Effect of Blanching and Frying Time on the Sensory Quality of Fried Sweet Potato Chips

TEFERI DAMTO*, GEREMEW CHALA
Department of Post-Harvest Management
Jimma University
Jimma, Oromiya
ETHIOPIA
*teferidamto@gmail.com

Abstract: - Sweet potatoes are a significant crop and are popular among consumers, particularly as chips. Frying of sweet potato slices is carried out to convert the roots to value added products. Frying method brings out unique flavor and texture to the products that improve their overall acceptability. The aim of this work was to determine the effect of blanching and frying time on sensory quality of fried sweet potato chips. Prior frying, sweet potato slices were blanched in order to inactivate enzymes and impart flavor. The blanching treatments were carried out at 65°C for 5 and 7 min and fried at 170°C for three different level of time (4, 5, and 6) minute. The mean of color and oil taste of the blanched, treated chips were in the range of 3.53-2.9and 3.97-2.9667, respectively. While, fried treated in the same parameters ranged between 3.8-.533, 92 and 3.5 and 3.667 respectively. The samples blanched at 5 minute and fried were gave darker chips compared to treated. Fried sweet potato chips blanched at 7 minute had the best sensory scores for all sensory quality attributes. So using this method is good for producing good quality chips. Therefore, treated with blanching and frying could be used to make a higher quality product that is more attractive to product developers and consumers.

Key-words: sweet potato; frying; blanching; sensory quality; chips

1 Introduction

Sweet potato is native to tropical and subtropical regions of the world and ranked the seventh most important crop following rice, wheat, maize, potato, cassava and barley (Woolfe, 1992). The sweet potato is extremely important for worldwide food security. Sweet potato is the second most important root and tuber crop in the world after potato (Horton, 1988). In Sub-Saharan Africa sweet potato is the third most important tuber crop after cassava (Manihotesculenta) and yam (Dioscorea spp.) (Ewell & Mutuura, 2004).More than 140 million tons of sweet potato is produced globally per year (FAO, 2000). The world average storage root yield of sweet potato has been estimated to be 14.8t ha-1. China is the leading producer of sweet potatoes with production reaching 75 million metric tons in 2011, which accounts for approximately 73% of global production (FAO, 2000).

In some of the world's poorest nations, taro and sweet potato are important part of food security packages (Yared Dagne, 2014). Ethiopia ranks fifteenth in the world in terms of sweet potato production (Dan et al, 2013). In Ethiopia, sweet potato is the second-most important root crop in the country after enset. It provides a healthy diet for millions of people across the country (Gurmu, Hussein, & Laing, 2015). Moreover, it is commonly cultivated as an integrated crop, along with livestock, in the crop–livestock farming systems (Belehu, 2003). Nationalities and Peoples' Region (SNNPRS) and Oromia are the main regions that produce sweet potato in Ethiopia (Gurmu et al., 2015). However, Ethiopia's average sweet potato storage yield is low with 8 t/ha, although the potential yield is 30 - 73 t/ha, and the international average is 14.8 t/ha (Belehu, 2003; Kivuva et al., 2014).In Ethiopia sweet potato ranks the first in total production (42.84%) and the second in area coverage (25.43%) next to Irish potato from root and tuber crops cultivated (CSA, 2014). Its root is used as food and feed. As food the root is usually consumed in boiled form. It is one of the cheapest sources of vitamin A. It is tolerant to adverse conditions like drought. It is an attractive food crop among farmers because it requires less care and input (CIP, 1995). It is a popular food in many parts of Eastern Africa. It is drought resistant, hardy and can grow in marginal areas, thus contributing to improved food security. The young leaves and vines can be consumed as vegetables or fed to livestock (CTA, 2007). The average yield ha-1 of sweet potato in Ethiopia is 33.74 ton ha-1 (CSA, 2014).

Sweet potato has numerous potential uses and benefits. As food, Sweet potato storage roots are boiled and eaten or chipped, dried and milled into flour which is then used to prepare snacks and baby weaning foods (Kidmose et al., 2007).Sweet potatoes tubers have good nutritional value, containing many vitamins, minerals, non-fibrous complex carbohydrates and dietary fiber (Suda et al., 2003). White and orange flesh sweet potato is rich source of β-carotene (provitamin A), a very good source of vitamin C and a good source of copper, dietary fiber, vitamin B6, manganese, potassium and iron, while purple-fleshed varieties are rich source of anthocyanins (Baybutt et al., 2000; Teow et al., 2007; Yang and Gadi, 2008). Sweet potato serves as a stable food vegetable (fleshy roots and tender leaves), snack food, wearing food, animal feed, as well as a raw material for industrial starch and alcohol. It is processed into diverse products (Ukom et al., 2009).

Antioxidants such as vitamin C have been shown to interact with and stabilize free radical**s** within the body. This action decreases the risk eye problems, like cataracts, many cancers and can help slow down the aging process. Vitamin C is also necessary for normal growth, absorption of iron, healing of wounds, formation of important protein used to make skin and stimulating the activity of the immune system. It is also needed for the maintenance of teeth and bones (Babalola et al., 2010).

One of the most important dietary compounds found in sweet potatoes is β-carotene, an important vitamin A source for human, which constitute 86 to 89% of orange and yellow fleshed sweet potatoes (Woolfe, 1992). Also, Burri (2011) suggested that orange-fleshed sweet potatoes are a nutritious and sustainable source for preventing vitamin A deficiency. Beta-carotene is most important as the precursor of vitamin A in human diet which maintains and protects eye tissues, but it has also been linked to enhanced immune response and suppressed cancer development. Carotenoids generally cannot be manufactured by humans so it must be added to their diet in appropriate amounts (Kopsell, 2006).

1.1 Statement of Problem

Sweet potato (Ipomoea batatas L.) is one of the most widely consumed tuber crops in the world .Sweet potatoes tubers have good nutritional value, containing many vitamins, minerals, non-fibrous complex carbohydrates and dietary fiber; however there is no sufficient technology that change this product to more finished product.Therefore, the application of new technologies to extend the post-harvest life of this commodity is needed. Blanching before frying also appears to be a good alternative.

1.2 Objective

The objective of this research is:

1.2.1 General Objective

- To determine the effect of blanching and frying time on the quality of fried sweet potato chips

1.2.2 Specific Objectives

- To evaluate the effect of different blanching and frying time on sensory quality of sweet potato chips
- To determine the suitable treatment to produce the acceptable organoleptic of sweet potato chips
- To examine the optimum blanching time , frying time and temperature of of sweet potato chips

1.3 Significance of Study

The study is believed to be significant in that it will be:

- Reduce postharvest loss of sweet potato in Ethiopia
- Produce the best quality sweet potato chips
- Provide information on treatment the parameters suitable for sweet potato chips.
- Reassure the consumer that a sweet potato chip is safe for consumption and addresses nutritional concerns.

1.4 Scope

The study generally covers:

- The processing method for production of sweet potato chips
- Developments of quality attributes of chips
- Sensory analysis majorly on Sensory Evaluation

2 Literature Review

2.1 Nutritional Value

The nutritional composition of sweet potato which are important in meeting human nutritional needs including carbohydrates, fibres, carotenes, thiamine,

riboflavin, niacin, potassium, zinc, calcium, iron, vitamins A and C and high quality protein (Tables 1). Sweet potato particularly provides energy in the human diet in the form of carbohydrates. According to USDA (2009), besides carbohydrates, they are also rich in dietary fiber and have high water content and also provide 359 kJ energy with low total lipid content, which is only about 0.05 g per 100 g. In addition, sweet potatoes also are high in minerals such as potassium, calcium, magnesium, sodium, phosphorus, and iron (USDA, 2009). Because of the various roles that sweet potatoes play around the world, the concept of nutritional quality and its contribution must transform to meet specific roles in human diet. For instance, staple type diets could require high vitamin C, iron, potassium, protein and as well as high fibre. Similarly, supplemental types of sweet components. However, as they will not be major food component, the level of components may be more flexible and good.

The phytochemicals, such as carotenoids and flavonoids, among the different varieties can differ from each other. Teow and others (2007) assessed the antioxidant activity, phenolic, and beta carotene contents of sweet potatoes with different flesh colors, which ranged from white, cream, yellow, orange, and purple. White flesh sweet potatoes were found to have the lowest antioxidant activity. The orange flesh varieties had a medium range antioxidant activity, and the darker orange flesh had slightly higher antioxidant activity. The purple flesh sweet potatoes had the highest antioxidant activity values, which was similar to that of fruits and vegetables, such as apples, avocado, cherries, broccoli and eggplants. The purple flesh varieties also had the highest phenolic content; contrastingly, the white flesh sweet potatoes had the lowest phenolic content. The anthocyanin content varied among the sweet potato flesh colors, which the purple and orange flesh varieties had anthocyanins that were detectable. For beta carotene, the orange flesh sweet potatoes had the highest amount versus the other varieties (Teow et al 2007).

Table 1. The nutritional value of raw sweet potato per 100g.

Nutrient	Units	Value per 100 grams
Water	G	77.28
Energy	kJ	359.00
Protein	g	1.57
Total lipid (fat)	g	0.05
Ash	g	0.99
Carbohydrate	g	20.12
Fiber, total dietary	g	3.00
Calcium, Ca	g	30.00
Iron, Fe	mg	0.61
Magnesium, Mg	mg	25.00
Phosphorus, P	mg	47.00
Potassium, K	mg	337.00
Sodium, Na	mg	55.00
Vitamin C	mg	2.40
Pantothenic acid	mg	0.80
Vitamin B-6	mg	0.21

Source: USDA (2009)

2.2 Types of Sweet Potato

There are hundreds of varieties of sweet potatoes with colors ranging from white, orange, and purple. Carotenoids and phenolic compounds give sweet potatoes the distinct flesh color. White Delight is a variety with white flesh, and NC414, NC415, Purple 04-069 and Okinawa are purple fleshed (Leksrisompong et al 2012; North Carolina Sweet Potato Commission 2015). The more consumer-recognized orange flesh sweet potato varieties include Beauregard, Hernandez,Jewel, Carolina Ruby, Porto Rico, Cordner and Covington (North Carolina Sweet Potato Commission 2015). Because of the varying flesh colors, the nutritional content can vary as well as the consumer acceptance.

2.3 Sensory Quality of Potato Chips

The sensory attributes of potato chips develop as a result of structural changes, chemical reactions, moisture loss and oil absorption in the raw potato during chip processing. Therefore, the dry matter constituents (e.g. starch, reducing sugars) of raw potatoes are of the importance as the sensory quality is largely dependent on the transformations of these constituents during the frying process (Bennet, 2001).

Quality can be described as the requirements necessary to satisfy the needs and expectations of the consumer (Claudio, 2006). According to Moreira et al (2006) states that the four principal quality factors in foods are: (1) appearance,

including colour, shape, gloss; (2) flavour including taste and odour; (3) texture; and (4) nutrition. Safety is also an important factor. Sensory quality of a food product relates directly to product quality as it is an important aspect of the total product quality as perceived by the human senses of sight, taste, smell, hearing and touch. Appearance, flavour and texture refer to sensory acceptability factors because they are directly perceived by the senses (Moreira et al., 2006). Bennett (2001) describes a quality chip as one having as addle-shaped curl, light golden colour, and having no blemishes. When placed in the mouth, it is crisp, has a slight potato flavour, is properly salted or seasoned and leaves a pleasant aftertaste in the mouth .The sensory quality of sweet potato potato chips is dependent on the composition of the potatoes, the frying oil and the processing parameters during chip manufacture (Gillat, 2001)

Table 2. Below shows the nutritional value of sweet potato chips per 100g. According to USDA (2010), sweet potato crisps contain higher energy (2074.00 KJ) compared to raw sweet potato (359.00 KJ). However, water content was reduced from 77.28 g in raw sweet potato to 4.00 g in sweet potato crisps due to evaporation during frying process. Besides that, protein, carbohydrate, fat and dietary fiber content in sweet potato crisps also higher than in raw sweet potato.

Table 2. Nutritional value of sweet potato crisps per 100gram

Nutrient	Units	Value per 100 grams
Water	g	4
Energy	kJ	2074
Protein	g	3.5
Total lipid (fat)	g	24.7
Ash	g	2.97
Carbohydrate	g	64.83
Fiber, total dietary	g	3.5
Sugars, total	g	7
Calcium, Ca	g	71
Iron, Fe	mg	2.55
Magnesium, Mg	mg	65
Phosphorus, P	mg	145
Potassium, K	mg	925
Sodium, Na	mg	35
Pantothenic acid	mg	1.55
Fatty acids (Total sat.)	g	0.54
Fatty acids (Total moonounsat.)	g	2.21

Source: USDA (2010)

2.3.1 Colour and Factors Affecting Colour of Sweet Potato Chips

Colour is probably the most important visual attribute in the perception of product quality among the different classes of physical properties of foods. Colour is an important visual appearance attribute among the major factors influencing consumer acceptability of fried products as it is the first quality parameter evaluated by consumers. Colour generally influences subjective sensory impression as it is regarded as a predictor of other quality characteristics such as flavour.For chips type product, the lightness of crisps colour are most desirable compared to golden and reddish brown colour (Pokorny, 1999).

2.3.1.1 Reducing Sugar Content

During the frying process, the colour of sweet potato slices changes due to the interaction of amine group with a reducing sugar which lead to non-oxidative browning known as Maillard reaction. Asparagine is the common free amino acids present in sweet potato. The higher level of reducing sugar content (e.g. glucose and fructose) in the sweet potato will contribute to darker colour of chips. Therefore, pre-treatment applied to sweet potato slices before the frying process to reduce reducing sugar level in the sweet potato (Garayo& Moreira, 2002).

2.3.1.2 Frying Condition

Frying condition also is one of the important variables that must be control to improve the colour of sweet potato chips. It includes the frying temperature, frying time and type of frying such as deep fat frying or vacuum frying. If too high frying temperature applied, the Millard browning reaction would proceed to unacceptable level (Chen et al., 2001). Regardless the frying type, conventional or vacuum, frying at high temperature increase the browning reaction as it is a temperature dependent reaction. In terms of frying type, the colour of vacuum fried sweet potato crisps is lighter than those that fried under atmospheric condition. It is because more Millard reaction occurred at the atmospheric condition due to present of oxygen (Garayo & Moreira, 2002).

2.3.2 Texture and Factors Affecting Texture of Sweet Potato Chips

Texture is also a key parameter in the development and acceptance of food products and an important attribute in determining consumer acceptability of fried foods (Krokida et al., 2005). Texture can be defined as ‘all the rheological and structural

(geometric and surface) attributes of the product perceptible by means of mechanical, tactile and where appropriate, visual and auditory receptors (Lawless & Heymann,1988). This attributes is significant for the acceptability of chips product. During frying, most of water evaporate and removed from the sweet potato slices resulting in textural changes. Texture attribute can be determined in terms of crispiness and hardness of the chips produced. Textural changes during frying are the result of much physical, chemical and structural change which produced during the frying (Troncoso et al., 2009). A high quality of sweet potato chips must have a very crispy texture as an indicator of freshness of the chips (Troncoso & Pedreschi, 2007).Crispness is one of the textural characteristics that are universally liked .One of the desirable textural attributes of sweet potato chip is often described as crispness(Kita et al., 2002). In foods described to be crispy, crispness is the most important quality attribute and its absence implies poor quality and loss of consumer acceptance. Crispness is associated with the textural experience of eating a food item which fails in a brittle manner (i.e. very suddenly and with relatively little deformation) at a low load suggested that crisp materials could generally be described as brittle, stiff cellular materials derived either from expanded starch or from starch-containing cellular materials such as potatoes.

2.3.2.1 Frying Condition

As a source of carbohydrate, potato and sweet potato mainly composed of starch component that may changes upon heating When frying sweet potato slices, starch granules are rapidly gelatinized and cause strong structure of raw sweet potatoes softening followed by formation of a firm and crispy crust upon furtherheating(Pokorny,1999).According Pokorny(1999),vacuum pressure was not significantly affecting the texture of potato chips. This indicate potato crisps fried under atmospheric condition are very weak in structure and easily collapsed during the rupture test (Garayo and Moreira, 2002)

2.3.2.2 Thickness of Slices

Slice thickness affect the amount of curl, strength and texture of crisps produced. Slices that are too thin may give negative effect on the texture of chips such as easily broken and oily of final products. On the other hand, thick slices tend to have high moisture content and less crisp (Bennett, 2001).

2.3.3 Flavour and Factors Contribute to Flavour of Sweet Potato Chips

The flavour of sweet potato chips is more complex than that of boiled, baked or mashed sweet potatoes, since the cooking temperatures are higher, and the absorbed oil contributes to the overall flavour profile of the product (Scanlon, 2003). In fried sweet potato products, flavour compounds are not only inherent in the raw sweet potato but also from the frying oil, Millard reaction products and from the interaction of Millard reaction products with lipid oxidation products. The complete composition and understanding of fried sweet potato flavour has not been fully established. Sensory differences in the aroma and taste of sweet potato chips made from different cultivars that varied in levels of dry matter, sugars, amino acids and lipids.

2.3.3.1 Lipid Oxidation

Lipid oxidation during frying is crucially important as it will impart flavour to the fried products. When oil is heated to elevated temperature, such as 180°C in the presence of oxygen, they may undergo oxidation and form hydroperoxides via free radical pathway. These compound are unstable and will be decomposed into secondary oxidation products which mostly volatile.

2.3.3.2 Maillard Reaction

Other important reaction that contributes flavour to the fried food is Maillard reaction. Even the Maillard reactions are undesirable in production of sweet potato chips; its roles has considered in terms of development of flavour on the final products. Maillard reaction occur when reducing sugars, lipid oxidation products and amino acids reacts heterocyclic compounds which give rise to food-related flavours and odours. It also produces non-enzymatic browning (Gillat, 2001).

2.3.3.3 Oil Uptake

Oil uptake during frying is also need to be considered during frying because the fat content of a product will also affect its flavour, odour and general organoleptic properties. The frying oil not only acts as heat transfer medium, because they are heated to high temperatures approximately 170-180°C, it will start to degrade through hydrolysis and oxidation of fatty acids. The breakdown products themselves give rise to flavour and can further react with carbohydrates, proteins and their decomposition products to produce taste traditionally associated with fried food (Gillat, 2001)

2.4 Effects of Pre-Treatment on Fried Chips

Pre treatments have a great effect particularly on the sensory properties and oil contents of fried products. The pre treatments are necessary before processing in order to retain colour, inactivate enzymes and/or enhance rate process. The ultimate aim of pre treatment is to improve quality of final product and reduce processing cost. Pre-treatment are very important in order to control chemical, physical and structural changes of raw material during frying process which may contribute to undesirable colour, texture and flavour of chips.There are several types of pre-treatment that is commonly use, such as blanching, drying, osmotic dehydration and soaking in calcium carbonate solution

2.4.1 Blanching

Blanching is a critical step in making sweet potato french fries. Blanching alters textural properties and imparts a soft or firm bite on sweet potato fries. The combination of temperature and time in the blanching process can create a creamy or firm internal in the sweet potato fry through the level of pectin and cell wall breakdown. Prior to drying, most food products are usually subjected to some form of pre-treatments, among which are hot water blanching and sulphiting. Blanching helps to inactivate enzymes that may lead to quality degradation .Blanching inactivates enzymes, improves the colour and texture of food products and reduces deterioration such as development of off flavor (Akpapunam et al., 20010). Osmo dehydration reduce changes in the physical, chemical properties and contributing to an improvement in quality. Blanching of is principally followed to inactivate the enzymes responsible for enzymatic and oxidative browning. The common methods of blanching include hot water, steam and chemical blanching. The loss of nutrients takes place during blanching which depends on temperature and time of blanching (Bennet, 2001)**.**When frying at high temperature blanched material dries more rapidly than the unblanched one (Moreira et al., 2008).

2.5 Product Quality Attribute

2.5.1 Oil Content

Oil content is one of the main quality parameters and sweet potato chip industry. Some of the parameters affecting the final oil content of fried products are product shape, temperature and frying time, moisture content, porosity, pore size distribution, and pre and post treatments. Oil uptake is essentially a surface-related phenomenon resulting from the competition between drainage and suction into the porous crust once the sweet potato is removed from the frying oil and starts cooling. During centrifugation, the centrifugal force acts perpendicular to the surface of the chips and separates the oil directly from the porous surface (Kita et al., 2005).The total oil content of fried products can be separated into two regions: the oil on the core of the product (internal oil) that is absorbed during frying, and the surface oil which is absorbed during cooling. Less oil is absorbed during the using different pre-treatment and de oiling steps (Moreira et al., 2001)

2.5.2 True Density

True density is the weight of the material per unit of true volume (kg/m3). True volume is the volume of the material including liquids, where all the volume of open and closed pores is excluded. A gas pycnometer,an apparatus that uses gas displacement, is generally employ to determine true density of materials given that the gas used is capable of penetrating all open pores up to the size of the gas (usually helium) molecule (Kawas, 2000).

2.5.3 Bulk Density

Bulk density is the mass per unit bulk volume (kg/m3), so it includes the air within the sample. Bulk volume in food can be difficult to calculate by its own geometrical characteristics since foods are usually irregular in shape (Kawas, 2000).Bulk volume of irregularly shaped materials can be measured by volumetric displacement of glass beads (Marousis et al., 1990), and by using liquid displacement with toluene (Costa et al., 2001; Lozano et al., 1983) or a water-ethanol mixture (Moreira et al., 2008).

2.5.4 Porosity

Porosity is a global characteristic of pores, which provides the volume fraction of total pores compared with the total volume of sample (Rahman, 1995). During frying liquid water moves from inside of the chips to the evaporation zone leaving the product through the surface as vapor. Some of the vapor remains trapped within the pores of the material due to restrictive intercellular diffusion. The vapor in this confined space will expand and become super-heated, distorting the pore walls and contributing for the chips porosity .The porosity increase slightly with oil temperature, and that

porosity rate has a similar behavior as the oil content rate during frying (Moreira et al., 2008).

2.5.5 Microstructure

Starch granules are often considered as semi-crystalline biopolymer entities where water molecules form an integral component of the crystalline domains. The ordered granule structure is disrupt by heating with water; this is known as gelatinization or melting (Parker and Ring, 2001). Almost any application of starch involves gelatinization the granule structure (Thiewes and Steeneken, 1997).A characteristic of sweet potato cells is the presence of a cell wall that limits the expansion of the cytoplasm. The outer layer of the cell wall is the middle lamella composes of pectic material that cements cell together and is dissolved during heating. Cells normally contain numerous starch granules (Miranda and Aguilera, 2006).Extracellular starch occurs when the cells rupture or disintegrate upon mechanical or thermal stress during processing. The frying process involves simultaneous heat and mass transfer that causes significant microstructural changes to both the surface and the body of the product. Gamble et al (1987) examine the microstructure of sweet potato chips using light microscopy. Also, integrity of cell walls and the presence of a dense starchy interior support the idea that oil cannot penetrate into the cells during frying

2.6 Sweet Potato Chip Processing

In addition to the raw sweet potato characteristics, the sweet potato chip processing steps are major factors influencing the potato chip quality. From the receipt of sweet potatoes at the processing plant and subsequent processing steps, the chip manufacturer ensures set specifications are maintained to yield chips of uniform quality. Sweet potato chip processing is a dynamic system of interdependent steps linked together to convert a sweet potato into a chip (Bennett, 2001).

Receiving ⇨ washing ⇨ peeling ⇨ trimming ⇨ slicing ⇨ Frying ⇨

Flavouring ⇨ packaging

Fig.1 Schematic diagram of potato chip processing

2.6.1 Receiving

This is one of the critical steps as the decision to accept or reject lot of sweet potatoes for processing is made during this step. The suitability of sweet potatoes for chip processing is established by carrying out raw sweet potato quality assessments on a representative sample of the lot immediately on receipt of the potatoes at the processing plant. These assessments include the determination of size and shape, presence of defects (external and internal) and specific gravity (solids content) (Bennett, 2001). It was observed at the sweet potato chip manufacturer that, a representative sample of the potatoes was peeled, sliced and fried to visually inspect the appearance of the chips against set standards of colour and after-fry defects.

2.6.2 Cleaning, Peeling and Trimming

The peeling duration is dependent on the surface characteristics of the sweet potatoes such as eye depth, cortex thickness and surface injuries (Lisiñska, 2004). The control of the peeling operation is essential as insufficient peeling may result in poor appearance of the chip (Bennett, 2001). Peeled sweet potatoes are passed on the inspection belts where defects are trimmed off (Bennett, 2001; Lisiñska, 2004). Presence of defects such as bruises, green and dark spots, decayed portions and eyes give a poor appearance to chips (Lisiñska, 2004).

2.6.3 Slicing

The slicing operation is of fundamental importance and among the most important steps to the manufacture of high quality sweet potato chips (Bennett 2001). The slicing step is known to impact upon chip appearance, colour, texture, slice contour, breakage, oil absorption, moisture content and frying time (Miranda & Aguilera, 2006). According to Bennett (2001) slices that are very thin have a negative impact on colour and tend to be oil soaked and easily broken, whereas, thick slices tend to have a high final moisture content and are less crispy. Uniformity between slices is extremely important as it may create undesirable characteristics of both thin and thick chips and affecting the sensory quality (Bennett, 2001).

2.7 Potato Chip Frying

Frying is a dehydration process which involves heat and mass transfer. In addition, different chemical changes occur during frying such as protein denaturation, starch gelatinization, surface browning, rapid water evaporation and oil absorption (Pinthus et al., 1995a).Oil absorption is affected by various factors such as frying temperature and time, food composition, porosity, pre treatment and oil quality (Pinthus et al;1995b).
Food frying is a common process in the food industry used to enhance the overall quality, texture

and flavour of snack foods, dough nuts, chips, french fries and poultry products (Chukwu, 2009). Frying is a unit operation which involves the immersion of food products in hot oil (175°C) until the desired product attributes are obtained, from creating the proper appearance to fully-cooked product. During frying, heat and mass transfer takes place simultaneously; heat is transferred from the oil to the food, water is evaporated from the food material and oil is absorbed (Krokida *et al*., 2001b). At these high temperatures the food material undergoes intense dehydration coupled with structural changes (i.e. formation of pores and crust, curling, expansion or shrinkage), physico- chemical transformations (colour and flavour formation) and microbiological inactivation (smith, 2005).The desirable sensory properties of potato chips are developed during frying and thus apart from the quality of the raw sweet potatoes the conditions during frying will affect the final product quality (Hubbard & Farkas, 1999; Lolos, Oreopoulou & Tzia, 1999).

2.7.1 Frying Temperature and Time

Frying time and temperature are processing variables that the manufacturer manipulates in order to produce optimum quality chips and depends on the raw sweet potato composition and slice thickness (Moreira *et al*., 1999; Gamble & Rice, 2003). These frying variables influence the texture (Miranda *et al*., 2005), final oil content (Baumann & Escher, 1995), colour and flavour (Pedreschi *et al*., 2005). It is reported that higher temperatures yield chips with less oil than lower temperatures since hotter oil has a lower density and is not adsorbed as easily whereas lower frying temperatures require longer frying times, allowing the chip surface to adsorb more oil (Saguy *et al.,* 2001).

2.7.2 Frying Oil

The frying oil is the heat transfer medium and contributes to the final characteristics of the fried food (Stier, 2004; Vitrac *et al.,* 2000). As the food fries it absorbs part of the frying oil and thus it contributes to the overall quality of the fried food (Stier, 2004). Frying continuously at elevated temperatures leads to oil breakdown (Stier,2004).Basic deterioration reactions during frying are hydrolysis caused by steam from the food, oxidation caused by air (oxygen) and thermal alterations caused by heat (Blumenthal, 2001).

3 Result and Discussions

3.1 Result (output of the experiment)

Table3. Main effect of blanching on sensory quality of fried sweet potato chips

Factors	Parameters					
Blanching time	Oil taste	Colour	Odour	Texture	flavour	Overall acceptability
0	2.9667^{B}	2.9^{B}	2.53^{B}	2.9^{B}	3.2^{B}	2.9^{B}
5	3.367^{B}	3.53^{A}	3.13^{A}	3.83^{A}	3.833^{A}	2.9^{B}
7	3.97^{A}	3.3^{AB}	3.3^{A}	3.167^{B}	2.9^{B}	3.6^{A}

*Means followed by the same letter within a column are not significantly different $p<0.05$

3.2 Discussion

Sensory qualities are the main criterion that makes the product to be liked or disliked. The average and least means square of Sensory attributes scores of liking chips from plum sweet potatoes blanched at 65°C at two blanched level with control at which no blanched taken was presented in the above tables.

3.2.1 Oil Taste

Oil taste is the parameters that give the product the unique texture flavour combination that makes them so desirable on the sense of smell. The sensory score of oil taste for the three treatment chips samples had ranged from 3.97 to 2.967. The highest score was recorded when sweet potato was blanched at 7 minute. The least score was recorded with the control treatment, which have no blanched taken place. Blanching has a significance effect on control and blanched at 5 as compared to 7. But blanching has no significance effect between 0 and 5. Among the treatment, treatment 7 has highly significance over the other treatment. This shows that blanching has significance effect on oil taste of the chips. According to Kimberly Button (2015) pre treatments, such as blanching and drying, can affect oil uptake by the product and final product texture.). In a study by Walter and others (2003), evaluated the blanching of purple-fleshed sweet potato strips with hot water blanching because hot water blanching is the preferred method of French fry manufacturers. The strips were blanched for 0, 5, and 10 minutes in boiling water, which was about 98°C(208.4°F).Oner and Wall used high temperature blanching that readily decreased the

force in which to penetrate the strips, and ultimately, the softest texture was observed in the 10 minute blanched strips. Although, the strips blanched for 10 minutes had more oil absorption after frying because the surface cell integrity was damaged allowing more water to release and oil to be absorbed (Oner and Wall, 2012)

3.2.2 Colour

The sensory score of color for the three samples had ranged from 3.53 to 2.9. Control is significant difference as compared to the two treatments 7 minute and 5. But there is no significance difference between treatment treated at 7 minutes and 5 minute. The highest score was recorded when sweet potato is blanched at 5 minute. The least score was recorded with the control treatment, which has no blanched. This indicate that blanching has a significance effect on colour. Blanching pre-treatment is usually performed to prevent development of off flavours and colour changes resulting from enzymatic reactions; as well as to decrease the initial microorganism load (Oluwole, O.B et al., 2015). Blanching pre-treatment of potato in hot water or chemical solutions before frying have been reported to improve colour and texture and could reduce oil uptake in some cases by gelatinization of the surface starch (Bunger et al., 2003; Rinac Brncic et al., 2004). Akpapunam and Abiante (1991) showed that sweet potato slices blanched in water and 1% sodium metabisulfite solution, respectively, prior to the dehydration (at 70°C for 165 min) and frying (at 190°C for 2 min) significantly improved the colour and general acceptability of the chips compared to those immersed in water, only. Colour of potato chips was significantly influenced by blanching. Blanching lead to lighter in colour potato chips than those of the control after frying at 150°C (Pedreschi F.,et al 2005). Rodriguez et al (1999) found that reducing sugars had the biggest influence on lightness, producing the brighter colours when these sugars were absent; however, reducing sugars did not entirely predict colour quality when present at low concentrations. Colour is one of the most important quality factors that need to be considered during frying. There is also similar observation found by Olu Malomo et al (2013) blanching affect the quality characteristics (colour) of sweet potato flour produced compared to un blanched sweet potato flour.

3.2.3 Flavour

Flavour is the sensation produced by a material taken in the mouth, perceived principally by the senses of taste and smell, and by the general pain, tactile, and temperature receptors in the mouth. The sensory score of flavour for the three treatment

chips samples had ranged from 3.833 to 2.9. the highest score was recorded when the sample or sweet potato blanched at 5 minute. The least score was recorded with the samples blanched at7 minute treatment. This show that 5(3.833) is highly significance on the other two treatments (0 and 7). But there is no significance effect between treatment 0 and 7. Luis (1997) established that flavour is one of the important quality factors of potato chips and is affected mainly by the type of oil used to fry chips, flavour compounds inherent in the raw potatoes, and added flavourings. According to Dagne Tafa and Tigist Abebe (2018) blanching improves the flavour of the chips.

3.2.4 Textures

Texture is also a key parameter in the development and acceptance of food products and an important attribute in determining consumer acceptability of fried foods (Krokida, Oreopoulou, Maroulis & Marinos-Kouris, 2001b; Miranda, Aguilera, & Beriestain, 2005).The sensory score of texture for the three treatments of chips samples had ranged from 3.833 to 2.9. The highest score was recorded when samples was blanched at 5 minute at constant temperature and this indicate that treatment 5 has highly significance difference on other two treatment (0 and 7). The least score was recorded with the control treatment, which has no blanched even though there is no significance difference between the two treatments (0 and 7). According to Kita (2002), the crisp texture of potato crisps depended on the content of starch in the tubers as well as nitrogen substances and non-starch polysaccharides. In a study by Walter and others (2003), low temperature blanching (LTB) was used to promote the firmness of sweet potato cylinder strips.Agblor and Scanlon (2000) assessed that texture and color of chips as affected by blanching, drying, and frying. Leeratanarak et al (2006) found that blanching reduced the hardness i.e. better texture of the product, however, the use of different blanching periods did not significantly affect the product hardness. Blanching alters textural properties and imparts a soft or firm bite on sweet potato fries. The combination of temperature and time in the blanching process can create a creamy or firm internal in the sweet potato fry through the level of pectin and cell wall breakdown (Kimberly Button, 2015)

3.2.5 Overall Acceptability

The overall acceptability refers to the assumption taken from the aggregate effect of the all consideration of the above quality parameters. The sensory score of this overall acceptability for the three treatments of chips samples had ranged from 3.67 to 2.9. The highest score was recorded when chips samples was blanched at 5 minute. This indicates that treatment 5 has no significance with treatment 7. The least score was recorded with the control treatment, which has no blanched. This indicates that blanching has significance effect on control as compared to other two treatments (5 and 7).

Andersson et al.,1996 reported that in the case of potato processing, blanching is used to inactivate peroxides, to improve the texture, colour and, to some extent, the flavour of final product. Potato blanching affects the enzyme activity that leads to quality degradation (Tizita Mamo, 2018). Potato product quality and acceptability are related to colon and texture (Pedreschi et al., 2005). Yost et al (2006) showed that colour is the first attribute of a food product that immediately convey a positive or a negative connection of overall quality. Colour also influences a consumer's perception of flavour, taste, and the intent to purchase a food product according to Dagne Tafa and Tigist Abebe (2018).Blanching pre-treatment of potato in hot water or chemical solutions before frying have been reported to improve colour and texture and could reduce oil uptake in some cases by gelatinization of the surface starch (Bunger et al., 2003; Rinac– Brncic et al., 2004).

3.3 Effect Frying Time on Sensory Quality of Fried Sweet Potato Chips

Table 4. The main effect of frying time on sensory quality of fried sweet potato chips

Factors	Parameters					
Frying	Oil taste	Colour	Odour	Texture	Flavour	Overall acceptability
4	3.3667^{A}	3.8^{AA}	3.1667^{AA}	2.8^{B}	3.133^{A}	2.9^{B}
5	3.433^{A}	3.4^{A}	2.9667^{AA}	3.4^{A}	3.5667^{AA}	3.8^{AA}
6	3.5^{AA}	2.533^{B}	2.833^{A}	3.7^{AA}	3.233^{AA}	3.4^{A}

* Means followed by the same letter within a column are not significantly different $p<0.05$

3.3.1 Oil Taste

Oil taste is the parameters that give the product the unique texture flavor –combination that makes then so desirable on the sense of smell. The sensory score of oil taste for the three treatment chips samples had ranged from 3.5 to 3.3667. The highest score was recorded when sweet potato was fried at 6 minute. The least score was recorded when chips sample was fried at 4 minute. This result indicate that there no significance among all treatments. The sweet potato chips also had more oil uptake with the longer frying time. The researchers indicated that the oil uptake can be affected by cellular structures in the different sweet potato varieties. Textural properties were evaluated by a compression test. The maximum force to compress decreased as frying time increased. The force to compress did increase slightly when the 4 to 5 minute frying time was used, which may be attributed to the crust development in the longer frying times. Crust development and sealing of the surface of the sweet potato fries can result in a low oil uptake. Other factors that can affect texture of sweet potato french fries are gelatinization of starch, sugar content, α-amylase activity, breakdown of cell wall, and protein denaturation while frying. All of the sweet potato varieties browned more with increased frying time due to the Maillard reaction that uses the reducing sugars in the sweet potatoes. Overall, Ginseng Red had the lowest oil content and the best crispy texture (Odenigbo et al., 2012). Mellema (2003) and Saguy & Dana (2003) observed that consumers' preference for low fat and fat-free products were driving the food industry to lower oil content in fried foods. Lisiñska (1989) reported that potato chips high in oil content appear greasy/oily

while those of very low oil content are of a hard texture and lack flavour.

According to woolfe (1992) variation in oil taste may be due to the different pre-frying treatments used in the various studies. For instance, high initial moisture content and blanching have been reported to contribute to increased oil absorption in fried sweet potato crisps (Woolfe, 1992). According to deMan (1999), lower frying temperature and longer frying time results in higher oil uptake. The author however stated further that oil absorption depends on conditions of frying and the nature and size of the food. In the present study, at each frying temperature, the fat content of the sweet potato crisps reduced with increase in frying time. Frying temperature and time, initial moisture content, pore size distribution, porosity, the geometry of the product, and pre and posttreatments are some parameters which can affect the final oil content of fried product (Saguy et. al., 1995; Moreira et. al., 1997; Bouchon and Aguilera, 2001). Frying temperature and time, initial moisture content, pore size distribution, porosity, the geometry of the product, and pre and posttreatments are some parameters which can affect the final oil content of fried product (Saguy et. al., 1995; Moreira et. al., 1997; Bouchon and Aguilera, 2001). Potato strips blanched at 97 °C for 2 min and subsequently fried presented impaired color, loss of textural quality, and increased oil absorption as compared to unblanched ones (Alvarez et al.,2000).the frying variables influence final oil content sweet potato chips according to study (Baumann & Escher, 1995).

3.3.2 Colour

The sensory score of colour for the three samples had ranged from 3.8 to 2.533. There is significant difference between means at 5 minute and control, even though there is no difference between treatment treated at minutes and minute. The highest score was recorded when sweet potato is fried at 4minute even though it has high mean there is no significance difference with treatment 5 but, it has high significance over the treatment 6. The least score was recorded when chips sample was fried at 6 minute. This indicate that frying has significance effect on treatment 6(colour). Sahin (2000) studied the effects of frying time and temperature on the colour kinetics of French-fried potatoes during frying; the author developed a multiple regression equation for total colour change as a function of time and temperature. The equation showed that increase in time and temperature increased total colour change.

3.3.3 Flavour

Flavour is the sensation produced by a material taken in the mouth, perceived principally by the senses of taste and smell, and by the general pain, tactile, and temperature receptors in the mouth. The sensory score of flavour for the three treatment chips samples had ranged from 3.566 to 3.133 The highest score was recorded when the sample or sweet potato fried at 5 minute and the least score was recorded with the samples fried at 4 minute treatment this indicate that there is no significance difference between all treatment. In fried potato products, flavour compounds are not only inherent in the raw potato but also from the frying oil, maillard reaction products and from the interaction of maillard reaction products with lipid oxidation products (Stier, 2000; Maga, 1994; Whitfield, 1992). Variations in flavour exist between varieties although there is little published research (Dale & Mackay, 1994). Ereifej, Shibli, Ajlouni & Hussein, (1997) reported sensory differences in the aroma and taste of potato chips made from different cultivars that varied in levels of dry matter, sugars, amino acids and lipids. The frying variables influence the colour and flavour (Pedreschi et al., 2005).

3.3.4 Textures

The sensory score of texture for the three treatments of chips samples had ranged from 3.7 to 2.8. The highest score was recorded when samples was fried at 6 minute at constant temperature. Treatment 5and 6 have highly significance difference over the treatment 4. But there is no significance difference between 5 and 6. The least score was recorded when the samples was fried at 4 minute. Frying has significance effect on Treatment 4 as compared to the two treatments (5 and 6). Crispness increased with increase in frying time. This indicates that frying temperature and time are important factors affecting the sensory quality of sweet potato crisps. (G. O. Fetuga et al., 2014). Verlinden et al(2000) found that hot water blanching of potatoes at 55–75 °C affected their texture parameters, as per reducing the maximum force and the rupture force of the samples, and increasing the deformation at maximum force and the rupture deformation. They attributed this behavior the loss of turgor pressure in the tissue during heating. Additionally, they found that blanching/cooling before cooking had a strengthening effect on potatoes, especially when blanching treatments were longer. The frying variables influence the texture (Miranda et al., 2005)

3.3.5 Overall Acceptability

The overall acceptability refers to the assumption taken from the aggregate effect of the all consideration of the above quality parameters. The sensory score of this overall acceptability for the three treatments of chips samples had ranged from 3.8 to 2.9. The highest score was recorded when chips samples was fried at 5 minute. Treatment 5 and 6 has high significance difference over treatment 4 but, no significance between them. The least score was recorded when samples was fried at 4minute.Frying has significance effect on Treatment 4 as compared to the two treatments (5 and 6). The desirable sensory properties of potato chips are developed during frying and thus apart from the quality of the raw potatoes the conditions during frying will affect the final product quality (Hubbard & Farkas, 1999; Lolos, Oreopoulou & Tzia, 1999).According to study found G. O. Fetuga et al (2014) taste, colour, flavour, crispness and overall acceptability were significantly affected by the individual and combined effects of frying temperature and frying time. This indicates that frying temperature and time are important factors affecting the sensory quality of sweet potato crisps.

4. Conclusions

The effects of blanching and frying time on the Sensory and nutritional characteristics of sweet potato chips were investigated .These results showed the blanching time treatment has effect on the quality characteristics of sweet potato as compared to unblanched samples. Blanching sweet potato could be used to enhance the quality of food products such as colour, flavour, texture, and overall acceptability fried sweet potato treated with 5 minute was the best sample in all sensory characteristics The sweet potato blanched at 7 minute was observed as a good quality than others and in the case of time frying at 5 and 7 minute resulted good overall acceptability So using these method is good for producing good quality chips. Generally, the pre-treatment improved the textural properties of fried samples in terms of hardness, springiness, chewiness, cohesiveness and, adhesiveness. Therefore, treated with blanching and frying could be used to make a higher quality product that is more attractive to product developers and consumers.

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