), such that with an increase of temperature the bulk density increased. Moreover, this study showed that the minimum bulk density (0.75g/cm^3) was recorded from low temperature (50^{o}C); however, the maximum bulk density (0.88g/cm^3) was obtained from the sample dried at 90^{o}C. The result of the present study is in agreement with that of Sana *et al.* (2014) who reported that the influence of temperature on bulk density was significant on rhubarb samples. Also Athanasia *et al.* (2004) attained a parallel result for tomato powder. The onion varieties were also affecting the bulk density of onion powder. From this study (Table 6) Bombay Red variety (0.84) and Sweet Carolin onion variety (0.82) had highest bulk density though no significant difference was apparent between them. But Qellafo onion variety recorded the lowest bulk density compared to the other onion varieties

Table 6. Effect of temperature during oven drying and onion varieties on Rehydration ratio, Shrinkage ratio and Bulk density

Factor		Water absorption capacity (ml)	Shrinkage ratio	Bulk density(g/cm^3)
Temperature	50	1.47^c	33.72^d	0.75^e
	60	1.61^c	36.56^d	0.79^d
	70	1.79^b	40.76^c	0.82^c
	80	2.02^a	46.04^b	0.85^b
	90	2.15^a	53.5^a	0.88^a
LSD (0.05)		0.14	3.58	0.03
Variety	Sweet Carolin	1.36^c	44.16^a	0.82^a
	Bombay Red	1.81^b	41.9^{ab}	0.83^a
	Qellafo	2.26^a	40.28^b	0.78^b
LSD (0.05)		0.11	2.77	0.02
CV (%)		8.06	8.83	2.8

Values with in a column with different letter superscripts are significantly different at P<0.05

4.1.1.5. Water activity

Water activity (a_w) is an important index for dried powder because it can greatly affect the shelf life of the powder produced. It is defined as the ratio of vapour pressure of water in a food system to vapour pressure of pure water at the same temperature (Fennema, 1996).Water activity is different from moisture content as it measures the availability of free water in a food system that is responsible for any biochemical reactions, whereas the moisture content represents the water composition in a food system. High water activity indicates more free water available for biochemical reactions and hence, shorter shelf life. Generally, food with $a_w < 0.6$ is considered as microbiologically stable and if there is any spoilage occur, it is induced by chemical reactions rather than by micro-organism. From the results (Table 7), the water activities of the fresh onion varieties were 0.98, 0.96 and 0.96 for Sweet Carolin, Bombay Red and Qellafo onion variety respectively; whereas, of the onion powder was in the range of 0.22–0.32. This meant that the oven dried onion powders were relatively stable microbiologically. The lowest water activity (0.22) was recorded for Sweet Carolin onion variety dried at 90^{o}C and the highest (0.32) for Bombay Red variety dried at 50^{o}C. But Sweet Carolin and Bombay Red onion varieties dried at 50^{o}C were no significant (P>0.05) difference. Again Bombay Red and Qellafo onion varieties dried at 60^{o}C were statistically the same (P>0.05). This result showed that water activity was highly affected by different drying temperature. The temperature was increase water activity was significantly decreased. These results were consistent with other researchers (Goula and Adamopoulos, 2005).

Table 7. Interaction effect of temperature and onion varieties on water activity (aw) of oven dried onion powder

Varieties	Temperature (^oC)					
	Fresh	50	60	70	80	90
Sweet Carolin	0.98^{a}	0.32^{c}	0.26^{ghi}	0.25^{hi}	0.24^{j}	0.22^{k}
Bombay Red	0.96^{b}	0.32^{c}	0.28^{e}	0.26^{fgh}	0.25^{i}	0.23^{j}
Qellafo	0.96^{b}	0.29^{d}	0.28^{e}	0.27^{ef}	0.27^{fg}	0.25^{i}
LSD (5%)	0.01					
CV (%)	1.48					

Values with different letter superscripts are significantly different at P<0.05

4.1.2. Effect on chemical quality

4.1.2.1. Crude fiber content (%)

ANOVA showed that oven drying temperature and onion cultivar were significant (P<0.05) effect on onion powder. The crude fiber content of fresh onions were 14.06, 8.88 and 9.55 for Sweet Carolin, Bombay Red and Qellafo onion varieties, respectively (Table 8). The maximum average crude fiber content in onion powder (10.48) was found to be the Qellafo variety dried at 50°C, which was significantly higher than the samples dried at other temperatures. The minimum average crude fiber content of onion powder (3.00) was recorded from Bombay Red onion variety dried at 90^oC. Sweet Carolin onion variety dried at 90°C, Bombay Red onion variety dried at 80°C and Qellafo onion variety dried at 90°C were statistically the same (P>0.05). The crude fiber content of onion powder decreased with increment of drying temperature. The result of the present study is in agreement with finding of Masud and Nazrul (2014) who reported that the influence of temperature on fiber content was significant on dried onion samples. Also the result is in line with the work of Girma (2015) who reported that the fiber content of onion powder was decreased with increasing of fluidized bed dryer temperature form 50 to 70^{o}C.

4.1.2.2. Vitamin C content (mg/100g)

Vitamin C is considered as an indicator of food processing quality because of its low stability during thermal treatments (Podsedek, 2007). Vitamin C content of fresh and dehydrated onion variety for the five applied temperature was shown in Table 8. It can be observed that drying temperature greatly influenced this component as compared with the corresponding value of the fresh samples ($P < 0.05$). There was a clear correlation between temperature and vitamin C loss. The vitamin C content of fresh onion varieties were 5.03mg/100g, 4.46mg/100g and 4.19mg/100g for Qellafo, Bombay Red and Sweet Carolin onion varieties respectively. After drying process the maximum average of vitamin C (1.78mg/100g) was observed from Qellafo onion variety which was dried at low temperature (50^{o}C); however, Qellafo onion variety was dried at 50^{o}C and 60^{o}C and Sweet Carolin onion variety was dried at 50^{o}C had statistically the same result. Also Bombay Red onion variety was dried at 80^{o}C and 90^{o}C and Sweet Carolin onion variety was dried at 80^{o}C were no significant ($P>0.05$) difference between them. On the other hand Sweet Carolin onion variety dried at 90^{o}C recorded low vitamin C (0.68mg/100g) compared to the sample dried at low temperature. It was noticed as well, that as the drying temperature increases, vitamin C composition was decreased.

This result is in accordance with the report of Fasuyi (2005); higher vitamin C content in fresh onion is due to absence of heat treatment that does easily degrade this compound. This heat liability feature of ascorbic acid also agrees with the findings of Shittu and Ogunmoyela (1999), Solanke and Awonorin (2002) and Edeoga (2006). Also Idah *et al.* (2014) reported that temperature has negative effect on vitamin C content of onion powder during drying period at different level of temperature (50 to 70^{o}C) such that at 70^{o}C vitamin C was highly reduced. Isaac *et al.* (2011) observed that heating treatments significantly affected the samples and Sarsavadia (2007) also reported that a longer drying period had an adverse effect on some quality aspects like reduction in ascorbic acid of onion powder.

4.1.2.3. Pyruvic acid content (µmol/ml)

Analysis of variance showed significant effect ($P<0.05$) of temperature and onion varieties on pyruvic acid content of onion powder. The pyruvic acid contents decreased (Table 8) at higher drying temperature. The pyruvic acid contents of fresh onion were 12.16µmol/ml, 10.07µmol/ml and 9.17µmol/ml for Qellafo, Bombay Red and Sweet Carolin varieties respectively and there was significant ($P<0.05$) difference between fresh onion varieties. The maximum average of pyruvic acid (6.93µmol/ml) was registered from Qellafo onion variety dried at 50^{o}C. The minimum pyruvic acid (4.45µmol/ml) was recorded from Sweet Carolin onion variety dried at 90^{o}C but at this temperature there was no significant ($P<0.05$) difference between Sweet Carolin and Bombay Red (4.46µmol/ml) onion varieties. The loss of pyruvic acid may be attributed to the damage to the cell structure of the onion slices and to subsequent losses of allinase at elevated temperatures Sharma and Prasad (2001). This result was similar with the work of Praveen *et al.* (2005) who reported that effect of hot air temperature on pyruvic acid content of onion slice was highly significant. Pyruvic acid content decreased with increasing of temperature. Compared to fresh onion slices, the pyruvic acid content in the dried onion decreased by 22–25%, resulting in what may be considered an acceptable concentration, considering even greater losses during hot-air drying. Drying 2-mm-thick onion slices at temperatures of 80^{o}C resulted in 65% loss in the pungent pyruvic acid component as reported by Adam *et al.* (2000).

Table 8. Interaction effect of temperature and onion varieties on fiber, vitamin C and pungency content of oven dried onion powder

Variety	Temperature (°C)	Fiber (%)	Vitamin C (mg/100g)	Pyruvic acid(µmol/ml)
	Fresh	14.06^{a}	4.19^{c}	9.17^{c}
	50	9.03^{c}	1.75^{d}	5.88^{g}
	60	8.00^{d}	1.34^{fg}	5.23^{ij}
Sweet Carolin	70	6.71^{ef}	1.1^{h}	4.99^{ijk}
	80	6.02^{f}	1.02^{h}	4.82^{jkl}
	90	4.07^{gh}	0.68^{i}	4.45^{l}
	Fresh	8.88^{cd}	4.46^{b}	10.07^{b}
	50	7.25^{e}	1.51^{ef}	5.37^{hi}
	60	5.90^{f}	1.42^{f}	5.15^{ij}
Bombay Red	70	4.23^{g}	1.14^{gh}	4.90^{ijkl}
	80	3.52^{gh}	1.06^{h}	4.67^{kl}
	90	3.00^{h}	0.95^{h}	4.46^{l}
	Fresh	9.55^{bc}	5.03^{a}	12.16^{a}
	50	10.48^{b}	1.77^{d}	6.93^{d}
	60	9.19^{d}	1.78^{d}	6.73^{de}
Qellafo	70	7.93^{de}	1.68^{de}	6.40^{ef}
	80	7.03^{def}	1.52^{ef}	6.11^{fg}
	90	3.49^{gh}	1.46^{f}	5.80^{gh}
LSD (5%)		1.15	0.22	0.48
CV (%)		12.40	6.95	4.56

Values with in column with different letter superscripts are significantly different at P<0.05

4.1.2.4. Ash content (%)

Ash is inorganic residue remaining after the water and organic matter have been removed by heating in a food. It is a measure of the total amount of minerals present within a food, whereas the mineral content is a measure of the amount of specific inorganic components present within a food (Morris, 2004). Analysis of variance showed that onion varieties had significant (P<0.05) effect on ash content of onion powder; but, there was no significant (P>0.05) effect of temperature on ash content of onion powder. Figure 2 indicated that the ash contents of onion powder were 2.2, 2.15, 2.1, 1.93 and 1.9 for 50, 60, 70, 80 and 90°C respectively. Even though the results are numerically different; they were statistically the same. This indicates that temperature did not affect the ash content of onion powder. This result is in agree with the work of Gopalan *et al.* (2004) who observed almost similar ash contents in solar and oven dried ginger powder. The ash content of onion powder was affected by onion cultivar (P<0.05). Among the onion cultivar (figure 3) Qellafo onion variety had high ash content (2.18). The minimum average ash content was observed from Bombay Red onion variety (1.57) and Sweet Carolin onion variety (1.61) those were statically the same.

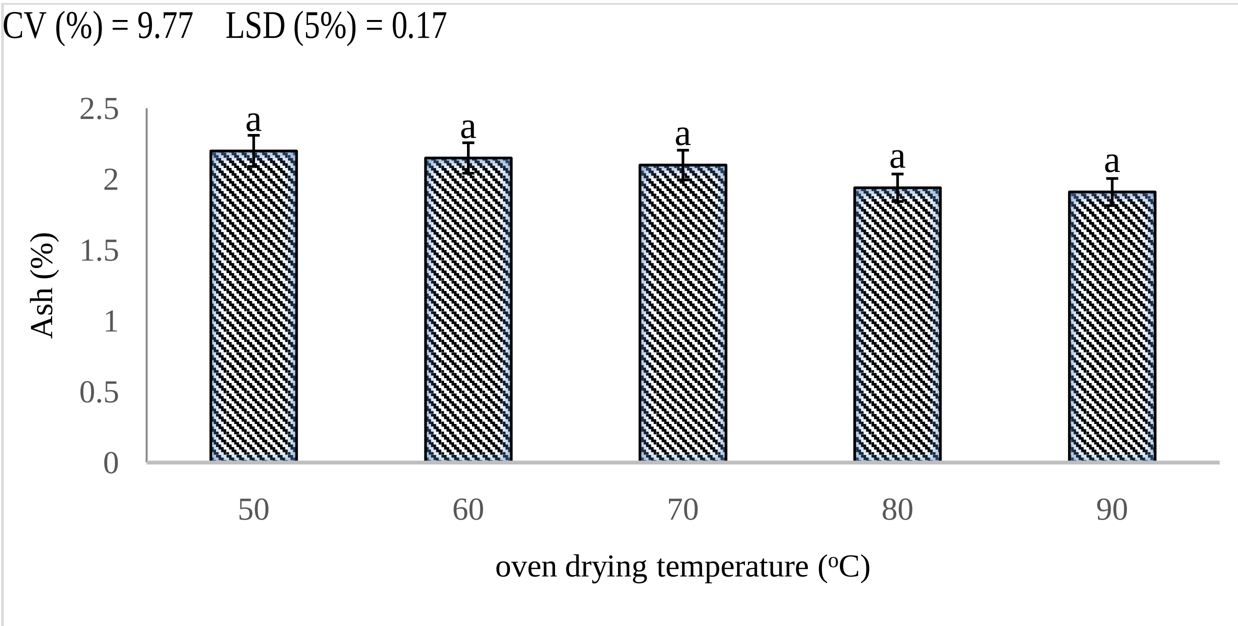

Figure 2. Effect of oven drying temperature on ash content of onion powder

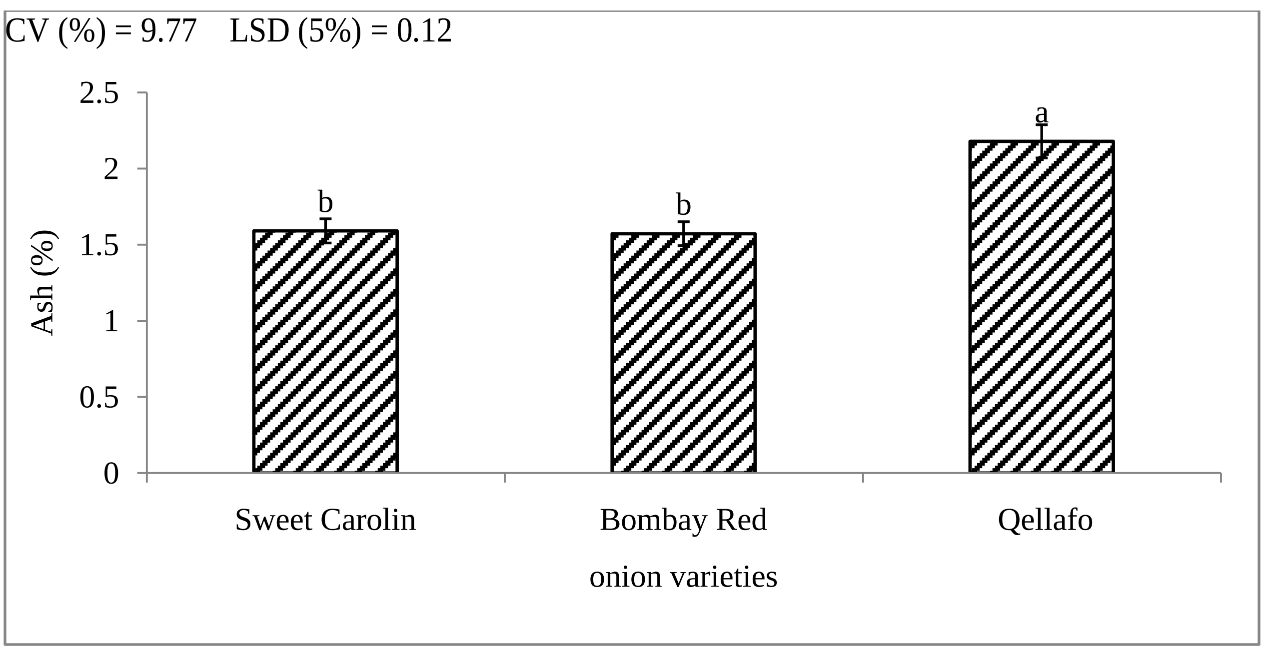

Figure 3. Effect of onion varieties on ash content of oven dried onion

4.1.2.5. Titratable acidity (%)

ANOVA showed that there was significant effect (P<0.05) of temperature and onion varieties on titratable acidity of onion powder. Figure 4 shows that the titratable acidity of reconstituted dried onion powder was affected by drying temperature. The highest acidity (0.35) was registered from the sample dried at 90°C. Samples dried at 80°C and 90°C recorded statistically the same result. The lowest acidity (0.29) was observed form the sample dried at 50°C, but statistically the same with sample dried at 60°C. These results indicate that by increment in drying temperature, the acidity was added. The reason for this event is conversion of sugar available in onion into organic acids. Also the titratable acidity of onion powder was significantly (P<0.05) affected by onion cultivar. The maximum average titratable acidity (0.32) was observed from Qellafo onion variety (Figure5). The minimum average titratable acidity (0.26) was observed from Sweet Carolin onion variety. There was significant (P<0.05) difference between onion cultivars. This result supports Mehmet *et al*. (2001) who reported that the titratable acidity of leeks was increased after drying. Also the result was similar with the work of Dev Raj *et al*. (2006) who reported that the titratable acidity of onion powder was increased with increment of drying temperature.

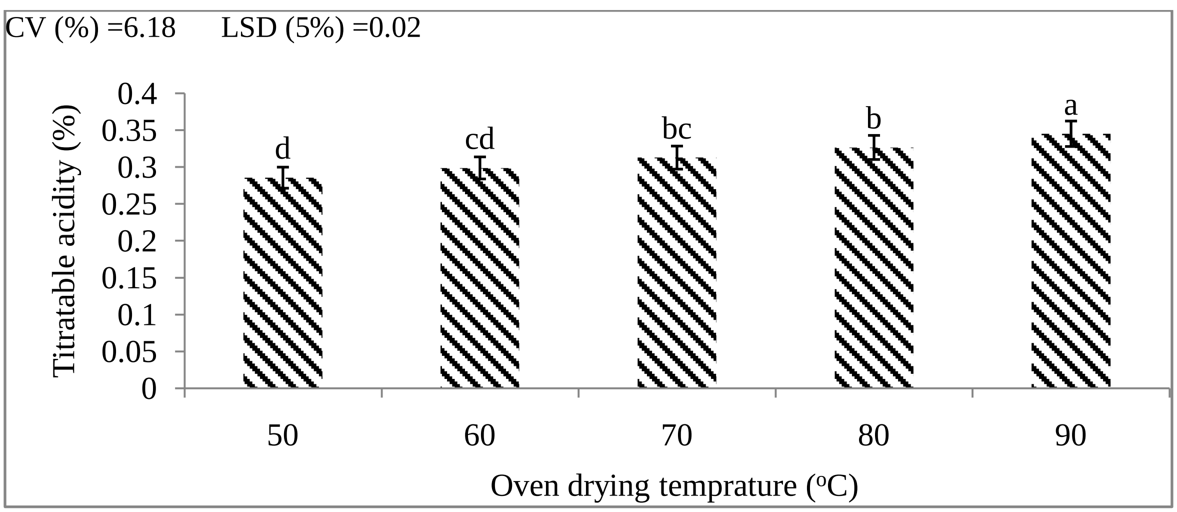

Figure 4.Effect of temperature during oven drying on titratable acidity of onion powder

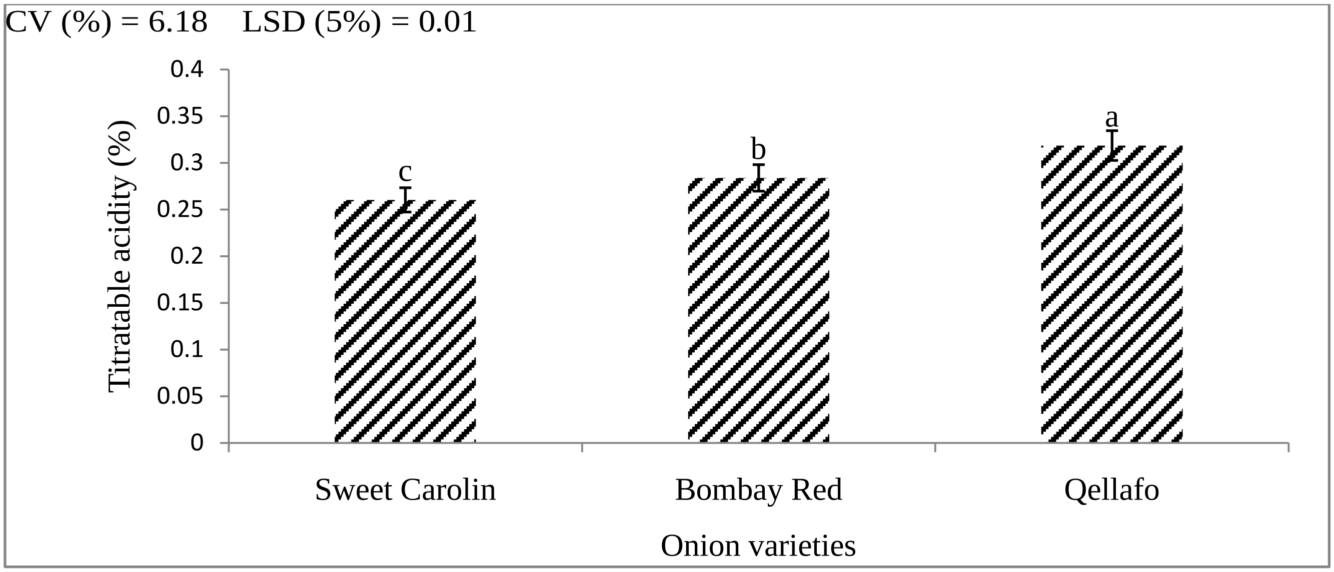

Figure 5. Effect of onion varieties on titratable acidity of onion during oven drying

4.1.2.6. pH value of onion powder

Analysis of variance showed significant effect ($P<0.05$) of temperature and onion varieties on pH of onion powder. The pH value of fresh onion varieties were 5.04, 5.34 and 5.36 for Qellafo, Sweet Carolin and Bombay Red onion varieties respectively (Table 9); But, no significant difference ($P>0.05$) between Sweet Carolin and Bombay Red onion varieties. After drying the highest pH value (4.32) was observed from Sweet Carolin onion variety dried at 50°C; While, at this temperature Bombay Red onion variety was recorded statistically the same result with Sweet Carolin onion variety. The lowest pH value was registered from the sample dried at 90°C (3.79, 3.69, and 3.76) for Sweet Carolin, Bombay Red and Qellafo onion varieties respectively. But there was no significant ($P>0.05$) difference between onion varieties dried at 90°C. Our results are in support of Mehmet *et al*. (2001) who reported that the pH value of leeks decreased after drying.

4.1.2.8. Moisture content (%)

Effect of temperature and varieties of onion moisture content are presented in Table 9. The moisture content of fresh onions varieties were 90.33, 83.5and 81.54 for Sweet Carolin, Bombay Red and Qellafo onion varieties respectively. After drying, the maximum average moisture content (9.00) was recorded from Sweet Carolin onion variety at 50^{o}C. Whereas the minimum average moisture content (4.93) was observed from Qellafo onion variety dried at 90^{o}C. The moisture content of onion powder was decreased with increasing drying temperature. This is because at higher temperature, the rate of heat transfer to the particle is greater, providing greater driving force for moisture evaporation. In other words, the rate of mass transfer increases with the increase in temperature. Thus water loss, solid gain and normalized solid content increased with increasing temperature. Consequently, powders with reduced moisture content are formed. Our results are supported by Abasi *et al.* (2009) who reported that the moisture content of the onion slice decreased with increment of temperature, so that the highest and lowest moisture content were 2.721 and 1.148, belong to the sample dried at 60 and 90°C, respectively. Also the result was line with the work of Abano *et al.* (2011) who reported that the moisture content of dried garlic was decreased with increasing of hot air temperature at 45, 50 and 55^{o}C.

Table 9.Interaction effect of temperature and onion varieties on pH and moisture content (%) of oven dried onion powder

Variety	Temperature (^oC)	pH	Moisture (%)
	Fresh	5.34^{a}	90.33^{a}
	50	4.32^{c}	9.00^{d}
	60	4.13^{efg}	8.23^{de}
Sweet Carolin	70	4.05^{gh}	7.80^{def}
	80	3.92^{ij}	7.27^{efg}
	90	3.79^{kl}	6.63^{fgh}
	Fresh	5.36^{a}	83.5^{b}
	50	4.31^{c}	7.77^{def}
	60	4.27^{cd}	6.67^{fgh}
Bombay Red	70	4.20^{de}	6.30^{ghi}
	80	4.02^{h}	5.93^{ghi}
	90	3.69^{m}	5.33^{hi}
	Fresh	5.04^{b}	81.54^{c}
	50	4.16^{ef}	6.57^{hgf}
	60	4.11^{fg}	6.27^{ghi}
Qellafo	70	3.97^{hi}	5.73^{hi}
	80	3.86^{jk}	5.50^{hi}
	90	3.76^{ml}	4.93^{i}
LSD (5%)		0.09	1.46
CV (%)		1.29	4.46

Values with in a column with different letter superscripts are significantly different at P<0.05.

4.1.2.9. Total Soluble Solid of onion powder

Significant changes in TSS after oven drying were obtained due to variation in the level of temperature and among variety. Result (Figure 6) indicates that the TSS value of onion powder was significantly (P<0.05) affected by onion cultivars. Sweet Carolin onion variety had highest

TSS value (6.93°Brix) than Qellafo and Bombay Red onion variety. Result indicated that the TSS value of onion powder gradually increased with temperature rise during oven drying period. The decrease in moisture content in the sample is usually accompanied by an increased percentage of TSS, since TSS is the major component of dry matter (Malundo *et al.*, 1995). Among the drying temperature the average minimum average TSS value of onion powder (6.30) was observed from the sample dried at 50°C; Whereas, the maximum average TSS value (7.48) was recorded from the sample which dried at 80°C, then declined at 90°C (7.23). But statistically the same result was registered from the sample which dried at 70°C, 80°C and 90°C (figure 7). The value of TSS of onion powder was considerably increased with rising of drying temperature but at some point it was decreased. This reduction may be due to degradation of sugars. Our result of present study are in agreement with that of Abano *et al.* (2011) who reported that the TSS value of dried garlic was increased with increasing of hot air temperature at 45, 50, 55°C. Also the result is similar with the work of Dev Raj *et al*. (2006) who reported that the TSS of onion powder increased with rise in drying temperature.

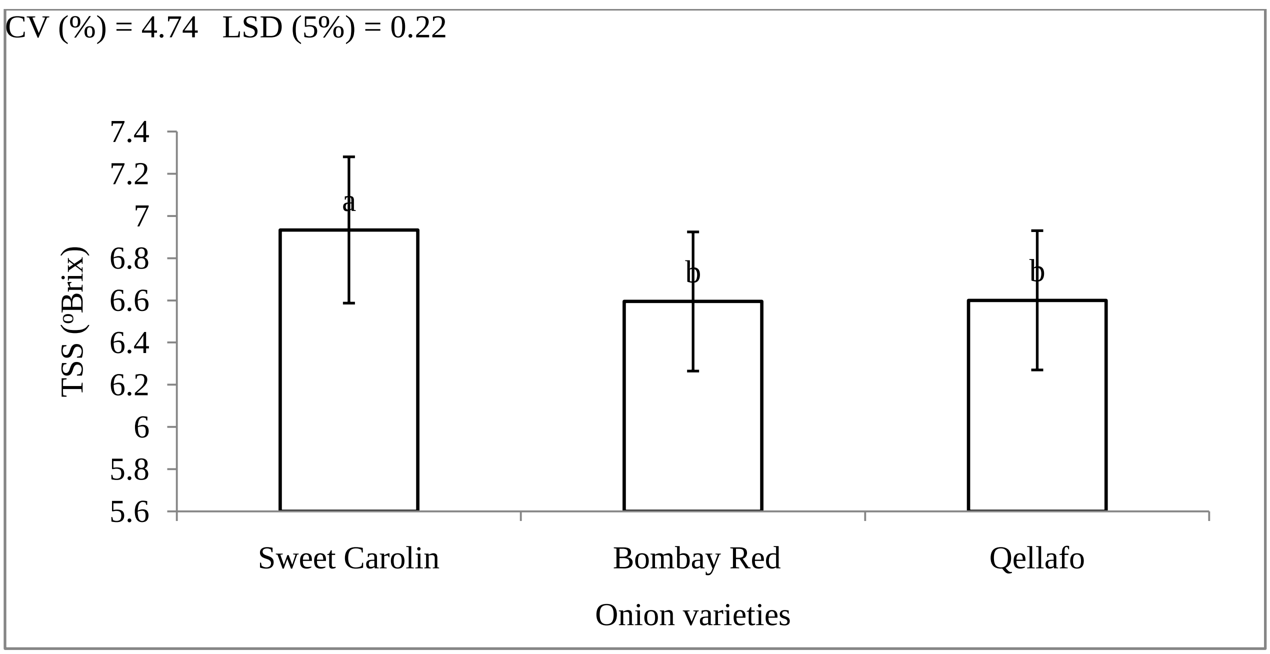

Figure 6. Effect of onion varieties on TSS content of onion powder

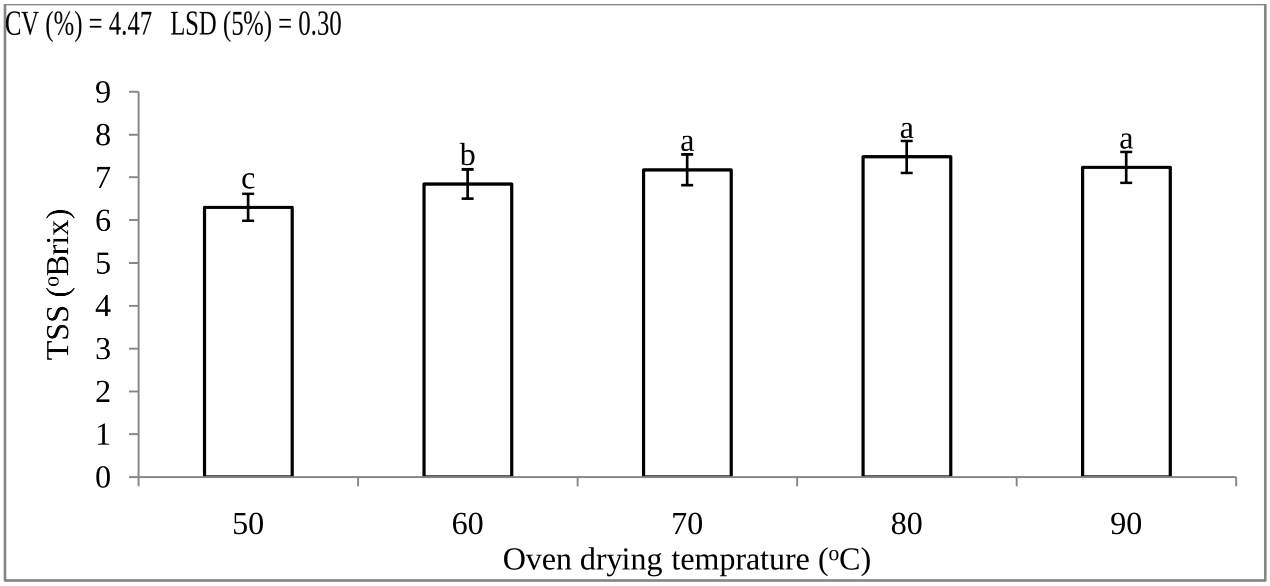

Figure 7. Effect of temperature during oven drying on TSS content of onion powder

4.1.3. Effect on sensory acceptability of onion powder

4.1.3.1. Color of onion powder

Color is one of the most important sensory qualities of food product. Analysis of variance showed significant ($P<0.05$) effect of oven temperature and onion varieties on subjective color acceptability of onion powder (Table 10). The values of color of fresh onion cultivars were 4.60, 4.48 and 4.21 in a scale of 5 for Sweet Carolin, Qellafo and Bombay Red onion verities respectively. They are statistically the same. Whereas, Qellafo onion variety dried at 50^{o}C was scored highest grade (4.1) than those of other treatments. This score was close to the "like" level on the 5-point Hedonic scale. At 80^{o}C there was no significant difference ($P>0.05$) among the onion cultivars. But the lowest value of color (2.59) was recorded from Sweet Carolin onion variety dried at 90^{o}C. This implies that when drying temperature increases color acceptability value decreases. This is due to non-enzymatic browning (NEB) which occurred faster at high temperature (Lopez *et al.*, 2006; Shi *et al.*, 2000). Our result are in agreement with the findings of Ayoola (2014) who reported that color of the onion slice decreased with increment of drying temperature from 50 to 70^{o}C. Also the results are line with the work of Girma (2015) who reported that the color of dried onion decreased with increasing temperature of fluidized bed dryer and oven from 50 to 70^{o}C.

4.1.3.2. Aroma of onion powder

Aroma is imparted by volatile compounds and perceived by the odor receptor sites of the smell organ. The result showed that the effect of temperature and onion varieties on aroma of onion powder were significant (Table 10). The value of aroma acceptability of fresh onion cultivars were 3.83, 4.00 and 4.37 for Sweet Carolin, Bombay Red and Qellafo onion cultivars respectively. Among the onion powder, Qellafo onion Variety dried at 50^{o}C (3.81) and 60^{o}C (3.74) hade best aroma than the other treatment, these were statistically the same (P>0.05). Those score was close to the "like" level on the 5-point Hedonic scale. The least aroma (2.47) was registered for Sweet Carolin onion variety dried at 90^{o}C. The difference in aroma was primarily due to loss and generation of volatile compounds during drying process (Sacilik *et al.,* 2005). Our results are in agreement with the findings of Ayoola (2014) who reported that aroma of the onion slice was decreased with increment of drying temperature from 50 to 70^{o}C. Also this result is in agreement with the observation of Vinita Puranik *et al*. (2012) and Mitra J *et al*. (2011) on drying of garlic and onion respectively.

4.1.3.3. Taste of onion powder

Effect of temperature and varieties on the taste of onion powder was presented in Table 10. The sensory score of taste of fresh onion varieties were 4.3, 4.42 are 4.44 for Bombay Red, Sweet Carolin and Qellafo onion varieties, respectively, which are statistically the same (P>0.05). The taste of powder sample dried at 50^{o}C from Sweet Carolin variety rated best. It scored 4.17, which is above the "like" level on the 5-point Hedonic scale. Besides, the lowest value was observed for Bombay Red onion variety which was dried at 90^{o}C (2.80); While at 90^{o}C, all onion varieties had statistically the same results (P>0.05). The result is close to the "neither like nor dislike" level on the 5-point Hedonic scale. The taste score decreased as drying temperature increased. Our results support the idea of Ayoola (2014) who reported that taste of the onion slice was decreased with increment of drying temperature from 50 to 70^{o}C. Our results are in line with the work of Girma (2015) who reported that the taste of dried onion powder decreased with increasing of fluidized bed dryer and oven temperature form 50-70^{o}C.

4.1.3.4. Overall acceptability of onion powder

The statistically analyzed data presented in Table 10 indicated that the overall acceptability was also affected by oven temperature and onion varieties. The overall acceptability score of fresh onion varieties was 4.04, 4.30 and 4.35 for Sweet Carolin, Bombay Red and Qellafo onion varieties, respectively but Bombay Red and Qellafo onion varieties were statistically the same. Among the five temperatures tested, $50^{o}C$ exhibited best acceptability. Qellafo onion variety dried at $50^{o}C$ scored highest overall acceptability (3.96) of all the other onion powders. This result was close to the "like" level on the 5-point Hedonic scale. On the other hand, the lowest overall acceptability of onion powder (3.02) was obtained from Sweet Carolin onion variety which was dried at $90^{o}C$. This result was close to the "neither like nor dislike" level on the 5-point Hedonic scale. Our results were line with the work of Girma (2015) who reported that the overall acceptability of dried onion was decreased with increased temperature from 50 to $70^{o}C$ of fluidized bed drying and oven temperature. Also similar with the result of the present work is that of Ayoola (2014) who reported that overall acceptability of the onion slice was decreased with increment of drying temperature from 50 to $70^{o}C$.

Table 10. Interaction effect of oven drying temperature and onion varieties on sensory acceptability of onion powder

Varieties	Temperature (°C)	Color	Aroma	Taste	Overall acceptability
	Fresh	4.60^{a}	3.83^{c}	4.42^{a}	4.04^{b}
	50	3.64^{de}	3.39^{fg}	4.17^{b}	3.68^{e}
	60	3.44^{fg}	3.22^{hi}	3.57^{c}	3.61^{efg}
Sweet Carolin	70	3.40^{fg}	3.12^{i}	3.41^{fg}	3.57^{fg}
	80	3.20^{hij}	2.94^{j}	3.27^{ij}	3.42^{h}
	90	2.59^{k}	2.47^{k}	2.81^{l}	3.02^{i}
	Fresh	4.21^{b}	4.00^{b}	4.3^{a}	4.30^{a}
	50	3.90^{c}	3.61^{de}	3.64^{d}	3.90^{cd}
	60	3.69^{d}	3.48^{ef}	3.49^{ef}	3.82^{d}
Bombay Red	70	3.49^{ef}	3.45^{fg}	3.28^{hij}	3.65^{ef}
	80	3.28^{ghi}	3.31^{gh}	3.07^{k}	3.54^{g}
	90	3.00^{j}	3.11^{i}	2.80^{l}	3.37^{h}
	Fresh	4.48^{a}	4.37^{a}	4.44^{a}	4.35^{a}
	50	4.10^{b}	3.81^{c}	3.55^{de}	3.96^{bc}
	60	3.88^{c}	3.74^{dc}	3.38^{fgh}	3.84^{d}
Qellafo	70	3.65^{ed}	3.5^{fe}	3.33^{ghi}	3.68^{e}
	80	3.36^{gfh}	3.42^{fg}	3.20^{j}	3.61^{efg}
	90	3.12^{ji}	3.10^{i}	2.91^{l}	3.40^{h}
LSD (5%)		0.17	0.14	0.11	0.088
CV (%)		2.75	2.48	1.96	1.43

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

4.2. Effect of Storage Period on Shelf Life Stability of Onion Powder

4.2.1. Color of onion powder

The color of onion is one of the important appearance characteristics. Discoloration was the main sign of deterioration of dried onion during 3 months storage at room temperature (Singh and Kumar, 1984). There was significant ($P<0.05$) change in color of onion during storage (Table 11). The values of 'L*' and 'a*' of onion powder were decreased during 90 days storage period at ambient conditions. The top L* value of onion powder (50.68) was recorded from Sweet Carolin onion variety dried at lowest temperature (50^oC) on day one. The least L* value of onion powder (36.49) was observed from Qellafo onion variety dried at 70^oC and stored for 90 days. The peak a* value of onion powder (11.02) was recorded from Sweet Carolin onion variety dried at lowest temperature (50^oC) on day one while the least a* value of onion powder (0.83) was observed from Qellafo onion variety dried at 70^oC after 90 days of storage. The b* value of onion powder increased with increment of storage period. The lowest b* value of onion powder (31.78) was registered from Sweet Carolin onion variety dried at 70^oC on day one. However, the highest b* value of onion value of onion powder (54.45) was observed from Bombay Red onion variety dried at 50^oC after 90 days of storage.

The total color change (ΔE) of onion powder was significantly increased with increment of storage period. The highest and the lowest total color changes were observed from Bombay Red onion variety dried at 50^oC. The lowest one (12.92) was recorded on day one of storage while the highest total color change (72.18) was recorded on day 90 of storage but it was statistically the same up to 60 days of storage period (71.15) and it increased to 72.18 at the end of storage duration. The findings of the present study conform from the previous findings (Kumar and Sagar, 2009) that red pigment (anthocyanin) degrades (manifested by decrease in *a** value) and non-enzymatic browning takes place (decrease in the L* and increase in the *b** values) during storage. This may be due to faster rate of colour degradation at higher temperature. These results are in agreement with the work of Lewicki *et al*. (1998) who reported that color decreased with increasing storage period in storage stability of dried onion which stored in plastic bottle under constant temperature at 25^oC. Also Ahmed and Shivhare (2001) reported decrease in the a* value and L* but increase in b*values during storage of onion paste for 71 days.

Table 11. Effect of storage period on color of oven dried onion varieties at room temperature.

Variety	Temperature (^oC)	period (day)	L*	a*	b*	ΔE
Sweet Carolin	50	1	50.68[a]	11.02[a]	37.29[pqr]	35.32[q]
		30	49.98[ab]	9.00[bc]	39.98[nopq]	64.66[cde]
		60	47.68[bcd]	8.12[cdef]	42.88[mno]	64.72[cde]
		90	46.68[def]	7.16[efg]	43.68[lmno]	64.55[cde]
	60	1	48.40[abcd]	9.83[ab]	33.80[pqr]	39.54[opq]
		30	47.47[bcd]	7.8[def]	35.81[opqr]	60.03[fgh]
		60	45.40[efg]	6.78[efgh]	38.77[nopq]	60.18[fgh]
		90	44.41[fgh]	5.83[hijk]	39.87[nopq]	59.98[ghij]
	70	1	42.79[hij]	8.33[bcde]	31.78[rs]	45.18[p]
		30	41.72[ijkl]	6.37[ghij]	33.84[qrs]	54.21[lmno]
		60	40.70[lmn]	5.28[jklm]	36.91[pqrs]	54.61[lmno]
		90	38.79[nop]	4.42[lmn]	37.98[pqr]	54.48[nmo]
Bombay Red	50	1	49.56[abc]	8.47[bcd]	48.46[ef]	12.92[t]
		30	48.42[abcd]	6.48[ghij]	50.49[cd]	70.27[ab]
		60	46.55[def]	5.47[ijkl]	53.39[ab]	71.15[ab]
		90	45.5[efg]	4.44[lmno]	54.45[a]	72.18[a]
	60	1	47.40[cde]	7.38[defg]	45.35[ijk]	16.27[st]
		30	46.49[def]	5.41[jklm]	47.96[fgh]	67.05[bcd]
		60	44.39[fgh]	4.38[lmno]	50.36[cd]	67.76[abc]
		90	43.39[ghi]	3.37[mnop]	51.90[bc]	67.81[abc]
	70	1	44.33[fgh]	6.32[ghij]	43.64[lmn]	19.50[s]
		30	43.33[ghi]	4.39[lmno]	45.56[jkl]	63.14[def]
		60	41.18[ijklm]	3.33[lmnop]	46.36[efg]	63.97[cdef]
		90	40.22[klmn]	2.23[nopq]	48.66[def]	64.05[cde]
Qellafo	50	1	44.38[fgh]	5.54[jklm]	42.47[mno]	32.73[pq]
		30	43.38[ghi]	3.58[lmno]	44.47[jklmn]	36.73[pq]
		60	41.28[ijklm]	2.54[nopq]	47.47[fgh]	63.04[defg]
		90	40.38[jklmn]	1.54[opq]	48.47[efg]	63.11[defg]
	60	1	42.85[hij]	5.05[klm]	41.17[nop]	34.7[qr]
		30	41.52[ijklm]	3.05[nopq]	43.17[klmn]	59.98[ghij]
		60	41.52[ijklm]	2.05[nopq]	46.17[hijk]	61.03[efghi]
		90	38.88[lmno]	1.06[opq]	47.17[fgh]	61.13[efghi]
	70	1	40.90[ijlkmn]	3.83[klmn]	39.63[opq]	37.27[pq]
		30	39.69[klmno]	1.83[nopq]	41.63[nop]	57.71[ijklm]
		60	37.35[opq]	1.39[nopq]	44.63[jklm]	58.57[jklm]
		90	36.49[pq]	0.83[pq]	45.63[jkl]	58.69[hijk]
Cv (%)			3.79	12.76	3.32	4.77
LSD (5%)			2.51	1.58	2.24	4.07

Values in column with different letter superscripts are significantly different at $P<0.05$.

4.2.2. Water activity of onion powder

The storage period significantly (P<0.05) affected the water activity of onion powder. From the results (Table 12), the water activities of the onion powders were in the range of 0.242–0.359. Sweet Carolin onion variety dried at 70^{o}C on initial day exhibited lowest water activity (0.242); whereas, the highest water activity (0.359) was observed for Qellafo dried at 50^{o}C stored for 90 days. Our results are in agreement with other researchers for green onion dried at 50 to 70°C (García *et al*., 2010) found a_w values in the range 0.29–0.40, which increased up to 0.62–0.65 after a period of storage of 126 days at room temperature. Also Juliana *et al.* (2012) reported that water activity of dehydrated onion increased during 12 month storage.

Table 12. Effect of storage period on water activity of oven dried onion powder at room temperature.

V*T	Storage period (day)			
	1	30	60	90
SC*50	0.321^{cd}	0.332^{bcd}	0.341^{ab}	0.350^{ab}
SC*60	0.251^{pq}	0.265^{op}	0.274^{no}	0.295^{ghi}
SC*70	0.242^{Q}	0.259^{opq}	0.268^{op}	0.276^{no}
BR*50	0.318^{de}	0.331^{bcd}	0.338^{bc}	0.348^{ab}
BR*60	0.281^{lmn}	0.291^{kl}	0.315^{def}	0.327^{bcd}
BR*70	0.262^{op}	0.273^{op}	0.283^{lm}	0.308^{efg}
Q*50	0.292^{kl}	0.319^{cd}	0.348^{ab}	0.359^{a}
Q*60	0.277^{op}	0.288^{klm}	0.305^{fg}	0.332^{bcd}
Q*70	0.270^{opq}	0.278^{hij}	0.294^{hij}	0.315^{de}
CV (%)	4.13			
LSD (5%)	0.09			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.3. Moisture content (%) of onion powder

Moisture content is a necessary parameter to predict the quality and shelf life of dehydrated vegetables. Analysis of variance show that the moisture content of onion powder significantly (P<0.05) affected by storage period (Table 13). During storage the moisture content of onion powder increased for all the samples. The less increase of moisture content was observed from the sample which was dried at highest temperature (70^{o}C). The lowest moisture content (5.73%) was observed from Qellafo onion variety dried at 70^{o}C on initial day. The highest moisture content (10.47%) registered for Sweet Carolin onion variety dried at 50^{o}C on day 90 storage period. This may be due to interaction among temperature, variation of the relative humidity of the surrounding air and the hygroscopic properties of onion powder. Our finding is in agreement with the work done by Algadi *et al*. (2014) who observed the moisture content of onion powder during ambient storage and gradually increased.

Table 13. Effect of storage period on Moisture content (%) of oven dried onion powder at room temperature.

V*T	Storage period (day)			
	1	30	60	90
SC*50	9.00^{cde}	9.27^{bc}	9.9^{ab}	10.47^{a}
SC*60	8.23^{ef}	8.5^{def}	8.97^{cde}	9.67^{b}
SC*70	7.80^{fgh}	8.25^{efg}	8.65^{def}	9.07^{cd}
BR*50	7.77^{fghi}	8.00^{fgh}	8.70^{de}	9.14^{bc}
BR*60	6.67^{mno}	7.01^{jkl}	7.52^{hij}	8.21^{efg}
BR*70	6.30^{pq}	6.49^{nop}	6.97^{jil}	7.64^{ghi}
Q*50	6.57^{nop}	7.03^{jkl}	7.14^{ijk}	7.68^{ghi}
Q*60	6.27^{pqr}	6.60^{mno}	6.91^{lmn}	7.30^{ij}
Q*70	5.73^{wxy}	5.95^{qre}	6.42^{opq}	6.85^{lmn}
CV (5)	9.97			
LSD (5%)	1.17			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.4. pH value of onion powder

The present study shows that storage period was significantly (P<0.05) affect the pH value of onion powder. Table 14 shows that Bombay Red onion variety dried at 50^{o}C scored the highest pH value (4.6) during initial day of storage. On the other hand, the lowest pH value (3.97) was observed from Qellafo onion variety dried at 70^{o}C on 90 days of storage period. The decrease in pH value of onion powder during storage might be attributed to the availability of more readily utilizable carbohydrate molecules by the microbes and thereby formation of acid. It is an established fact that a decrease in pH is usually attributed to the metabolic activity of bacteria (Jay, 1996). These observations agree with the findings of Shankaralingam *et al. (*2004), who observed that the pH of carrot powder was decreased with increasing of storage period.

Table 14. Effect of storage period on pH value of oven dried onion powder at room temperature.

V*T	Storage period (days)			
	1	30	60	90
SC*50	4.55^{b}	4.46^{cde}	4.38^{efg}	4.32^{gh}
SC*60	4.51^{c}	4.36^{fg}	4.22^{jkl}	4.13^{mno}
SC*70	4.47^{cd}	4.32^{gh}	4.21^{jkl}	4.05^{o}
BR*50	4.6^{a}	4.46^{cde}	4.40^{def}	4.31^{ghi}
BR*60	4.49^{cd}	4.41^{def}	4.31^{ghi}	4.27^{ij}
BR*70	4.57^{b}	4.44^{cdef}	4.29^{hij}	4.20^{kl}
Q*50	4.51^{c}	4.39^{efg}	4.22^{jkl}	4.16^{lmn}
Q*60	4.4^{def}	4.31^{ghi}	4.17^{lm}	4.11^{no}
Q*70	4.38^{efg}	4.27^{hij}	4.04^{oq}	3.97^{q}
CV (%)	2.59			
LSD (5%)	0.03			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.5. Titratable acidity (%) of onion powder

The acidity of onion powder increased significantly at (P<0.05) throughout the storage period (Table 15). The lowest acidity (0.25%) was recorded from Sweet Carolin onion variety dried at 50^{o}C on initial day of storage. But after storage the acidity of onion powder was slightly increased. At 70^{o}C the sample from Qellafo onion variety dried exhibited highest acidity (0.37%) during 90 days storage period. No significant difference (P<0.05) means observed among the sample of Qellafo variety dried at 70^{o}C on 60 days and dried at 60^{o}C on 90 days. Increase in titratable acidity of onion powder might be due to acids produced by microorganism and it also due to oxidation of sugar in to acid during processing and is influenced by storage temperature (Gould, 1992). Similar observation were reported by Sarker *et al.* (2014) and Safdar *et al*. (2010) who observed the increasing acidity content of stored tomato powder packed in different packaging material and who observed the decreasing of pH contents of tomato paste during storage at 25^{o}C, 6^{o}C and -10^{o}C respectively. Our results are in line with the observations of Sharma *et al*. (2013) in dehydrated and stored quality of Anardana.

Table 15. Effect of storage period on Titratable acidity (%) of oven dried onion powder at room temperature.

V*T	Storage duration (day)			
	1	30	60	90
SC*50	0.25f	0.27^{def}	0.29^{cde}	0.30^{cde}
SC*60	0.27^{def}	0.28^{de}	0.29^{cde}	0.30^{cde}
SC*70	0.28^{de}	0.29^{cde}	0.29^{cde}	0.31^{cd}
BR*50	0.28^{de}	0.29^{cde}	0.31^{cd}	0.32^{c}
BR*60	0.30^{cde}	0.31^{cd}	0.33^{bcd}	0.34^{bc}
BR*70	0.31^{cd}	0.32^{c}	0.33^{bcd}	0.34^{bc}
Q*50	0.31^{cd}	0.33^{bcd}	0.34^{bc}	0.35^{ab}
Q*60	0.33^{bcd}	0.34^{bc}	0.35^{ab}	0.36^{a}
Q*70	0.35^{ab}	0.35^{ab}	0.36^{a}	0.37^{a}
CV (%)	5.352			
LSD (5%)	0.02			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.6. Vitamin C (mg/100g) content of onion powder

Vitamin C content of onion powder was significantly affected with storage period. A decline in vitamin C content was found with increase in storage period. The highest vitamin C (1.78mg/100g) recorded for Qellafo onion variety dried at 50^{o}C on initial day of storage (Table 16), but no significantly difference was observed with the same variety dried at 60^{o}C on initial day of storage (1.77mg/100g). Whereas, the Sweet Carolin onion variety dried at 70^{o}C on day 90 of storage recorded the lowest vitamin C (0.95mg/100g) and Bombay Red onion variety was dried at 50^{o}C after 90 days of storage (0.91mg/100g). Those results are statistically the same. The observed decrease in ascorbic acid content might be due to degradation of ascorbic acid molecules forming dehydro ascorbic acid by oxidation (Lal *et al.*, 2009). These results are in line with the results of Sharma *et al*. (2013) in dehydrated and stored quality of Anardana.

Table 16. Effect of storage period on Vitamin C (mg/100g) content of oven dried onion powder at room temperature.

V*T	Storage duration (day)			
	1	30	60	90
SC*50	1.75^{a}	1.68^{abcd}	1.63^{abcde}	1.58^{bcde}
SC*60	1.34^{klmn}	1.28^{lmno}	1.21^{mnop}	1.15^{nopq}
SC*70	1.11^{nopq}	1.08^{rstuv}	1.02^{tuvw}	0.95^{pq}
BR*50	1.51^{efgh}	1.45^{efg}	1.38^{hijk}	1.30^{lmno}
BR*60	1.42^{ghij}	1.36^{ijkl}	1.29^{lmno}	1.22^{mnop}
BR*70	1.14^{nopq}	1.09^{nopq}	0.99^{uvw}	0.91^{pq}
Q*50	1.78^{a}	1.70^{bc}	1.63^{abcde}	1.56^{cdef}
Q*60	1.77^{a}	1.71^{bc}	1.64^{abcde}	1.59^{bcde}
Q*70	1.68^{bc}	1.64^{bcd}	1.58^{bcde}	1.53^{defg}
CV (%)	10.11			
LSD (5%)	0.21			

Values with different letter superscripts are significantly different at $p<0.05$. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.7. Pyruvic acid (µmol/ml) content of onion powder

The pyruvic acid decreased in all powdered samples during the storage period of three months, and results are presented in Table 17. The highest pyruvic acid (6.93µmol/ml) was recorded in Qellafo onion variety dried at 50^{o}C on initial day of storage period. Whereas, the lowest value of pyruvic acid (4.63µmol/ml) observed for Bombay Red onion variety dried at 70^{o}C on day 90 storage period. This reduction of pyruvic acid during drying and storage may be due to the degradation of the capsaicinoid pigments (pungency components) present in the onion. Our results is in agreement with Tummala *et al.* (2008) who reported that the pyruvic acid of onion powder decreased in all powder samples packed plastic bottle during the storage period of 180 days.

Table 17. Effect of storage period on pyruvic acid (µmol/ml) content of oven dried onion powder at room temperature.

V*T	Storage duration (day)			
	1	30	60	90
SC*50	5.88^{fghi}	5.82^{jk}	5.32^{kl}	5.23^{lmn}
SC*60	5.23^{lmn}	5.15^{lmn}	5.06^{mno}	4.95^{mno}
SC*70	4.99^{mno}	4.86^{nop}	4.78^{opq}	4.68^{pq}
BR*50	5.37^{kl}	5.29^{am}	5.13^{lmn}	4.91^{mno}
BR*60	5.15^{lmn}	5.03^{mno}	4.94^{mno}	4.84^{nop}
BR*70	4.90^{no}	4.8^{nop}	4.73^{opq}	4.63^{pq}
Q*50	6.93^{a}	6.82^{ab}	6.7^{abc}	6.65^{bcd}
Q*60	6.73^{ab}	6.65^{abc}	6.55^{bc}	6.40^{bcd}
Q*70	6.40^{bcd}	6.32^{cde}	6.26^{def}	6.18^{efgh}
CV (%)	5.09			
LSD (5%)	0.44			

Values with different letter superscripts are significantly different at $p<0.05$. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

4.2.8. Microbial load of onion powder

Microbiological quality is a common criterion used to determine food safety and shelf life of dehydrated products; however drying process is not lethal to all microbes. Microbial load count of the dehydrated foods depends on safety quality of utensils used during processing (Jay, 2005). From Table 18 shows that the highest bacterial count ($7.33x10^{-4}$) was recorded from Sweet Carolin onion variety dried at $50^{o}C$ at the end of 90 days storage.

On the other hand, very low bacteria ($0.66x10^{-4}$) were detected from Qellafo onion variety dried at $70^{o}C$ on initial day of storage; although, there growth was slow up to 30 days after they increased at fast rate. Our results agree with the finding of Shankaralingam *et al.* (2004), who reported that total plate count increased at each storage interval in carrot powder on 30 days of storage period. This is also in agreement with the findings of Chidanandaiah *et al.* (2009), Kumar and Tanwar (2011), Bhat *et al.* (2010), Bhat *et al.* (2013a) and Bhat *et al.* (2013b) who also reported the similar results in meat patties, chicken nuggets, chevon Harissa, chicken seekh kababs and chicken meat balls, respectively.

Table 18. Effect of storage duration on bacterial count (CFU/g) of oven dried onion powder at room temperature.

V*T	Storage period (day)			
	1	30	60	90
SC*50	$2.66x10^{-4jklm}$	$3.66\ x10^{-4fghi}$	$5.66\ x10^{-4bcd}$	$7.33\ x10^{-4a}$
SC*60	$2.66\ x10^{-4jklmn}$	$3.33\ x10^{-4hijk}$	$4.33\ x10^{-4efgh}$	$6.00\ x10^{-4b}$
SC*70	$1.66\ x10^{-4lmno}$	$2.66\ x10^{-4jklm}$	$4.66\ x10^{-4defg}$	$5.66\ x10^{-4bc}$
BR*50	$2.66\ x10^{-4jklmn}$	$4.00\ x10^{-4efghi}$	$5.00\ x10^{-4cdef}$	$7.00\ x10^{-4ab}$
BR*60	$2.00\ x10^{-4lmn}$	$3.33\ x10^{-4hijk}$	$4.33\ x10^{-4efgh}$	$6.33\ x10^{-4ab}$
BR*70	$1.66\ x10^{-4lmno}$	$2.33\ x10^{-4klmn}$	$3.33\ x10^{-4hijk}$	$6.00\ x10^{-4bc}$
Q*50	$1.66\ x10^{-4lmno}$	$3.33\ x10^{-4hijk}$	$4.66\ x10^{-4defgh}$	$6.33\ x10^{-4abc}$
Q*60	$1.33\ x10^{-4mno}$	$2.33\ x10^{-4klmn}$	$4.00\ x10^{-4efghi}$	$5.33\ x10^{-4cde}$
Q*70	$0.66\ x10^{-4no}$	$1.66\ x10^{-4lmno}$	$3.33\ x10^{-4hijk}$	$4.33\ x10^{-4efgh}$
CV (%)	15.13			
LSD (5%)	1.34			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^oC), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

Furthermore, the maximum values of fungus ($3x10^{-4}$) were observed from Bombay Red onion variety dried at 50^oCafter 90 days storage period. No fungus were detected fungus from all onion powder sample irrespectively treatments on initial day of storage duration and in some of the treatment up to 30 days of storage period (Table 19). Afterwards they increased at slow rate and appeared on 90 days storage period and followed a significantly (P < 0.05) increasing trend in all the treatments. Singh *et al.* (2011) reported that yeast and mold appeared during the last day of storage of chicken snacks due to the availability of nutrients in meat. Among the treatments the counts were significantly (P < 0.05) higher for snacks containing black gram flour both on 21st and 28th day of storage. In addition, this result agrees with Shankaralingam *et al. (*2004), who reported that an increase in total plate count at each storage interval in carrot powder on 30 days of storage period.

In general, the results obtained from present study showed that the onion powder which was stored for 90 days had the highest microbial counts while the onion powder which not stored lower microbial counts. These low microbial counts of stored onion 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. Famurewa *et al*. (2013) reported that the microbial load of tomato paste packed in polyethylene and plastic bottle maximum ($12x10^{-3}$cfu/g) and ($3x10^{-}$

^{3}cfu/g) minimum which was higher than that reported in this study and also similar observation was reported on fungi with this study. Neena *et al.* (2013) reported that result higher than this study and also observe mould count on storage stability of leaf curl resistant cultivar of produced tomato powder.

Table 19. Effect of storage period on fungal count (CFU/g) of oven dried onion powder at room temperature.

V*T	Storage duration (Days)			
	1	30	60	90
SC*50	0.00^{i}	$1.00\ x10^{-4fg}$	$2.00\ x10^{-4cd}$	$2.33\ x10^{-4bc}$
SC*60	0.00^{i}	$1.00\ x10^{-4fg}$	$1.33\ x10^{-4ef}$	$2.00\ x10^{-4cd}$
SC*70	0.00^{i}	$0.66\ x10^{-4gh}$	$1.00\ x10^{-4fg}$	$1.33\ x10^{-4de}$
BR*50	0.00^{i}	$0.66\ x10^{-4gh}$	$1.66\ x10^{-4de}$	$3.00\ x10^{-4a}$
BR*60	0.00^{i}	$0.33\ x10^{-4hi}$	$1.33\ x10^{-4de}$	$2.33\ x10^{-4bc}$
BR*70	0.00^{i}	$0.33\ x10^{-4hi}$	$1.33\ x10^{-4ef}$	$2.33\ x10^{-4bc}$
Q*50	0.00^{i}	$1.00\ x10^{-4fg}$	$2.00\ x10^{-4cd}$	$2.66\ x10^{-4ab}$
Q*60	0.00^{i}	$1.00\ x10^{-4fg}$	$1.66\ x10^{-4de}$	$2.33\ x10^{-4bc}$
Q*70	0.00^{i}	$0.33\ x10^{-4hi}$	$1.00\ x10^{-4fg}$	$1.66\ x10^{-4de}$
CV (%)	11.66			
LSD (5%)	0.6			

Values with different letter superscripts are significantly different at p<0.05. Where, V= onion variety, T= oven drying temperature (^{o}C), SC= Sweet Carlin, BR= Bombay Red, Q= Qellafo onion variety

In general, the present study showed that the best quality of onion powder was obtained from Qellafo onion variety dried at 50^{o}C (Table 20). However, the best microbial quality of onion powder was observed at 70^{o}C. For this reason, further research should be done using different packaging materials that differs from the present study and different storage condition to give conclusive recommendation about quality profile of the studied onion varieties under different drying temperature along with best shelf life.

Table 20. Best quality recorded for oven dried onion varieties across the studied parameters

Factors		Parameters												
	T (^{o}c)	color	Wac	SR	BD	PA	VC	Mc	pH	TA	TSS	a_w	fiber	Sensory
SC	50													
	60													
	70													
	80													
	90				✓						✓	✓		
BR	50	✓												✓
	60													
	70													
	80													
	90				✓			✓	✓					
Q	50			✓		✓	✓						✓	✓
	60						✓							
	70													
	80													
	90		✓					✓		✓				

Where, SC = Sweet Carolin, BR =Bombay Red, Q =Qellafo, T =Temperature, wac =Water absorption capacity, SR =shrinkage ration, BD =bulk density, PA =pyruvic acid, VC =vitamin C, Mc = moisture content, TA =titratable acidity, TSS =total soluble solid, a_w =water activity.

5. SUMMARY AND CONCLUSIONS

The present study showed strong variability among onion varieties, level of drying temperature and storage duration for parameters studied under this research. Accordingly, the present result indicated that drying temperature had great influence on the physicochemical and sensory quality of onion powder. Bombay Red onion variety scored the minimum total color change at 50^{o}C (12.92) whereas Sweet Carolin onion variety scored the maximum total color change at 90^{o}C (51.58). Furthermore, other functional parameters such as rehydration ratio, bulk density and shrinkage ratio of onion powder exhibited higher value at high temperature. Accordingly, the maximum average water absorption capacity (2.15), shrinkage ratio (53.5) and bulk density (0.88) were observed at 90°C.

On the other hand, the maximum average of pyruvic acid (6.93µmol/ml) was observed from Qellafo onion variety dried at 50^{o}C; but, the minimum average of pyruvic acid (4.46µmol/ml) was observed from Bombay Red onion variety dried at 90^{o}C. Moreover, Qellafo onion variety had also higher vitamin C (1.77mg/100g and 1.78mg/100g) which were dried at 50^{o}C and 60^{o}C respectively. However, at high temperature vitamin C was highly degraded into 0.68mg/100g. Likewise, Sweet Carolin onion variety dried at 50^{o}C had the maximum amount of fiber content (9.03) whereas the minimum average fiber content was observed from Bombay Red onion variety dried at 90^{o}C. Similarly, the moisture content of onion powder was affected by temperature which was ranged from 4.93 to 9%. Furthermore, the present study showed that the best color and aroma were observed from Qellafo onion variety dried at 50^{o}C. On the other hand, the best taste was observed from Sweet Carolin onion variety dried at 50^{o}C. Generally onion dried at 50^{o}C scored the highest overall acceptability score than the other drying temperature.

Moreover, the present finding showed that storage period was significantly affected the quality of onion powder. The maximum and minimum total color change were observed from Sweet Carolin onion variety dried at 50^{o}C on day 90 and day one storage period (72.18 and 12.92 respectively). Likewise, Moisture content and Water activity (a_w) increased significantly during storage period. The minimum average water activity (0.242) was recorded from Sweet Carolin onion variety dried at 70^{o}C on initial day of storage period. Whereas, the maximum average water activity was obtained from Qellafo onion variety dried at 50^{o}C on 90 days of storage period. Similarly, Sweet Carolin onion variety dried at 50°C scored the highest moisture content (10.47%) on 90 days of storage period, whereas Qellafo onion variety dried at 70°C on initial day of storage scored the lowest moisture content (5.73%).

Correspondingly, the present study showed that vitamin C and pyruvic acid decreased during storage period. Qellafo onion variety dried at 50°C and 60°C scored the highest vitamin C on initial days of storage. However the Sweet Carolin and Bombay Red onion varieties dried at 70°C score the lowest vitamin C on 90 days of storage period. Similarly, the maximum average of pyruvic acid (6.93µmol/ml) was recorded from Qellafo onion variety dried at 50°C on day one whereas the minimum average of pyruvic acid was observed from Bombay Red onion varieties dried at 70°C on day 90 during storage.

Furthermore, the present finding indicates that the storage period significantly affected microbial load of onion powder. The maximum microbial loads were observed on day 90th storage period. The Sweet Carolin onion variety dried at 50°C on day 90 scored the highest bacterial counts however Qellafo onion variety dried at 70°C on day one scored the lowest microbial count. Similarly, Bombay Red and Qellafo onion varieties dried at 50°C on day 90th was scored the highest fungal count ($3.00x10^{-4}$ and $2.66x10^{-4}$, respectively).

According to the present study, With respect to bulk density, total soluble solid and water activity Sweet Carolin onion variety dried at 90°C had best quality than the other samples. From total color change Bombay Red onion variety dried at 50°C scored best color; whereas, respect to shrinkage ratio, pyruvic acid, vitamin C, fiber and sensory acceptability Qellafo onion variety dried at 50°C scored best quality, also Qellafo onion variety dried at 90°C had good water absorption capacity, moisture content and titratable acidity. During storage duration Qellafo onion variety dried at 50, 60 and 70°C had best pyruvic acid, vitamin C and moisture content.

Generally, the present finding indicates that the best quality of onion powder was obtained from Qellafo onion variety dried at 50°C. However, the best microbial quality of onion powder obtained at 70°C. Therefore, further research should be done using different packaging materials and storage condition to give conclusive recommendation about quality profile of the studied onion varieties under different drying temperature along with best shelf life.

6. FUTURE LINE OF WORK

The present study was done using only oven drying condition and plastic bottle packaging material at room temperature. Therefore, it is advisable to study using other different drying methods, packaging materials and different storage temperatures to recommend convenient storage media, drying condition and storage temperature. In addition to that, it was not possible to store powders for more than 90 days, due to financial and time limitation hence further research was necessary to determine the influence of storage duration for extended storage time. And also further studies need to be carried out to study the effect of drying time and different pre-treatment on quality and shelf life stability of onion powder.

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Appendices

Appendix 1 - ANOVA Table for Color of onion powder at different drying temperature

Source of variations	d.f.	Mean Squares			
		L*	a*	b*	ΔE
Variety	2	133.51*	66.76*	419.10**	2487.10*
Temperature	5	922.23**	63.42**	851.26**	282.02*
Variety* temperature	10	68.31**	5.17**	44.39**	5.21*
Cv (%)		7.71	17.56	5.31	13.43
LSD		5.96	2.12	3.71	7.62

Appendix 2 - ANOVA Table for ash % content of onion powder at different drying temperature

Source of variations	d.f.	Mean Squares	Pr.
Variety	2	2.14	<.0001
Temperature	5	2.41	<.0001
Variety* temperature	10	0.06	0.0560

Appendix 3 - ANOVA Table for rehydration ratio, shrinkage ratio and bulk density of onion powder at different drying temperature

Source of variations	D .f.	Mean Squares		
		RR	SR	BD
Variety	2	3.05*	57.52	0.0098*
Temperature	4	0.71*	558.63*	0.024**
Variety* temperature	8	0.01	11.24	0.00023
Cv (%)		8.07	8.83	2.798
LSD		0.11	2.77	0.017

Where; - RR -Rehydration ratio, SR -shrinkage ratio, BD –bulk density

Appendix 4 - ANOVA Table for water activity of onion powder at different drying temperature

Source of variations	D .f.	Mean Squares	Pr.
Variety	2	0.0003	0.0002
Temperature	5	0.74	<.0001
Variety* temperature	10	0.001	<.0001

Appendix 5 - ANOVA Table for fiber, Vitamin C and pungency of onion powder at different drying temperature

		Mean Squares		
Source of variations	d.f.	fiber	Vitamin C	Pyruvic acid
Variety	2	27.28**	1.46**	15.23**
Temperature	5	66.22**	15.96**	39.11**
Variety* temperature	10	2.06*	0.07 *	0.39**
Cv (%)		12.40	6.95	4.56
LSD		1.15	0.22	0.48

Appendix 6 - ANOVA Table for mosture, TA, pH and TSS of onion powder at different drying temperature

		Mean Squares			
Source of variations	d.f.	moisture	TA	pH	TSS
Variety	2	46.82**	0.02*	0.12	0.68*
Temperature	5	9236.10**	0.04*	2.48	6.27**
Variety* temperature	10	6.53**	0.01	0.02	0.08
Cv (%)		4.46	6.18	1.29	4.74
LSD		1.46	0.01	0.09	0.22

Appendix 7 - ANOVA Table for sensory quality of onion powder at different drying temperature

		Mean Squares				
Source of variations	d.f.	color	aroma	Taste	flavor	Over all acceptability
Variety	2	0.37**	1.15**	0.55**	0.04*	0.24**
Temperature	5	2.45**	1.39**	1.51**	0.77**	0.86**
Variety*temperature	10	0.07**	0.03*	0.15**	0.01	0.01*
Cv (%)		2.75	2.48	1.96	1.95	1.43
LSD		0.17	0.14	0.11	0.11	0.09

Appendix 8 - ANOVA Table for water activity, pH and titratable acidity of onion powder during storage

		Mean Squares		
Source of variations	d.f.	a_w	pH	TA
Variety	2	0.011	0.28*	0.05*
Temperature	4	0.033*	1.06**	0.02*
Day	3	0.014*	1.36	0.00*
Variety* Temperature	8	0.001*	0.04**	0.01*
Variety*Day	6	0.00*	0.01	0.00
Temperature*Day	12	0.00*	0.02*	0.00*
Variety* Temperature*Day	24	0.00*	0.01**	0.00**

Appendix 9 - ANOVA Table for moisture, vitamin and pungency of onion powder during storage

Source of variations	d.f.	Mean Squares		
		moisture	VC	Pungency
Variety	2	67.24*	3.89	40.76
Temperature	4	25.14*	2.32**	6.25*
Day	3	13.28	0.25	0.11*
Variety* Temperature	8	0.54*	0.31*	0.86*
Variety*Day	6	0.08	0.01	0.01
Temperature*Day	12	0.02*	0.02	0.02**
Variety* Temperature*Day	24	0.03*	0.04*	0.01**

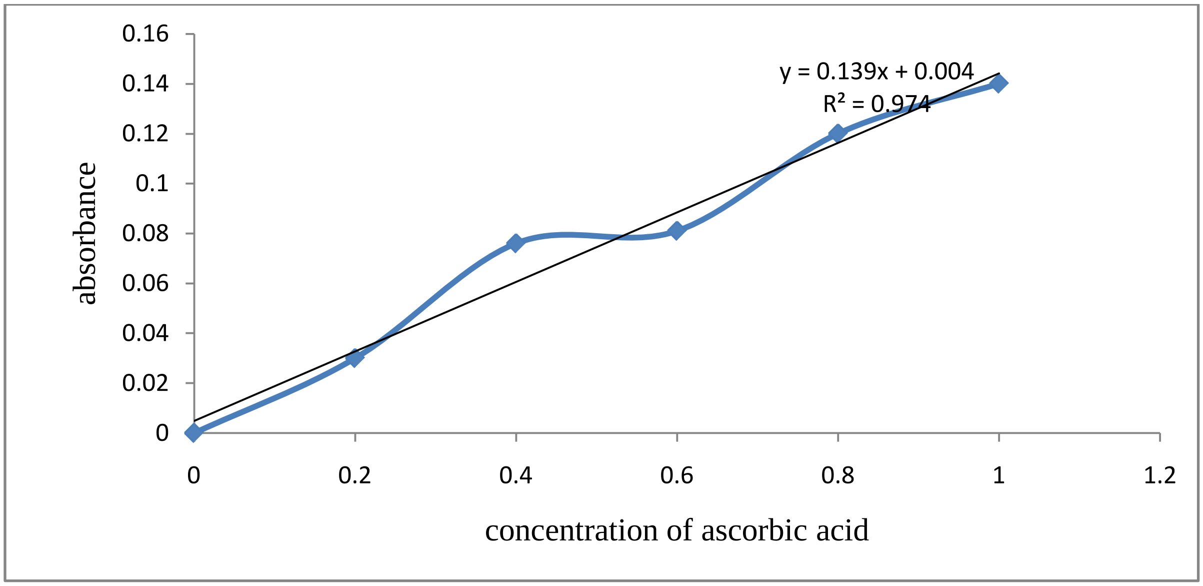
Appendix 10 - ANOVA Table for color of onion powder during storage

Source of variations	d.f.	Mean Squares			
		L*	a*	b*	ΔE
Variety	2	250.12*	279.51	2022.55*	1.15
Temperature	4	702.54*	65.31*	404.92*	275.23*
Day	3	149.21	105.92*	341.25	7076.62
Variety* Temperature	8	25.67*	3.99*	5.03*	5.89*
Variety*Day	6	0.03	1.63	0.00	1129.43
Temperature*Day	12	0.01*	0.41*	0.00*	279.67*
Variety* Temperature*Day	24	0.02*	0.41*	0.00*	5.39*

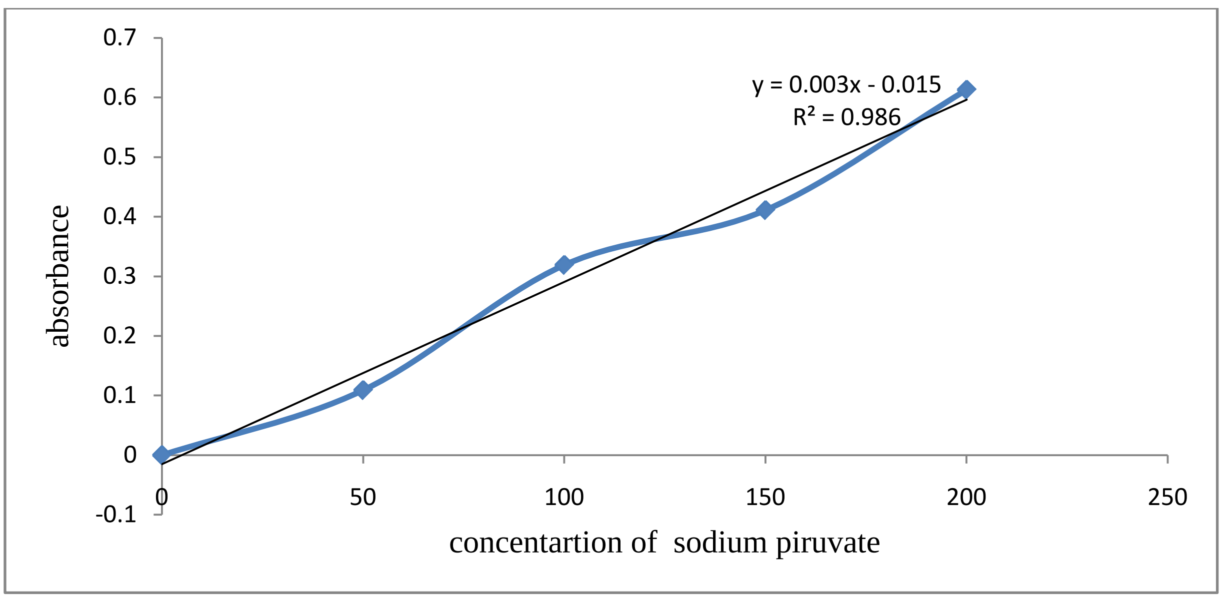
Appendix 11 - ANOVA Table for microbial quality of onion powder during storage

		Mean Squares	
Source of variations	d.f.	bacteria	Fungus
Variety	2	21.62	0.11
Temperature	4	29.41*	4.38*
Day	3	134.40**	35.28*
Variety* Temperature	8	1.76	0.15*
Variety*Day	6	0.57	0.51
Temperature*Day	12	0.23*	0.73*
Variety* Temperature*Day	24	0.27*	0.07*

Appendix 12- Standard curve of ascorbic acid (mg/100g)



Appendix 13- Standard curve of sodium pyruvate (ml/µmol)



Appendix 14- Sensory Evaluation Form

Date: ____________
Time: ________

You are provided with *dried onion powder* samples each with a three digit code. Please indicate how much you like or dislike each sample by checking and mark your choice with the number that corresponds to your preference on each parameter.

NB Please clean your mouth with water before proceeding to next sample for evaluation.

Scale:

1. Dislike Very Much
2. Dislike
3. Neither Like nor Dislike
4. Like
5. Like Very Much

No.	Sample Code	Color	Aroma	Taste	Overall Acceptability
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

Thank you!!!