EVALUATION OF COMMERCIAL POTATO CRISPS PROCESSING IN KENYA: CHARACTERISTICS OF THE MARKET AND INDUSTRY, AND SUITABILITY OF THE LOCAL CULTIVARS FOR PROCESSING

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DECLARATION

This thesis is my original work and has not been presented for a degree award in any other University.

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DEDICATION

This work is dedicated to my late mother, Dorfin for her dedication, love and care, and to my father, Abong' and uncle, Omolo, for being wonderful guardians. Most of all, I dedicate it to my wife, Joyce and our son, Baraka whose understanding, patience and encouragement enabled me to carry out this work smoothly to its conclusion. To God be the Glory, Honor and Power.

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ABSTRACT

Potato crisps are increasingly becoming important as a snack food in Kenya. However the processing industry is faced with several constraints, the main one of which is lack of adequate quality raw potatoes. The objective of this study was to evaluate the performance of locally produced potato cultivars for processing into crisps, a major snack food in Kenya. A survey was conducted in the year 2009-2010 to obtain baseline information on the status of processing industry, consumption patterns, diversity and characteristics of potato crisps. Available potato varieties and cultivars undergoing National Performance Trials were evaluated for processing into crisps and the best performing tubers were selected for further assessment. Losses of reduced ascorbic acid (RAA) during frying, packaging and storage of potato crisps from the selected cultivars were determined. The performance of the selected potato cultivars in terms of oil uptake, color, texture and organoleptic properties of crisps was evaluated, at varying slice thickness and frying temperature. The effect of packaging and storage temperature on the shelf life of crisps made from the selected potato cultivars was also determined.

The results of the survey indicated that a total of 24 brands of crisps were available in the market. All the outlets surveyed stocked local, while 15% of the outlets also stocked imported brands of crisps in addition. The frequency of crisps purchased was influenced by factors such as festive occasions, seasons and purchasing power. Characteristics of the brands evaluated which included color, size, thickness, moisture, salt and oil content varied significantly ($P \leq 0.05$) among the brands. About 90% of crisps processors were small and medium enterprises. About 4% of the processing firms identified the main constraints as lack of proper equipment and market, 43% indicated lack of finances to increase volume of production, while 64% as lack of suitable potatoes and due to poor quality. Dutch Robjin was the potato variety used by most processors (76%).

The specific gravity of the cultivars evaluated for crisps processing varied from 1.074 to 1.098 and dry matter content from 19.50% to 24.20%. Reducing sugar levels significantly ($P \leq 0.05$) varied among the cultivars and ranged between 0.07 and 0.4%. The varieties Dutch Robjin, Tigoni and Kenya Baraka and the clones 393371.58, 392657.8, 391691.96 and 393385.39 were identified as suitable for processing. They had desired physical characteristics with low levels of reducing sugars ($\leq$ 0.25%), and were highly rated by sensory panelists. There was significant ($P \leq 0.05$) reduction in the level of ascorbic acid, 45% in the average, in all the cultivars when tubers were fried into crisps. Package type and storage temperature significantly ($P \leq 0.05$) influenced the retention of ascorbic acid in crisps during storage.

Crisps made from the selected four cultivars differed significantly ($P \leq 0.05$) in oil absorption which ranged from 35.12% in Dutch Robjin to 36.52% in clone 391691.96. For each cultivar, the oil content of crisps differed significantly ($P \leq 0.05$) with temperature and was highest (38.42%) at frying temperature of 160 °C and lowest (33.08%) at 180 °C. The oil content was significantly ($P \leq 0.05$) higher (48.54%) in slices of 1.0 mm thick than in slices of 1.5 mm (35.12%) and 2.0 mm (29.80%). Texture significantly ($P \leq 0.05$) increased with increase in frying temperature and slice thickness. Potato cultivar and slice thickness significantly ($P \leq 0.05$) influenced the lightness (L*), redness (a*) and yellowness (b*) color parameters. Redness and yellowness parameters significantly ($P \leq 0.05$) decreased with increase in frying temperature.

Results of shelf life evaluation indicated that aluminium foil pack was the most effective material in controlling moisture, and reducing lipid deterioration. Cultivar significantly ($P \leq 0.05$) influenced the formation of peroxides. Crisps from Cv. 391691.96 had the lowest (0.38%) peroxide values while it was highest (7.44%) in Tigoni crisps after 24 weeks of storage. The products stored at 35 °C had significantly ($P \leq 0.05$) shorter shelf life compared to those stored at 25 and 30 °C. Crisps flavor, aroma and acceptability significantly ($P \leq 0.05$) varied with cultivar and storage temperature.

Variety Tigoni that is known to be high yielding can produce equally good quality crisps should be promoted alongside Dutch Robjin that is currently used by many crisps processors in Kenya. The advanced clones 391691.96 and 393385.39 were comparable to Dutch Robjin. The National Potato Research Centre (KARI) should therefore ensure adequate production and distribution of seeds of these cultivars to farmers for supply to processors. Variety, frying temperature and slice thickness are important factors influencing oil uptake, color, texture and sensory properties of crisps processed from local potato cultivars and should therefore be considered by processors.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background information

Potato in Kenya is an important food and cash crop that has been known to play a major role in food security (MoA, 2005). Potato production is confined to the highlands (1500-3000 m above sea level) where the crop has higher yields than most of the major food crops. High production of potatoes is concentrated in Central, Rift Valley and Eastern. High altitudes of Western and Coast provinces are also involved in production to a smaller extent (Kabira, 1990). The production of the crop is increasing due to economic decline of competing cash crops such as maize and pyrethrum, and increasing demand from consumers and processors (Kabira, 2002).

Many potato varieties have been grown and marketed in Kenya. The varieties include Roslin Eburu, Roslin Tana, Roslin Gucha, Roslin Bvumbwe, Nyayo, Kenya Sifa, Kenya Baraka, Desiree, Asante, Tigoni, Annet, Dutch Robjin and Kerr's Pink (KAIC, 2004). Most of the varieties, however, are faced with the challenge of susceptibility to diseases and poor processing qualities (Lung'aho *et al.*, 2006; MoA, 2007). The National Potato Research Center (KARI-Tigoni) continues to develop new varieties presumed to be superior to existing ones in terms of disease tolerance (mainly late blight and viruses). The processing qualities of the available varieties have never been adequately established. Among the existing varieties, the round red-skinned types Kerr's Pink and Dutch Robjin have been used for crisps (Kabira, 2002). Though limited to sensory evaluation, crisp processing characteristics of Asante, Tigoni and Furaha were also evaluated (Kabira, 2000; Kabira, 2002). Many advanced clones from the International Potato Centre (CIP), Lima-Peru have been introduced at various periods into the national potato breeding programme for variety development. These clones have undergo multi-locational trials and the most promising ones undergo national performance trials in collaboration with Kenya Plant Health Inspectorate Service (KEPHIS) for possible release as varieties (Kiplagat, 2008).

The most important products in the Kenyan potato processing industry are potato chips (French fries), followed by crisps and frozen fries whose demand have rapidly increased due to rapid growth of fast food restaurants and snack bars in the urban areas (Walingo *et al.*, 2004; Kabira, 2007). Potato crisp processing for instance has undergone tremendous growth over the last three decades. In early 1980s, only five potato crisps producers were located in Nairobi city (Durr and Lorenzl, 1980). In 1995, there were at least twenty two processors with an average production of 61 tons per month while in 2004 the number of enterprises was estimated at forty in the same region (Walingo *et al.*, 2004). The main outlets for crisp sales in the city were noted to be supermarkets (60%) and wholesalers (40%) with high consumptions during Christmas, Easter, school holidays and tourist seasons.

The Potato crisp is a brittle but firm slice of potato which has deep fried in vegetable oil and to which edible salt or permitted food grade spices, color and flavor may be added (KEBS, 2007; Salvador *et al.*, 2008). Potato crisps should be prepared from fresh and clean potato tubers that are generally round and measuring 40-60 mm in diameter (Kabira and Lemaga, 2006).

Basic steps in processing of crisps begin with raw material selection, peeling, washing, trimming, slicing, water drainage, frying, and end with flavoring and packaging. There are, however, variations in the type and size of slices used and flavors incorporated in the final product. The processing industry requires potatoes with well-defined characteristics. The potato varieties used in preparation of potato crisps vary among processors and countries depending on the suitability and availability. Crisps therefore, depending on country of origin and the processor vary in quality. The major hindrance to crisps industry in Kenya is the unavailability of sufficient quantities of preferred quality potato varieties (Walingo *et al.*, 2004; Kabira, 2007).

Processing potato crisps is carried out at high temperatures (150-200 °C) which affects many quality attributes including nutritional content, texture and colour, oil uptake and organoleptic properties. However, no information is available on the performance of potato cultivars in processing crisps in Kenya. The present study sought to establish the current status of potato crisps processing industry, diversity, characteristics and consumption pattern of crisps in Nairobi, Kenya. In addition, this research in collaboration with Kenya Agricultural Research Institute and a major potato crisp processor was designed to evaluate locally produced potato cultivars for suitability in production of potato crisps.

1.2 Problem statement and justification

Potato crisps manufacturing industry is an important outlet for Kenyan farmers' production yet the country has only one variety for crisping, Dutch Robjin (Maingi, 2009). Unfortunately, the best processing tubers of this variety come from only one region of the country, which is Bomet in the Rift Valley Province. The tubers of Dutch Robjin variety have medium to deep eyes that may lead to substantial peeling and trimming losses. There exist several potato cultivars that if identified can provide in addition to Dutch Robjin adequate processing materials in an expanding crisps market for local and export (Walingo *et al.,* 2007; Ooko, 2008). Indeed, during periods of scarcity the over 40 processors suffer capacity under-utilization of their factories with DEEPA Industries, one of the largest and oldest processing enterprises, in Nairobi having up to 35-60% of the 20 tonnes capacity per day under-utilized (Walingo *et al.*, 2004). Although managers are aware of quality attributes of potato varieties for production of the best quality crisps, lack of sufficient quantities of these varieties force them to use any available variety (Walingo *et al.*, 2004).

The government of Kenya has outlined the key role value addition in agricultural sector will play under economic pillar in its vision 2030 policy paper, a development blueprint covering the period 2008 to 2030. The vision synergizes Strategy for Revitalization of Agriculture (SRA) 2004-2014 which aimed at improving the standard of living of Kenyans by substantially reducing the number of people affected by hunger, famine and starvation (MoA, 2008). These measures are also in line with the Millennium Development Goal number one of halving extreme poverty and hunger by the year 2015. The potato in Kenya just like the other roots and tubers in the Sub-Saharan Africa (SSA) is a major source of sustenance. It accounts for more than 20% of calories consumed world over (Scott *et al.*, 2000; Haverkort, 2004; Hsieh *et al.*, 2009). Its production and processing ensures employment to thousands of Kenyans. Although the government in a legal Notice No. 44 published in 2005 is promoting the processing of potatoes as a means of adding value to improve marketability and diversify potato products, the implementation has been slow (MoA, 2009; Njogu, 2009).

Consumption of crisps as snacks in Kenya is on the steady increase. This study was conducted to provide critical information on industry, diversity and consumption patterns of crisps. The study further aimed at enlightening the small-medium scale processors on alternative and available good processing cultivars. There was therefore need to evaluate the performance of locally produced potato cultivars for processing into crisps which is one of the major snack foods consumed in Kenya.

1.3 Objectives

1.3.1 Broad objective

To evaluate commercial potato crisps processing in Kenya in terms of characteristics of the market and industry, and suitability of the local cultivars for processing.

1.3.2 Specific objectives

1. To carry out baseline survey on the status of processing industry, consumption patterns, diversity and characteristics of potato crisps sold in Nairobi.
2. To evaluate selected potato cultivars for suitability in processing potato crisps.
3. To determine the effects of frying temperature, packaging and storage temperature on the ascorbic acid contents of crisps from selected potato cultivars.
4. To determine the effect of slice thickness and frying temperature on oil uptake, color, texture and organoleptic properties of crisps from selected potato cultivars.
5. To determine the effect of packaging and storage temperature on the shelf life of crisps from the suitable crisping cultivars.

CHAPTER TWO

LITERATURE REVIEW

2.1 Production and distribution of potato in Kenya

Potato is globally the most widely grown food crop after maize, wheat and rice (MoA, 2007; MoA, 2009; Lachman *et al.*, 2009). The crop has its origins in the Andes Mountains of Peru and Bolivia from where it spread throughout the world. Spanish explorers took the plant to Europe in the late 16th century as a botanical curiosity and by the 19th century the crop had spread throughout the continent, providing cheap and abundant food for the workers of the Industrial Revolution (CIP, 2007). In Kenya, potato was introduced over 100 years ago by the European settlers and is currently the second most valuable staple food crop after the cereal grains (MoA, 2009).

Potato production is confined to the high altitude areas (1500-3000 m above sea level) where it has higher production potential than maize and other cereals (Hunt 1980; Kabira 1990). Most growing areas are in Central Province (Kiambu, Murang'a and Nyeri), Eastern (Meru), Rift Valley (Molo, Mau Narok and Kinangop) and small quantities in the high altitudes of Coast and Western provinces. The potato varieties including Roslin Eburu, Roslin Tana, Roslin Bvumbwe, Nyayo, Kenya Sifa, Kenya Baraka, Desiree, Asante, Tigoni, Annet, Dutch Robjin and Kerr's Pink are currently grown and marketed in Kenya (KAIC, 2004).

2.2 The status of potato crisps processing in Kenya

By definition crisps are firm slices of potatoes cooked by deep-frying in vegetable oil, with or without table salt or spices (MoA, 2005; KEBS, 2007). Good quality crisps should have a thickness of 1.0 mm to 1.5 mm and light yellow to golden brown in color and should be good in texture and external surface appearance with no rancid smell, bitterness or any surface or internal pigmentation, lesions or black specks (KEBS, 2007).

The red-skinned Dutch Robjin tubers are the most commonly used for production but also Asante and Furaha were shown to produce acceptable crisps in terms of sensory evaluation (Kabira, 2000). By 2002 the number of crisp processors was estimated at 40 in Nairobi alone excluding smaller ones who do not channel their products through the supermarkets (Walingo *et al.*, 2004). The other major towns also have similar trend but fewer establishments. The processing industry in Nairobi uses about 2% of the total production of potato in Kenya. The sector has grown since its inception about 20 years ago and still has potential for growth as evidenced by the numbers of enterprises that have sprung up in recent years. Major imports of the product come from South Africa, Europe and Israel (Walingo *et al.*, 2004). The increased number of new entries shows that the market is available, but the local processors are faced with the challenge of improving quality to effectively compete with imported products (Walingo *et al.,* 2004). Potato crisps have large surface area to volume ratio and hence uptake and retention of oil is considerably high (Cuesta *et al.,* 2001). The storage hazards that must be checked are moisture absorption, flavor reversion and rancidity development in retained oil that is accelerated by light. The quality parameters of importance are yield that depends on specific gravity, variety and maturity of the tubers, color normally determined by chemical composition that fluctuates with variety, maturity, storage temperatures and cultural practices (Kabira and Lemaga, 2006)

2.3 Nutritional contribution of potato to the human diet

Table 1indicates the average contents of major constituents of a potato tuber. The total solids content (dry matter content) is important for quality and should be at least 20% for high processed products yields and less oil absorption (Ooko, 2008; Kabira and Lemaga, 2006). Dry matter content varies with tuber size (more in small tubers and less in larger tubers) and is determined indirectly by measuring the specific gravity since the relationship is well documented (Burton, 1989).

In Britain, potato was considered a better source of protein than energy and the most important source of vitamin C (Burton, 1989). About 2 kg of boiled potatoes can provide 6.4 g N that is enough to meet daily requirements. Cooking and processing by any method does not lead to appreciable loss of the dietary N from the potato (Burton, 1989). Freezing was , however, shown to reduce protein content in frozen French fries processed from selected cultivars in Kenya (Abong' *et al.,* 2009b). The potato protein has a high biological value equaling that of soybean protein but varies slightly with varieties (Kabira, 1990). The potato was considered as fattening but the truth is that it is a poor source of energy and can only fatten at excessive levels of consumption (Burton, 1989). The energy increases, however, by 20 to 50% due to fat in processing of crisps (Hagenimana *et al.*, 1997; Garmakhany *et al.*, 2008).

Table 1: Average contents of major constituents of a potato tuber

Constituent	Average weight (% of total tuber)	Range
Water	79.00	66.06-86.70
Dry matter	21.00	15.70-26.00
Carbohydrates	17.90	15.4-24.80
Protein	1.90	1.50-2.35
Lipid	0.12	0.05-0.10
Ash	1.00	0.07-2.00

Source: Ooko (2008)

Important minerals found in the potato tuber include calcium, potassium, sodium, iron, zinc, magnesium and manganese. According to Burton (1989) and Ooko (2008), the potato is moderately good source of iron (2.5-10 mg), phosphorus and magnesium (60-140 mg), copper (0.06-2.83 mg), calcium (30-90 mg) and an excellent source of potassium (in 100 g of potato). About 200 g of potatoes provides 10% of phosphorus and magnesium, up to 20% copper, iron and iodine. Approximately 200 g will supply 2-4 g dietary fiber which is equivalent to about half that supplied by other commonly eaten vegetables (Burton, 1989).

2.3.1 Nutritional contribution of ascorbic acid (vitamin C) to the human diet

Potatoes are rich in certain antioxidants, such as polyphenolics (phenolcarboxylic acids), vitamin C, carotenoids and selenium (Lachman *et al.*, 2009). The major vitamin contribution is in terms of vitamin C (ascorbic acid). Potato tubers have been reported to contain up to 46 mg/100 g ascorbic acid in (fresh weight basis) depending on the variety, maturity of the tubers at harvest and the environmental conditions under which they were grown (Nourian *et al.*, 2003; Haase and Weber, 2003; Han *et al.*, 2004; Burlingame *et al.,* 2009). Variety has been shown to be the greatest determinant of variation of ascorbic acid concentration in potatoes (Hamouz *et al.*, 2009; Hemavathi *et al.,* 2010). Several authors have described considerable reduction in the quantities of ascorbic acid during cooking and storage in potatoes, with losses varying widely according to cultivar, cooking and handling methods. Hagg *et al.* (1998) observed reduction of ascorbic acid with storage in stored peeled potatoes in four Finnish potato cultivars. The concentration of vitamin C decreased markedly during storage; after 20 weeks, the content had decreased by more than 50% in five cultivars of Tenerife potatoes (Rivero *et al*, 2003). The levels of ascorbic acid in long term stored samples (6–9 months) dropped below 10 mg vitamin C/100 g FW (Haase and Weber, 2003).

Ascorbic acid is susceptible to loss on cooking and processing especially when the potato is cooked and kept hot. Loss of the vitamin is also aggravated by subsequent storage, but refrigeration slows down its break down (Haase and Weber, 2003). The reduction in vitamin content in potato chips from Nigeria was found to be less than 25% compared to 63-75% loss on boiling (Agbo, 2005). The UK supply of vitamin C from potatoes was estimated to be 19.4-30% (Kwiatkowska *et al.*, 1989).

Recommended daily allowance (RDA) of vitamin C varies not only with age, but also from country to country. The Food and Agriculture Organization (FAO, 2001) indicated that the recommended nutrient intake of vitamin C ranges from 25 to 70 mg/day, depending on age and that as little as 6.5-10.0 mg/day of the vitamin will prevent the appearance of scurvy on the body. In previous studies, however, based on available biochemical, clinical, and epidemiological studies, the recommended daily allowance (RDA) for ascorbic acid was suggested to be 100–120 mg/day for an adult to achieve optimum cellular levels that can significantly reduce risk of heart disease, stroke and cancer in healthy individuals (Naidu, 2003).

2.3.2 Oil content of potato and potato products

Raw and boiled potatoes have very little amounts of oil, normally below 1% (Abong' *et al.*, 2009b). There is, however, a marked increase in oil content when potatoes are deep fried. The amount of oil absorbed influences flavor of the product and calories supplied by a particular food (Garmakhany *et al.*, 2008). Fried foods may contain amounts of oil that in some cases is more than 40% of the weight of the total product (Gamble *et al.*, 1987; Kita *et al.*, 2007). French fries made from Kenyan cultivars, for example, were found to contain about 12% oil (Abong' *et al.*, 2009d); crisps can contain oil contents of up to 45% depending on potato cultivar and processing parameters (Hagenimana *et al.*, 1997; Kita *et al.*, 2007). Consumption of crisps is therefore of concern to nutritionists and health practitioners who advocate a decreased oil intake in diets depending on the part of the world they are based. Crisps with low oil content and desirable sensory attributes are hence expected to be accepted by increasing numbers of health conscious consumers (Hagenimana *et al.*, 1997).

Many factors have been reported to affect the oil content of crisps as well as French fries including oil quality, frying temperature and duration, slice thickness, product shape and composition in terms of moisture content, solids and fat, pre-frying techniques such as blanching, drying and frying and any added coating such as methylcellulose or colloids (O'Connor *et al.*, 2001; Garcia *et al.*, 2004; Garmakhany *et al.*, 2008). Gamble *et al.* (1987) found the loss of moisture and the oil uptake in French fries during frying to be interrelated; a reduction of the initial moisture content by drying was recommended to reduce the oil uptake into potatoes. Deep-fat frying of potato slices for crisps production involves an initial, very short period of heating at high moisture level resulting in gelatinization of starch followed by a rapid dehydration period to a final moisture content of about 2% (Ufheil and Escher, 1996). There exists an intimate contact between the frying oil and the surface of the potato slices that ensures high heat and mass transfer rates. In addition, the frying oil is taken up by the potato slices to a final oil content of approximately 35% for most industrially manufactured crisps (Ufheil and Escher, 1996).

In earlier investigation by Ufheil and Escher (1996), an increase of fat content with decreasing initial dry matter, decreasing slice thickness, decreasing oil temperature and increasing frying time was found, the relative influence of the four factors being quite different. Selection of appropriate variety and proper control of process parameters are very important in determining the oil uptake by crisps (Kabira and Lemaga, 2006).

2.4 Quality requirements for potato crisps processing

2.4.1 Selection of raw potatoes for crisps processing

Processing quality parameters of concern to the processor include variety, dry matter content, oil content, color, texture, flavor and reducing sugars (Smith, 1975; Hunt, 1980; Wong, 1992).

2.4.1.1 External tuber characteristics

Shape and size are important attributes that have to be considered when selecting raw tubers for crisps processing. There are four distinct potato shapes that are known to exist: round, oval, kidney shaped and pointed (Harris, 1978). Crisps require round medium sized tubers for uniform cutting especially for machine cutting. Too large tubers are undesirable as large crisps lead to high percentage of broken pieces in pre-packaging or packaging stages. Crisps therefore require round/oval tubers of between 40-60 mm in size, but` should not be more than 60 mm (Kabira and Lemaga, 2006). Size of the potato is influenced more by variety and cultural practices such as fertilizer application, weeding and irrigation. Shape and size influences the peeling losses or recovery with high losses for very small tubers (Kabira and Lemaga, 2006; KEBS, 2007).

Depth of tuber eyes is an important aspect during peeling, more so when abrasive method is used. Deep eyes take longer to peel with excessive losses. Trimming time increases if the peeler has not removed eyes sufficiently resulting in increased costs. These are varietal characteristics and therefore one ought to choose potatoes with shallow eyes if excessive losses are to be avoided (Kabira and Lemaga, 2006).

2.4.1.2 Internal tuber characteristics

Flesh color, a result of anthocyanins (pink) and carotenoids (yellow/white) influences the color of finished product and depends on variety (Harris, 1978). Color is genetically determined and varieties should thus be carefully selected (Kabira and Lemaga 2006).

Total solids content determines greatly the processing quality. Dry matter content influences the yield, oil content of the fried products and texture of the finished products. It also influences textural characteristics for French fries associated with palatability and mealiness. Tubers of high dry matter content are known to produce fries of high yield that absorb less oil and have good nutritive value (Smith, 1975). If the dry matter content is too low, the crisps will be too soft/too wet and require more heat. Dry matter content varies with tubers from 13.1 to 36.8% (Smith, 1975; Ooko, 2008) and is high at maturity and is sometimes associated with physical differences in the type of potatoes. Dry matter content is directly associated with specific gravity; dry matter content of >20% is appropriate for crisps processing (Kabira and Lemaga 2006; Ooko, 2008). Tuber specific gravity of $\geq$1.080 is desirable for processing and those with high values are desired (Kabira 1983; MoA, 2005).

The reducing sugar content influences the color of the finish-fried product and hence its acceptability. Tubers with high reducing sugars result in dark and bitter products. For crisps, tubers levels between 0.1 and 0.25% of fresh weight basis are required (Kabira and Lemaga 2006). The major sugars in potatoes are sucrose, fructose and glucose. Reducing sugars contents are low in fully mature potato tubers but accumulate with storage at low temperatures (Kabira, 1990; Abong' *et al.*, 2009a). At temperatures below 10^{o}C, starch is converted to reducing sugars accumulating to high and unacceptable levels in the tubers (Roe *et al.,* 2006; Ooko, 2008). Due to the need to prolong storage life wich is aimed at minimizing sprouting, shriveling and spoilage, ware potato tubers can be stored at temperatures of ≤ 4 °C followed with reconditioned at ≥ 15 °C prior to processing in order to reduce the levels of reducing sugars to acceptable levels (Olsson *et al.*, 2004; Kyriacou *et al.*, 2008; Kyriacou *et al.*, 2009). Some cultivars, however, sustain the reducing sugars to unacceptably higher levels that may not allow for processing (Mattheus *et al.*, 2004). Production of high-yielding potato cultivar, with an acceptable golden yellow fried product after long periods of storage at low temperature is desirable and of high priority in many breeding programmes (Harvey *et al.*, 1998; Oltmans and Novy, 2002).

The amount of reducing sugars determines to a great extent the color of fried potato products and has been used to predict color. However, taking into account the levels of amino acids may give a better color prediction because both sugars especially glucose and amino acids (asparagine) are involved in maillard reactions responsible for the production of color of fried potatoes at temperatures above 100 °C (Olsson *et al.*, 2004; Roe *et al.*, 2006; Viklund *et al.*, 2007b; Serpen and Gökmen, 2008). Studies in United Kingdom have shown that potatoes grown under high nitrogen levels have lower amounts of free sugar at all times, and consequently-tended to have higher color scores. Potatoes with high nitrogen contents were, however, shown to accumulate more color per unit of sugar indicating that amino acids may be playing a synergistic role in fried potato products' color development (Roe *et al.*, 2006). In-depth analysis has clearly shown that about 90% of the variation in crisps color could be accounted for when only reducing sugars are considered while up to 98% of the variation could be accounted for by including amino acids in the regression analysis (Roe *et al.*, 2006)..

2.5 Shelf life of potato crisps

Depending on product, potatoes absorb varying amounts of cooking oil; potato crisps having oil contents ranging from 25 to 45% while French fries have on average 12% (Debnath *et al.*, 2009; Abong' *et al.*, 2009d). It is, however, important to note that oils used to process foods such as crisps undergo reactions including thermo-oxidative and hydrolytic changes which may have negative effects on consumers, especially when crisps are stored for a long time at high temperatures (Kita *et al.*, 2007).

Just like any other food product intended for sale, packaging protects potato crisps from atmospheric conditions and damage. It provides consumers with ingredient and nutritional information. Packaging also retards product deterioration, adds value and extends as well as ensuring quality and safety of food (Marsh and Bugusu, 2007). Consumer demand for food products with high quality has increased generally increased. Food packaging has, therefore assumed outstanding importance in maintaining product quality while offering protection from microbial and chemical contamination, as well as from oxygen, water vapor and light (Silva *et al.*, 2004).

Quality attributes related to crisps that require evaluation during storage include presence of off-flavor due to fat oxidation, peroxide formation, fat break down and changes in moisture content (Melton *et al.*, 1993). These factors are affected by among other factors the variety of potato used for crisps processing due to variation in the chemical composition (Pant and Kulshrestha, 1994; Abong' *et al.*, 2009a).

CHAPTER THREE

CONSUMPTION PATTERNS, DIVERSITY AND CHARACTERISTICS OF POTATO CRISPS IN NAIROBI, KENYA

3.1 Abstract

Consumption of crisps as snack is on the increase in Kenya and more so in the urban areas. Some potato crisps are imported and others locally produced. It is, however, not known whether local and imported products are processed to the required Kenyan standards. This study aimed to determine the consumption patterns and the characteristics of potato crisps in Nairobi City.

Potato crisps consumption pattern was determined using a structured questionnaire administered to 215 consumers. A total of 80 retail outlets were surveyed to establish the brands and characteristics of potato crisps sold. The available brands were sampled and evaluated in the laboratory for color, size, thickness, moisture, salt and oil content. Results showed that 33% of consumers were males while 67% were females. A majority, 74%, consumed potato crisps once a week, on average. Apart from gender, the frequency of purchase was influenced by factors such as festive occasions, seasons and purchasing power. Tropical heat brand was the most preferred (22%) followed by Krackles (11%). Pringles, an imported brand was purchased by only 0.6%, so were the local brands Delice and Highlands. The most preferred flavor was onion-salted. The most common packaging unit (52%) ranged between 30-50 g due to affordability and possibly convenience. These were retailing at USD. 0.4-0.5. The least purchased units weighed 150 g and above (2% consumers).

About 28% of the consumers bought crisps for own consumption, while 72% purchased for family. Only 15% of the outlets surveyed stocked other potato products besides crisps.

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A total of 24 brands of crisps were available in the market. The most commonly stocked brands were Tropical Heat and Krackles in 46 and 45% of the outlets surveyed, respectively. All the outlets surveyed stocked local, and 15% of the outlets also had imported brands. The units of packaging ranged from less than 10 g to 1 kg. The most popular unit packages (40%) varied from 10 to 100 g, selling between USD. 0.1-0.8. The study showed that potato crisps are highly consumed by children and youths and moderately by adults. The characteristics of the brands evaluated including color, size, thickness, moisture, salt and oil content varied significantly ($P \leq 0.05$) among the brands. Crisps thickness varied from 1 to 2 mm; the oil content varied from 24 to 40% while the moisture and salt contents varied from 1 to 6%, and 1 to 3%, respectively.

Consumption of crisps in Nairobi is dependent on gender, festive occasions, and seasons of the year and availability of disposable income. Except for the thickness, most brands had characteristics that conformed to the local crisps standards. This study provides the most current information on the crisp market and the results are useful to consumers, processors, policy makers and other stakeholders in the potato processing subsector.

3.2 Introduction

Potato is one of the world's major food crops, consumed daily by millions of people of diverse cultural backgrounds in many countries (Pedrschi *et al.*, 2005; Lachman *et al.*, 2009). According to the National Policy on Potato Industry (MoA, 2008), the potato in Kenya is an important food and cash crop that plays a major role in food security being highly produced and utilized after maize. Most of the potato produced in Kenya is consumed primarily where it is grown (Walingo *et al.*, 2004). The nutritional significance of the potato in the urban areas is evidenced by the increasing number of fast food restaurants in major towns of Kenya. Depending on the area, potato is widely consumed in Kenya with Nairobi being a major market for all forms of potato products. In 1994, 95% and 93% of the households in Nairobi and Kisumu, respectively, utilized potatoes (Omosa, 1994). There has been a worldwide increase in consumption of potato products indicating the need to pay more attention on consumer behavior and innovations in the sector (Buono *et al.*, 2009).

The most important products in the Kenyan potato processing industry are ready-to-eat potato chips (French fries), crisps and frozen chips. Potato crisp is a fragile but firm slice of potato which has been cooked by deep frying in vegetable oil and to which edible salt and permitted food grade spices, color and flavor have been added (KEBS, 2007; Salvador *et al.*, 2008). Depending on the processor, there are many different types of crisps targeting different consumer preferences. These preferences and other consumer characteristics determine the consumption pattern in any given market.

Potato crisp processing in Kenya has undergone tremendous growth over the last three decades with the number of processors in Nairobi alone increasing from five in the early 1980s (Durr and Lorenzl, 1980) to an estimated 20 processors in 2003 (Walingo *et al.*, 2004). The main outlets for crisp sale are supermarkets and many other small outlets. High consumption is noted during Christmas and Easter festivities and during school holidays. Peak consumption is also noted during peak tourist seasons (Walingo *et al.*, 2004).

The increasing prevalence of obesity in children and adolescents has been partly attributed to increased consumption of snacks with high fat and sugar that make up substantial daily calorie intake. This increasing trend has been reported both in the developed and developing countries all over the world (Vardavas *et al.*, 2007). Through media advertising and education, consumers are becoming more aware of the need to monitor intake of polyunsaturated fats, mono-unsaturated fats and cholesterol. As knowledge increases, so does the concern for various aspects of fats and fat-soluble components in human diet. Salt has been used as a method of food preservation for long. Potato crisps have been popular salty snacks all over the world for over 150 years (Pedreschi *et al.*, 2005b). However, the relevance of salt to hypertension and its subsidiary side-effects is becoming increasingly documented. The public health concern arises due to addition of salt to foods rather than from the amounts naturally present a given food (FAO, 2010).

Potato crisps processing and consumption in Kenya has not been well studied. This study was designed to determine the current consumption pattern, diversity and characteristics of potato crisps in the city of Nairobi.

3.3 Materials and methods

3.3.1 Survey of consumption patterns and characteristics of potato crisps

This study was carried out between October 2009 and January 2010. Nairobi was purposively selected due to the large number of supermarkets and factories that process crisps. The study was a cross-sectional survey applying quantitative data collection methods. The consumer sample size of 195 was determined according to Nassiuma (2000) using the equation: n (sample size)=$\square^2pq/L^2$ ($\square^2 = 1.96^2$, p (probability of finding crisps consumer in the supermarket)=0.15, q (1-p)=0.85 and $L^2=0.05^2$). A total of 215 consumers were available for interview from 55 randomly selected supermarkets and data collected using a structured questionnaire which had previously been pre-tested in 10 selected retail outlets (Appendix1). Data was collected on gender of consumer, frequency of purchase, the preferred brand, package size and flavor, and reasons for indicated pattern of purchase.

A separate questionnaire (Appendix 2) was administered to 80 randomly selected retail outlets to determine the characteristics of the potato crisps. Supervisors from the 55 supermarkets were interviewed. In addition 10 shop and 15kiosk owners were available for interviews.

3.3.2 Sampling of marketed potato crisps

Duplicate crisp samples of all brands available were purchased from randomly selected supermarkets and shops (kiosks). Since some of the products from the kiosks did not have brand names or labeling, the 5 samples collected from these outlets were coded as Kiosk 1, Kiosk 2, Kiosk 3, Kiosk 4 and Kiosk 5. All the samples were taken to Food Chemistry Laboratory, University of Nairobi for analysis of salt content, moisture content, color, oil content, size and thickness.

3.3.3 Laboratory analysis

Moisture content: Moisture content was determined on triplicate samples by standard analytical methods (KEBS, 2007).

Oil content: The oil content was determined by extraction of 5 g of finely ground samples in Soxhlet apparatus for 8 hours using analytical grade petroleum ether (boiling point 40-60 ^{o}C) according to method of KEBS (2007). The oil content was calculated as percent.

Total salt content: Salt content was determined using the modified FAO/WHO method No. 16.209 (AOAC, 1980). Approximately 5 g accurately weighed finely ground samples were dispersed in 100 ml of distilled water and allowed to stand for 5-10 min, while swirling occasionally. One milliliter of 5% potassium dichromate solution was added and titration performed with 0.1 N silver nitrate solution to the first appearance of an orange-brown color that persisted for 30 sec. The sodium chloride was calculated as percent as follows:

$\% NaCl = 5.85N (V_1 - V_0)/W$; where N= normality of silver nitrate; V_1= ml silver nitrate for titrating the sample; V_0= ml silver nitrate for titrating the blank, and W= weight of sample in g.

Size and thickness of crisps: Ten pieces of potato crisps were picked randomly for each brand and used for measurement of diameter and thickness. The measurements were performed using a hand-held vernier caliper (NSK Nippon Sokutei, Japan) according to Kabira and Lemaga (2006). All measurements were performed in duplicates and data recorded in mm.

Potato crisp color: Crisps color was determined according to Potato Chips/Snack Food Association (PC/SFA) (1987) color chart ranging from a score of 1 to a score of 5. A score of 2.5 was the maximum acceptability score.

Data analysis: Data from consumption pattern and supermarket interviews were analyzed for frequencies and means using SPSS version 11.5 while data from laboratory evaluation were subjected to analysis of variance (ANOVA) and means separated by least significant difference test using Statistical Analysis System (SAS version 9).

3.4 Results and discussion

3.4.1 Consumption patterns of potato crisps in Nairobi, Kenya

The survey found that approximately 33% of the 215 respondents interviewed were males while 67% were females. This shows that a majority of the buyers of potato crisps were females or that they are the main group of people who are involved in the actual shopping for household goods in Kenya. A majority of the respondents (74%) bought the product 2-5 times in a month compared to 4% daily, 8% once while 15% bought the product 6-8 times in a month (Figure 1). This is closely comparable to an average consumption rate of two times a week that was reported by Omosa (1994) in Nairobi and Kisumu.

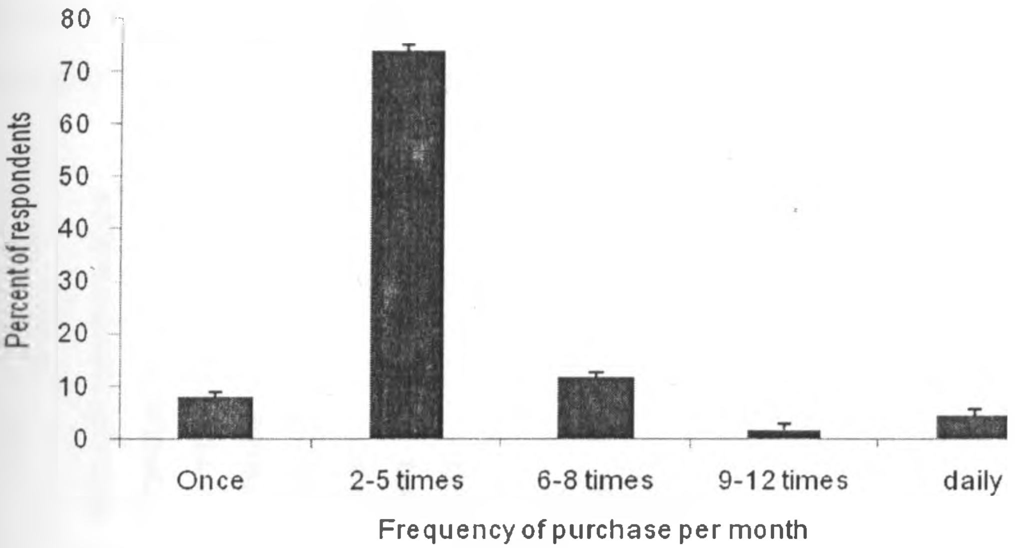

Figure 1: Frequency of purchase of potato crisps by consumers in Nairobi, Kenya. All values are given as mean ± standard errors

A part from gender, the frequency of purchasing crisps was influenced by factors such as festive occasions, seasons and availability of money. Occasions that called for celebrations, travelling and outings were cited as being favorable for buying crisps indicating that many people are increasingly using crisps as a preferred snack. Furthermore, most purchases took place at the end of the month when most salaried workers had money to spend compared to mid-month with none or little purchase done.

Frequency of consumption of the various brands of potato crisps varied widely as shown in Figure 2. Many consumers (22%) preferred Tropical Heat brand, a good number (11%) preferred Krackles while a low of 0.6% preferred Pringles, Delice and Highlands. Reasons advanced for preferring a particular brand were taste or sweetness (22%), nice flavor (15%), affordability (6%), nice packaging (6%), availability (1%), and crispiness (3%). Approximately 2% had no choice of selecting brands especially in small supermarkets that stocked as few as one or two brands. The results indicate that the Tropical Heat brand is superior in sweetness, flavors and crispiness compared to the other brands. Besides being from an established and one of the oldest potato crisps processing companies, Tropical Heat brand was nicely packaged into a range of units that were affordable to consumers of all levels of income. Despite being of very good quality, Pringles was consumed by a few people, mainly foreigners who could afford to pay the high prices.

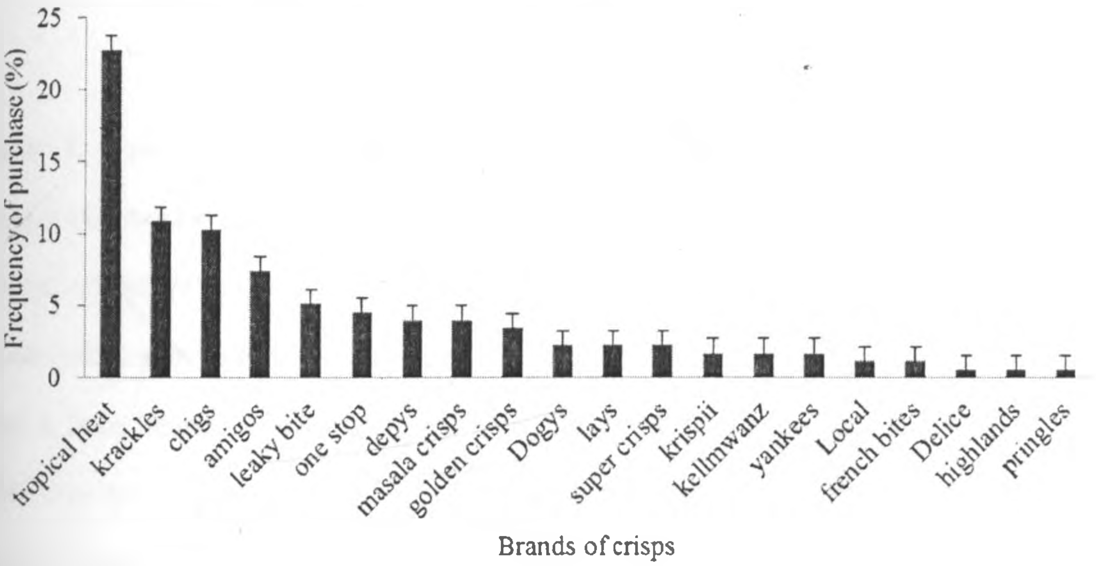

Figure 2: Brands of potato crisps consumers often buy and their frequency of purchase in Nairobi, Kenya. All values are given as mean ± standard errors

Processors of potato crisps use a variety of flavors on their processed products (Figure 3). The most preferred flavor by consumers was onion (24%), salt (12%) and chillies (7%). A small group (0.5%) of processors used chilly-lemon and onion-chilli. Other flavors used included cheese, tomato, vinegar, masala, garlic and mixtures of any two or more of these. Preference for onion, salt and chillies flavors may be due to the fact that they are commonly used in food preparation of foods consumed in Kenyan households.

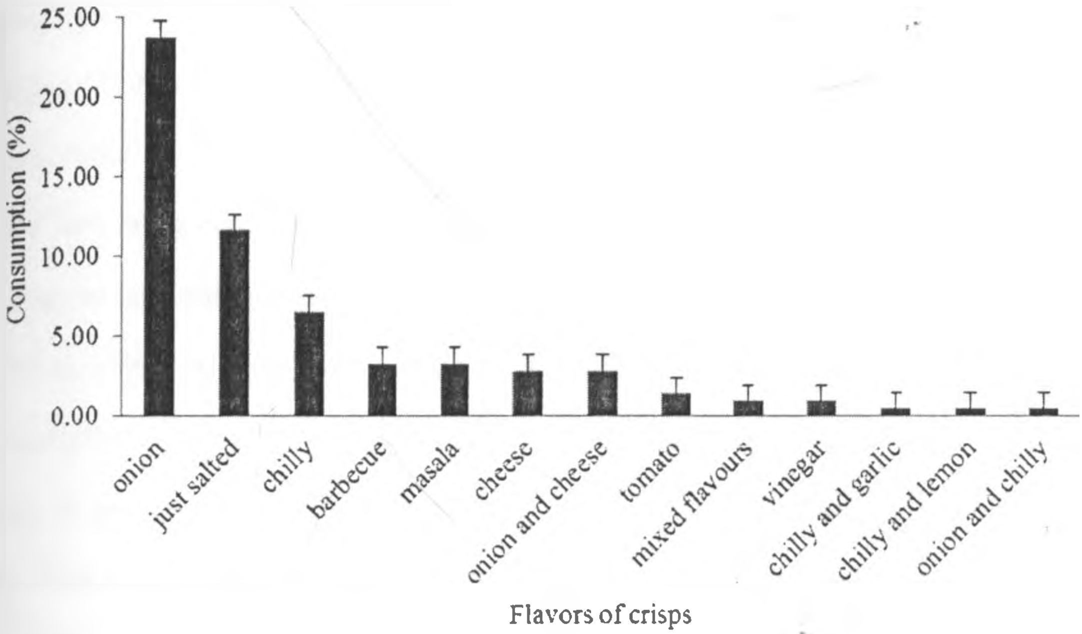

Figure 3: Types of flavors of potato crisps consumed in Nairobi, Kenya. All values are given as mean ± standard errors.

A large number (88%) of potato crisps bought by the respondents were packaged in polythene bags which tended to be cheaper; 10% were packaged in polythene bags lined with aluminium foil which were a little higher in price while 2% were packaged in plastic containers or cans lined with aluminium foils which were quite expensive, and were mainly for imported brands. Packaging is an essential marketing parameter of any food stuff displayed on the shelves of shops. The principal roles of food packaging are to protect food products from contamination and damage, to contain the food, and to provide consumers with ingredient and nutritional information. Traceability, convenience, and tamper indication are secondary functions of increasing importance. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact (Marsh and Bugusu, 2007). It notable that packaging in aluminium foil would lead to prolonged shelf-life of the product. The cost of packaging in such materials is, however, high leading to higher prices of potato crisps.

Units of packaging varied from as low as 20 g up to 1 kg. However, the most purchased packaging units, 52%, ranged from 30-50 g due to affordability; retailing at USD. 0.4-0.5 compared to units of 150 g and above that were least purchased (2%) due to their high costs, retailing at USD. 1.3 and above.

About 28% of the consumers bought potato crisps for their own consumption while 72% of those interviewed intended product for their family members. This result was different from the findings of Omosa (1994) who observed a larger number (59%) of consumers who bought crisps for self-consumption. It therefore indicates that crisps are increasingly consumed by many people in the family. A good portion of crisps meant for the family, 53%, was specifically taken to the children only. This information explains why a large number of consumers (56%) bought more potato crisps during the holidays when schools were closed, 17% during back to school periods compared to 8.5% during school days. the higher consumption of potato crisps are consumed by children is an important reason why quality should be assured to prevent any health hazards as children are at a greater risk of toxicity.

There were various reasons why respondents bought crisps (Figure 4). The major criterion for choosing type of crisps was sweetness (35.2%), followed by quality (15.9%) and affordability (15.3%) while the least criterion was crispiness (0.6%). Sweetness is a function of the fresh potatoes used, preparation and flavours used. The processors therefore need to satisfy the consumers' perceived level of sweetness.

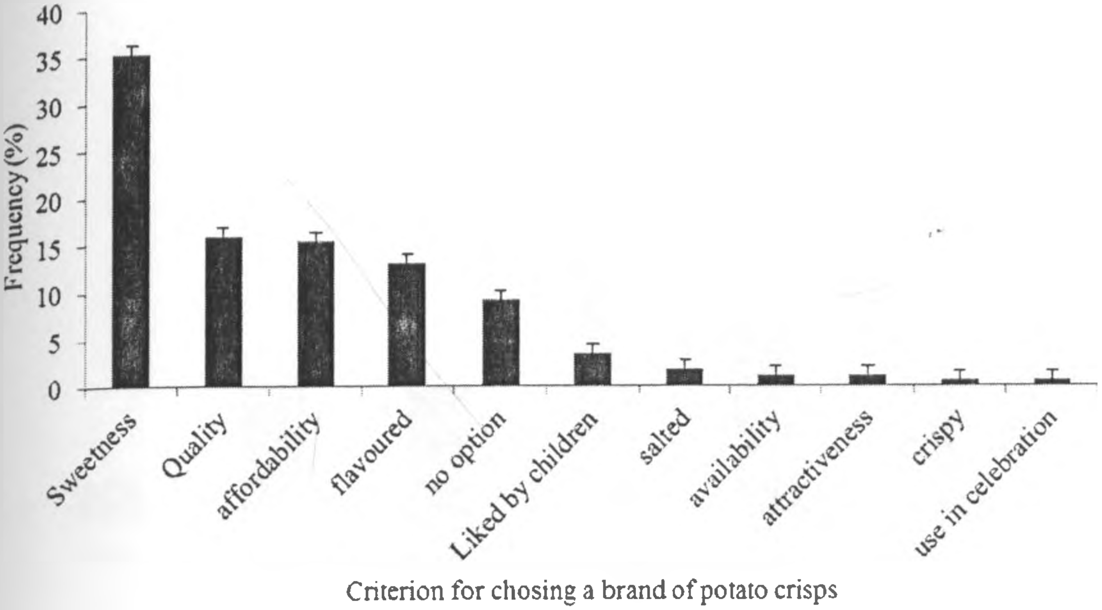

Figure 4: Criterion for choosing potato crisps brands by consumers in Nairobi, Kenya. All values are given as mean ± standard errors.

3.4.2 Characteristics of potato crisps sold in Nairobi, Kenya

All the outlets surveyed sold potato crisps. Besides potato crisps, 15% of the outlets (all being supermarkets) sold other potato products such as *chevda* and potato sticks. This is shows how important potato crisps have become a snack food for a large consumer base in Kenya making it a necessary and important stock on the supermarket shelves. The frequency of purchasing (procuring) potato crisps from processors in a month varied from once a month (4%) to four times a month (38%) as indicated in Figure 5. This means that a majority of the shops would procure crisps at least once a week. A good number of outlets (15%) would also purchase crisps depending on volumes of sales and how fast the brands of crisps move. However, the quantities purchased per month could not be ascertained by most of the interviewees (86%) who were mostly supervisors in charge of crisps section of the supermarkets while 6% reported a purchase of between 1 kg to 15 kg and 2% purchased 20 kg and above on each occasion.

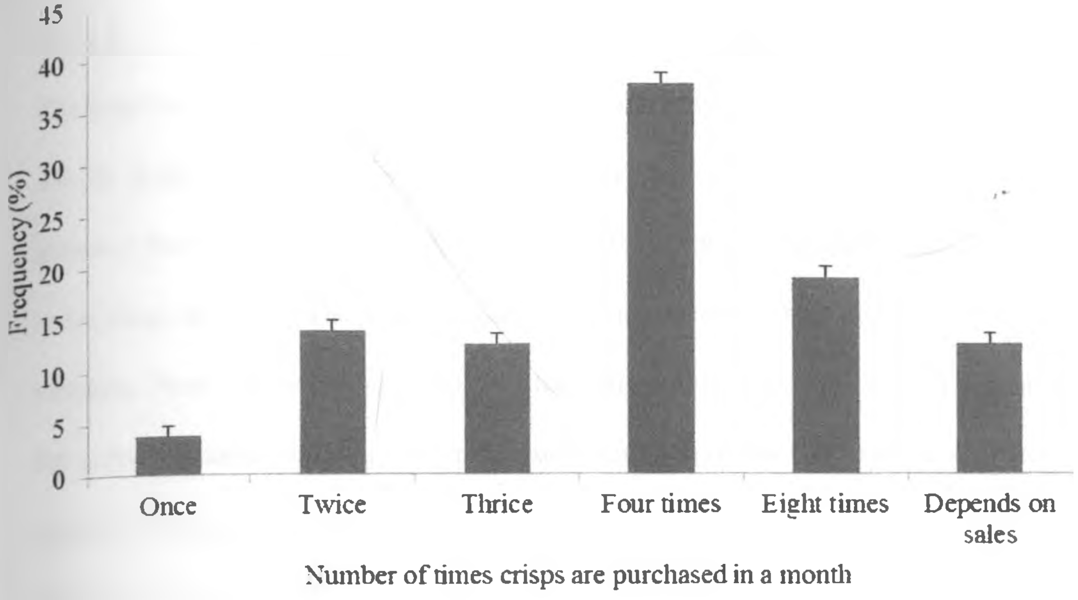

Figure 5: Frequency of stocking potato crisps in retail outlets in Nairobi, Kenya. All values are given as mean ± standard errors.

A total of 24 brands of crisps were being sold in Nairobi during the period of study. The crisps sold in the supermarkets were from companies, both processing and importing, licensed by the Kenya Bureau of Standards. It is worth noting that only crisps sold in supermarkets were clearly labeled and could be appropriately identified while those from kiosks were neither labeled nor branded in any way (Figure 6). Samples obtained from kiosk therefore limit traceability and have no tamper proof indications which are functions of increasing importance (Marsh and Bugusu, 2007).

Figure 6: Unbranded crisps sold in small shops (kiosks) in Nairobi, Kenya.

The most stocked brands in the outlets were Tropical Heat and Krackles, available in 46 and 45% of the outlets, respectively. Delice was the least stocked being available in 2% of the outlets (Figure 7). The larger volumes of stocks indicate popularity of the two brands in the market.

All the shops surveyed stocked brands of crisps made in Kenya while only 15% of the outlets had imported brands in addition to local ones. Imports constituted not more than 2% of the crisps stocked in the shops surveyed. The imported crisps originated from various countries including South Africa, Belgium, North America, Malaysia, and the United Kingdom. This was an indication that most of the crisps marketed in Kenya are processed locally from the local cultivars. It was noted that the imported crisps were quite expensive, in some cases costing as much as twice the cost of the local ones for the same quantity. The imports were, however, of better quality compared to local ones; they had uniform size and color with low oil contents. This is in agreement with the findings of Walingo *et al.* (2004).

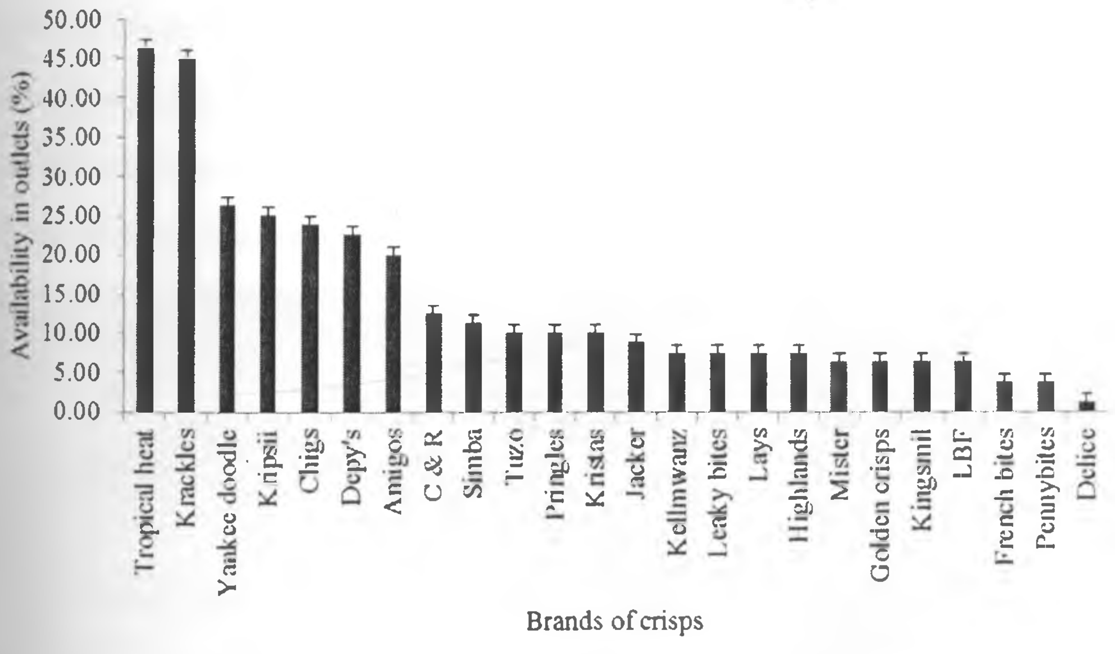

Figure 7: Frequency of purchase of various brands of potato crisps by consumers in Nairobi, Kenya. All values are given as mean ± standard errors.

Many reasons were advanced by the outlets as to why they stocked particular brands. A large number of the outlets stocked potato crisps brands depending on how fast they were moving on the shelves (61.3%) compared to those who stocked crisps depending on the availability (31%), affordability (28%), good quality (24%) and being from established companies (18%). How fast the potato crisps move from the shelves is determined by consumer preference taking into account the product taste, appearance and flavor used. The marketers will therefore stock fast moving brands since their main aim is to make profits from high volumes of sales.

The major packaging material for potato crisps was polythene (60%) or polythene lined with aluminium foil (28%). Other outlets (14%) sold imported crisps packaged in tins and plastic containers with aluminium foil. The latter packaging materials were used in the imported brands only (Figure 8). The imported crisps were more attractive in terms of packaging compared to local crisps. Type of packaging determines storage life as it influences the intensity of light exposure on the product. Extended exposure of products to light is reported to lead to oxidation of fats leading to rancidity (Lennersten and Lingnet, 1998). The imported crisps are therefore likely to last longer on the shelves compared to local crisps. The imported products require extra protection since most of them have to be shipped from overseas and may take long to reach the destination.

Figure 8: Packaging of locally produced (left) and imported (right) potato crisps sold in various retail outlets in Nairobi, Kenya.

The units of packaging ranged from less than 10 g to 1 kg. The most popular unit packages (40%) varied from 10 g to 100 g as they were cheap and affordable to most customers and were sold at between USD. 0.1 and 0.8. The unit packages in 90% of kiosks were not indicated but on laboratory analysis, the unit sale weight varied between 5g and 20 g selling between USD. 0.05 and 0.1. The prices for imported crisps were, however, significantly ($P \leq 0.05$) higher compared to those of locally made ones, in some cases even double for the same quantity. This could be attributed to the investment on attractive packaging, quality crisps produced and transport cost from countries of origin.

The study found that potato crisps are a popular snack food item for young children and adolescents while parents are moderate buyers of the products. Large variations in sales were reported and this was attributed to seasons and type of shop. Most sales for supermarkets were recorded at month ends when many people had money and during school holidays characterized by celebrations and festivities. For kiosks, high sales were recorded mainly during school days since the major consumers were school going children who bought crisps on their way to school.

Potato crisps were stored in cool dry and open shelves for up to 4 weeks before restocking. Major complaints by customers involved underweight products (22%) while 3% were about the crisps being broken, oily, salty or too costly. Potato crisps are fast moving goods and given the low levels of moisture, very little deterioration would occur on shop shelves. Due to high oil content, crisps are known to suffer from of rancidity which reduces shelf-life. After about three months, consumers begin to perceive changes in flavor and taste which may lead to product rejection (Surkan *et al.*, 2009).

Crisps packaged in polythene bags placed in cartons were mainly transported by vans to supermarkets or bicycles and on foot to kiosks for sale. Most shops (43%) accepted a supplier of crisps when their products to be supplied were known to be fast moving. Approximately 21% of shops, mainly supermarkets, insisted on Kenya Bureau of Standards mark of quality and that crisps be of required weights since correct weight was critical to customer satisfaction. Only 26% of the shops recorded potato crisps losses which were mainly due to breakages (11%), rodents' damage in stores (4%) and on expiry (3%). The losses were, however, less than 5% in all the recorded cases.

This was due to the fact that in most cases the suppliers took liability for broken or expired products and provided replacements.

It was noted that 82% of the shops at times of the year suffered from a scarcity of crisps supply from the suppliers. The shortage was attributed to lack of raw potatoes for processing occasioned by high competition by domestic ware potato demand especially in the moths of April-July. Drought also contributed to the shortages at times. Another cause of scarcity was transport problems encountered by the suppliers.

In terms of pricing, 64% of outlets said that the prices had generally remained constant due to high competition by many processors. This means that crisps processing has continued to attract a large number of processors scrambling for the same market. Some outlets (19%) had, however, had price increases occasioned by scarcity especially in cases of small shops where there was only one supplier. About 11% of outlets on the other hand said the trend in pricing had been characterized by fluctuation. Consumption trend as reported by respondents varied widely with 54% of outlets recording an increase attributed to the fact that more people have developed a liking for crisps and its use in festivities, while 19% indicated that consumption was constant, and 15% said consumption fluctuated depending on prevailing economic situation.

3.4.3 Color, diameter, thickness, oil, moisture and sodium chloride contents of potato crisps sold in retail outlets in Nairobi, Kenya

Table 2 summarizes the characteristics (color, diameter, thickness, oil, moisture and sodium chloride contents) of different brands of crisps found in Nairobi City. Color of crisps significantly ($P \leq 0.05$) differed among the brands ranging from a minimum score of 1 to 2.3. Since the maximum upper limit was a score of 2.5, it therefore means that all the brands sold in the supermarkets and kiosks, conformed to the recommended standards (PC/SFA, 1987). Most potato crisps are known to turn brown on prolonged storage due to physico-chemical changes that occur depending on storage conditions (Kulkarni and Govinden, 1994). Color is one of the sensory properties that determines acceptability of a food product at first site (Surkan *et al.,* 2009) and hence must conform to consumer requirement (Krokida *et al.*, 2001).

Table 2: Color, size, thickness, oil, moisture and sodium chloride contents of potato crisps sold in retail outlets in Nairobi, Kenya

Brand	Color[1]	Diameter (mm)	Thickness (mm)	Oil content (%)	Moisture content (%)	Sodium chloride (%)
C and R	1.50 ± 0.00e	37.50 ± 0.71e	1.00 ± 0.00d	40.15 ± 0.24a	2.42 ± 0.04h	1.67 ± 0.15
Chigs	1.63 ± 0.18d	35.00 ± 0.00f	1.50 ± 0.00b	30.31 ± 0.18e	2.33 ± 0.27h	1.50 ± 0.02
Delice	1.63 ± 0.18d	40.00 ± 0.00cd	1.00 ± 0.00d	37.54 ± 0.47b	3.16 ± 0.24e	2.03 ± 0.12c
Highlands	1.13 ± 0.17g	40.00 ± 0.00cd	1.00 ± 0.00d	29.77 ± 0.72e	3.68 ± 0.01d	1.20 ± 0.10f
Jacker	1.50 ± 0.00e	44.00 ± 0.00a	1.00 ± 0.00d	24.40 ± 0.11g	1.65 ±0.04i	1.92 ± 0.01c
Kellmwanz	1.00 ± 0.00h	32.50 ± 0.71g	1.00 ± 0.00d	31.10 ± 0.59e	4.08 ± 0.20c	1.25 ± 0.31f
Kingsmill	1.12 ± 0.18g	35.50 ± 0.70f	1.50 ± 0.00b	35.50 ± 0.71c	4.97 ± 0.30b	1.63 ± 0.05d
Kiosk 1	2.00 ± 0.00c	40.00 ± 0.00cd	1.00 ± 0.00b	35.06 ± 0.98c	3.42 ± 0.12de	1.20 ± 0.37f
Kiosk 2	1.25 ± 0.35f	40.00 ± 0.01cd	1.00 ± 0.00d	34.68 ± 0.49c	3.55 ± 0.12d	1.71 ± 0.03d
Kiosk 3	1.50 ± 0.00e	40.00 ± 0.02cd	1.00 ± 0.00d	31.28 ± 0.53e	3.41 ± 0.16de	1.10 ± 0.04fg
Kiosk 4	1.50 ± 0.01e	42.50 ± 0.71c	1.00 ± 0.00d	28.40 ± 0.62f	3.35 ± 0.31de	1.41 ± 0.19e
Kiosk 5	1.75 ± 0.35d	41.00 ± 0.14c	1.00 ± 0.00d	28.59 ± 1.42f	4.06 ± 0.57c	1.89 ± 0.00cd
Krackles Plain	1.56 ± 0.55e	38.25 ± 0.50de	1.25 ± 0.29c	32.97 ± 0.69de	2.80 ± 0.51fg	2.43 ± 0.61b
Krackles Ripples	1.13 ± 0.45g	42.50 ± 0.49c	1.50 ± 0.30b	32.39 ± 0.55de	3.17 ± 0.32e	1.91 ± 0.72c
LBF	1.37 ± 0.18f	36.50 ± 0.71f	1.00 ± 0.00d	39.50 ± 0.71a	3.95 ± 0.28db	1.32 ± 0.02e
Pennybites	2.25 ± 0.30b	35.00 ± 0.00f	1.00 ± 0.00d	35.50 ± 0.71c	5.45 ± 0.22a	1.54 ± 0.05d
Simba	1.50 ± 0.00e	43.50 ± 0.71b	1.00 ± 0.01d	35.59 ± 0.53c	3.26 ± 0.67e	1.49 ± 0.28e
Amigos	1.00 ± 0.00g	36.50 ± 0.70f	1.50 ± 0.00b	31.38 ± 0.57e	2.92 ± 0.19f	1.22 ± 0.06f
Depy's	2.37 ± 0.17a	35.50 ± 0.71f	1.50 ± 0.01b	33.58 ± 0.62d	3.34 ± 0.12e	1.57 ± 0.19de
Frenchbites	2.25 ± 0.35b	35.00 ± 0.00f	1.50 ± 0.00b	30.94 ± 0.66e	2.30 ± 1.06h	2.16 ± 0.04c
Golden crisps	1.13 ± 0.10g	40.00 ± 0.00cd	1.00 ± 0.00d	36.24 ± 0.14bc	1.85 ± 0.02hi	1.27 ± 0.05ef
Kripsii	1.00 ± 0.00h	32.50 ± 0.70g	1.00 ± 0.01d	38.08 ± 0.19b	1.09 ± 0.03j	1.44 ± 0.03e
Kristas	1.62 ± 0.18d	40.00 ± 0.00cd	1.50 ± 0.00b	29.01 ± 1.41e	2.79 ± 0.10f	1.96 ± 0.03c
Lays	1.00 ± 0.00h	44.50 ± 0.70a	1.00 ± 0.01d	24.37 ± 0.37g	2.34 ± 0.40g	2.96 ± 0.16a
Leakybite	1.63 ± 0.00d	41.00 ± 1.41c	1.50 ± 0.00b	32.19 ± 0.40de	2.91 ± 0.16f	1.96 ± 0.17c
Mister	1.00 ± 0.17h	32.50 ± 0.71g	1.00 ± 0.00d	25.37 ± 0.13g	2.65 ± 0.24fg	1.87 ± 0.02cd
Pringles	1.00 ± 0.00h	45.00 ± 0.00a	1.00 ± 0.00d	33.52 ± 0.80d	3.56 ± 0.04d	1.59 ± 0.10de
Tropical	1.13 ± 0.17g	36.00 ± 5.65f	1.50 ± 0.00b	31.79 ± 0.71e	2.44 ± 1.10h	1.72 ± 0.11d
Tuzo	1.50 ± 0.00e	40.00 ± 0.00cd	1.50 ± 0.00b	30.44 ± 2.19e	3.09 ± 0.03f	1.67 ± 0.21d
Yankee Doodle	1.13 ± 0.18g	31.00 ± 1.41h	2.25 ± 0.35a	35.75 ± 0.62c	3.29 ± 0.42e	1.34 ± 0.10e
Yankee Plain	1.38 ± 0.17f	35.00 ± 0.00f	1.50 ± 0.00b	40.22 ± 0.04a	3.05 ± 0.21f	1.95 ± 0.12c

[1]Evaluation was done on a scale of 1 to 5. 2.5 was the maximum acceptable score; Results are means of duplicate samples ± sd; Means with the same letters within the same column are not significantly different at 5% level of significance.

The average sizes of crisps (in diameter) significantly ($P \leq 0.05$) varied among the brands. The brand Yankees Doodle recorded the lowest diameter of 31 mm compared to Golden crisps and Tuzo both of which were 40 mm. The size of potato crisps is determined by the size of raw potato and the sorting criterion used in a particular industry (Kabira and Lemaga, 2006); the larger the potatoes so will the diameter of the resulting product. During processing (slicing), however, a potato tuber produces several pieces which vary in size. The size to be allowed into the subsequent processing operations is at the discretion of the manufacturers. The Kenya Bureau of Standards (2007) recommends processors to use potatoes of sizes 45-60 mm for the best quality in terms of firmness and crispiness to be achieved. This reduces lots of breakages of crisps made from too large potatoes.

From this study, the upper limit for size had been observed by processors, but lower size limit does not seem to have been observed and it therefore means that the industries are not keen on size selection probably due to cost implications. This explains why local potato crisps had large variation of size compared to imported ones, which were more uniform (Figure 9).

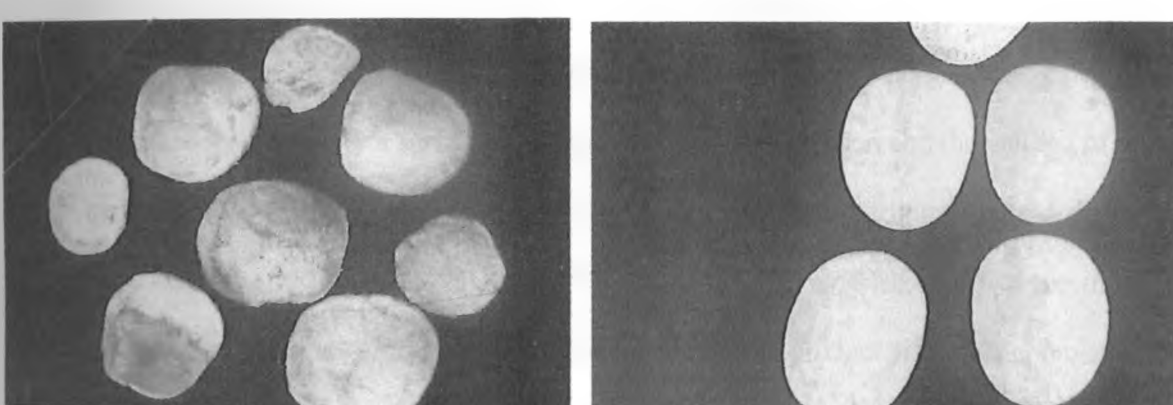

Figure 9: Variation in size of potato crisps between local (left) and imported (right) crisps sold in retail outlets in Nairobi, Kenya

With the exception of Yankeess Doodle with an average thickness of 2.25 mm, all the other brands of potato crisps in the market met the 1-1.5 mm thickness criterion recommended by Kenyan Bureau of Standards (KEBS, 2007) (Table 3).

Table 3: Statutory requirement for potato crisps in Kenya

Characteristic	Maximum limit
Moisture content, %	4.7
Fat content, % dry weight	40.0
Sodium chloride, % dry weight	2.5
Thickness	1.0 mm- 1.5 mm
Color	Light yellow to golden yellow

Source: Kenya Bureau of Standards (2007)

The importance of thickness of crisps has been studied at length in the developed countries. The thinner sizes, due to their larger surface area to volume ratio, have been shown to absorb a lot of frying oil compared to those with large size (Kita *et al.*, 2007).

The oil content varied significantly ($P \leq 0.05$) among the brands of crisps ranging from 24.37% in the brand Lays to 40.22% in the brand Yankees doodle. Except for brands C and R and Yankee Doodle, all the other brands had the required amount of oil, maximum 40%. It was, however, noted that most of the imported brands had quite low oil contents below 30% compared to most locally produced brands that had amounts exceeding 30%. This could be attributed to differences in processing oils, frying temperatures and dry matter characteristics of potatoes used and processing parameters. Oil uptake by crisps is majorly a surface phenomenon involving adhesion and the method of drainage of oil upon retrieval of potato slices from the frying oil bath may contribute to the differences of oil contents (Ufheil and Escher, 1996). Many factors have been reported to affect the oil content of crisps including oil quality, frying temperature and duration, product size, shape, moisture content, and dry matter content. Pre-frying techniques such as blanching, drying and coating also affect oil uptake (Ufheil and Escher, 1996; O'Connor *et al.,* 2001; Cuesta *et al.*, 2001; Kita *et al.*, 2007; Ziaiifar *et al.,* 2008; Abong', *et al.*, 2009d). In earlier studies of oil uptake by potato crisps, Gravoueille (1996) noted that potato tuber dry matter was a major factor for the potato processing industry, and that it was required to be between 23 and 25% to minimize the oil uptake and improve the yield. Potatoes with high dry matter (>20%) have been shown to produce higher yields with lower oil content than those of lower dry matter (Lulai and Orr, 1979; Melton *et al.,* 2001).

The moisture content of crisps marketed in Nairobi varied from as low as 1.09% in Krispii to as high as 5.45% in Penny Bite. All the brands except Kingsmill and Penny Bite met the required upper limit of 4.7%. Deep-fat frying of food products such as potato crisps is a drying process in which rapid moisture loss occurs and crisps being small slices are bound to have minimal moisture contents (Esturk *et al.*, 2000). The amount of moisture content depends among many other factors on packaging material, storage conditions and the amount of moisture at the end of processing. Moisture content is an important shelf-life determinant; the higher the levels of moisture the faster the microbial spoilage of food products. Crisps, being food products that can store up to 6 months would require that moisture levels be kept as low as possible.

The amount of salt in the crisps differed significantly ($P \leq 0.05$) among the different brands ranging from 1.10% in Kiosk 3 coded sample to 2.96% in the brand Lays. The Kenyan standard recommends levels of up to 2.5%, a criterion that almost all the brands met with exception of the brand Lays. A similar study in Crete found high salt levels of up to 3.4% (Vardavas, 2007). It also shows that taking most crisps brands in Nairobi does not pose great danger especially to children who are the main crisps consumers with regard to salt levels. However, due to concerns of the negative effects of high salt consumption coupled with the fact that most crisps consumers are children, this limit should be reduced to 2%. Consumption of high salty snacks can be a dietary hazard for human beings and especially children (Vardavas, 2007).

3.5 Conclusions and recommendations

The consumption of potato crisps in Nairobi depends on gender, occasions, seasons of the year, and availability of disposable income. Approximately 24 processors were identified based on brands of potato crisps obtained from the shops. Except in the sizes, most brands with a few exceptions had characteristics that conformed to the crisps standards. The sale of potato crisps in Nairobi can, however, be improved if processors produce uniform products which are attractive in color. Processors of the branded crisps should also target the kiosks through sale of smaller unit weights that are more affordable to the consumers. Supermarkets sell the bulk of potato crisps in Nairobi as opposed to kiosks which sold few and unbranded crisps. It is, however, noted that maximum oil content set at 40% by the Kenyan regulatory body is quite high and could be reduced to about 35% which was achieved by 55% of the brands evaluated.

CHAPTER FOUR

CHARACTERISTICS OF THE INDUSTRY, CONSTRAINTS IN PROCESSING, AND MARKETING OF POTATO CRISPS IN KENYA

4.1 Abstract

There has been an increase in the number of potato crisps processors in Kenya in the last few decades. However, the characteristics of these firms are not clearly understood. This study was designed to characterize the potato crisps processing industry in Kenya in terms of varieties used, pre-processing handling practices and constraints encountered. The potato crisps industry was surveyed between December 2009 and February 2010 using a structured questionnaire. Using labels of a total of 24 brands of potato crisps found selling in 80 supermarkets and kiosks in Nairobi, the processors were identified, contacted, visited and interviewed. Together 23 processors were identified and these had processing plants in Nairobi and Nakuru. The information collected included size of firm, range of products, constraints in processing crisps, marketing of the product and the variety of potatoes processed. The number of employees in the processing industries ranged from 2 to 250; 61% of the processing firms had 5 or less employees, 22% had 6-10 employees and only 4% had 100 or more employees. In addition to potato crisps, 60% of the firms also processed peanuts, 30% processed *chevda* and potato sticks, 26% processed pop-corns, 13% processed banana crisps, 9% processed cassava crisps and 4% also processed arrow roots crisps, spices, peas and herbs. About 4% identified the main constraints as lack of proper equipments and market, 64% complained of lack of potatoes and its poor quality while 43% indicated lack of finances to increase volume of production. As pertains to produce sales, 83% of the processors sell their products directly to supermarkets, 4.3% through wholesalers and 13% directly to individuals and shops.

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Dutch Robjin variety sourced from Bomet, Rift Valley Province was the potato cultivar of choice for many processors and other cultivars were used in processing during periods of scarcity of cv. Dutch Robjin. A large number of processors (70%) stored their raw potatoes for relatively short periods of time ranging from 2 days to 3 weeks. A few (30%) processing firms stored potatoes for a month or longer. The potato crisps processing industry in Kenya is largely dominated by small scale processors who process crisps only as one of a diversity of other products. The industry is faced with several constraints including raw potato price fluctuations, scarcity and poor quality of potatoes, lack of adequate processing and storage facilities, skills and information on raw potato storage. The industry relies heavily on one variety that is not always available for all the processors. This information is important for potato breeders and postharvest technologists to avail sufficient suitable potato cultivars for crisping.

4.2 Introduction

Most potatoes in Kenya have until recently been consumed unprocessed, mainly in the area of production in the rural areas. However, consumption of potatoes has increased in urban centers as evidenced by the increasing number of fast food restaurants and processing industries, especially Nairobi city (Walingo *et al.*, 1998). The attractiveness of potatoes lies in the diversity of possible cooking methods including baking, roasting, boiling, stewing, frying and the manufacture of products including crisps and French fries. Processing and marketing of crisps for instance has become a major commercial activity in urban centers. Our earlier study showed that the Nairobi city dwellers eat potato crisps twice a week on average, mainly as snack (Abong' *et al.*, 2010a).

Processing of crisps has undergone tremendous growth over the last three decades. In early 1980s, only five potato crisps processors could be located in Nairobi city (Durr and Lorenzl, 1980). In 1995, there were at least fifteen processors with an average production of 61 tons per month and by 2004 the number of enterprises was estimated at more than 20 (Walingo *et al.*, 2004). Manufacturers of potato crisps have specific requirements with regard to variety, quality of raw materials to process quality products and quantity of the fresh potatoes they are prepared to purchase (Walingo *et al*., 1998). In Kenya, unfortunately, no varieties are grown specifically for processing. Processors, however, were reported to prefer the elongated white-skinned varieties; Nyayo and Roslin Tana for processing of fries (Abong' *et al.*, 2009c), while the round red-skinned Kerr's Pink and Dutch Robjin were preferred for crisps (Kabira, 2007). With only one variety and skewed production, it is possible that the growing industry does not get sufficient suitable raw materials. They are therefore forced to turn to alternative cultivars with quality characteristics close to the preferred in order to sustain processing capacities. This often leads to products of diverse quality characteristics, some of which do not conform to the international crisps specifications.

Little information is available regarding the current trends and possible constraints in processing and marketing of potato crisps in Kenya. This study was therefore designed to characterize the potato crisps industry in Kenya in terms size and diversity of firms, the varieties of potatoes processed, marketing, number of products and constraints in processing.

4.3 Materials and methods

4.3.1 Survey of potato crisps processors

This study was carried out between December 2009 and February 2010. A structured questionnaire (Appendix 3) which had been previously pre-tested was used to interview a total of 23 processors in Nairobi and Nakuru. The processors had been identified from labels of their products found selling in 80 supermarkets and selling outlets in Nairobi. The processors were contacted, visited and interviewed. The 23 processors consisted of 19 from Nairobi and 4 from Nakuru. Data was collected from the senior management and pertained to raw materials for processing, size of operation, marketing of products and constraints in crisp processing.

4.3.2 Data analysis

Data were analyzed using Statistical Package for Social Scientists (SPSS) version 11.5. Chi-square analysis was performed to determine relationships.

4.4 Results and discussion

4.4.1 Characteristics and constraints in crisps processing firms in Kenya

Results showed that majority (83%) of the 23 processing firms surveyed, were located within Nairobi city while a few (17%) were located in Nakuru town. This confirms earlier report by Walingo *et al.* (1998) that indicated the highest concentration of potato processors was in Nairobi city. The industries were of a wide range of size depending on the number of employees. The number of employees ranged from 2 to 250; up to 61% of the firms had 5 or fewer employees, 22% had 6-10 employees and only 4% had 100 and more employees (Figure 10). This means that processing of potato crisps is mainly by small-scale processors.

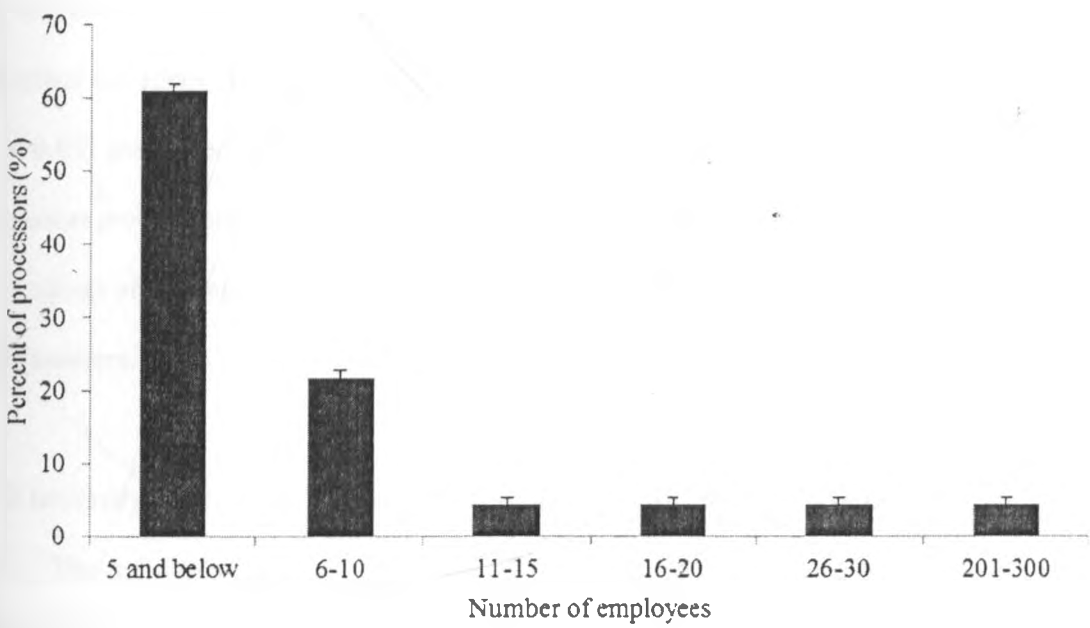

Figure 10: Number of employees in crisps processing industries in Kenya. All values are given as mean ± standard errors

Majority of the industries (48%) had been processing potato crisps for between 4-6 years compared to 17% that had been established for over 10 years while only 4% had been in the business for 1 year. The duration of operation did not, however, have any significant ($P > 0.05$) influence on either the volume of production or the number of employees showing that growth of the industry was in terms of numbers and not processing capacity. The apparent lack of expansion in size of individual industries was attributed to lack of adequate financial support which had been cited as a constraint. The potato crisps processors were faced with several constraints. Approximately 4% indicated lack of improved equipment and market, 64% complained of lack of appropriate potatoes and 43% indicated lack of finance to increase production capacity as a constraint. These results agree well with the observations of Walingo *et al.* (1998) and Kabira (2002).

The frequency of potato crisps manufacture by the processors ranged from twice a week to daily with majority of industries (44%) processing 4 times a week. In each processing day, a majority of the industries (52%) processed 50-100 kg of potato crisps. Only about 4% processed 1 ton and above. The production output depended on capacity of the processing industry where the majorities are operating on small-scale. The frequency of processing was, however, not significantly ($P > 0.05$) associated with the processing capacity. The study established that up to 44% of the processors produce crisps on order while 57% generally produced for free market. This is contrary to the findings of Walingo *et al.* (1998) who reported that most processors would rely on orders placed by consumers.

4.4.2 Diversity of products and packaging of potato crisps from industries in Kenya

The industries processed other products as a form of diversifying their markets. In addition to potato crisps, 60% processed peanuts, 30% *chevda* and potato sticks, 26% pop-corns, 13% banana crisps, and 9% cassava crisps while 4% also processed arrow roots crisps, spices, peas and herbs. The survey, however, indicated that 91% of the firms processed potato crisps as the main product which ranked first in terms of sales. There was therefore a lot of importance attached to potato crisps compared to other products that targeted the same market such as peanuts and *chevda*. Processing of other products was indicated by many firms as a means of diversification and spreading risks, rather than relying on a single product.

The unit weight of sale for potato crisps ranged from 10 g to 500 g with the most common package being 50 g or less and 101-200 g (Figure 11). Potato crisps are eaten as snack and the smaller units are convenient for school children while the larger packs are convenient and portable for older persons. Smaller packages were more easily affordable selling at between USD. 0.1-0.8.m It was noted that packages of 200 g or more were mainly from large-scale processors. All the processors packaged potato crisps in polythene which is the package of choice for many processors of snack foods. Most of the crisps had a shelf-life of 3-5 months, as was indicated on the packages.

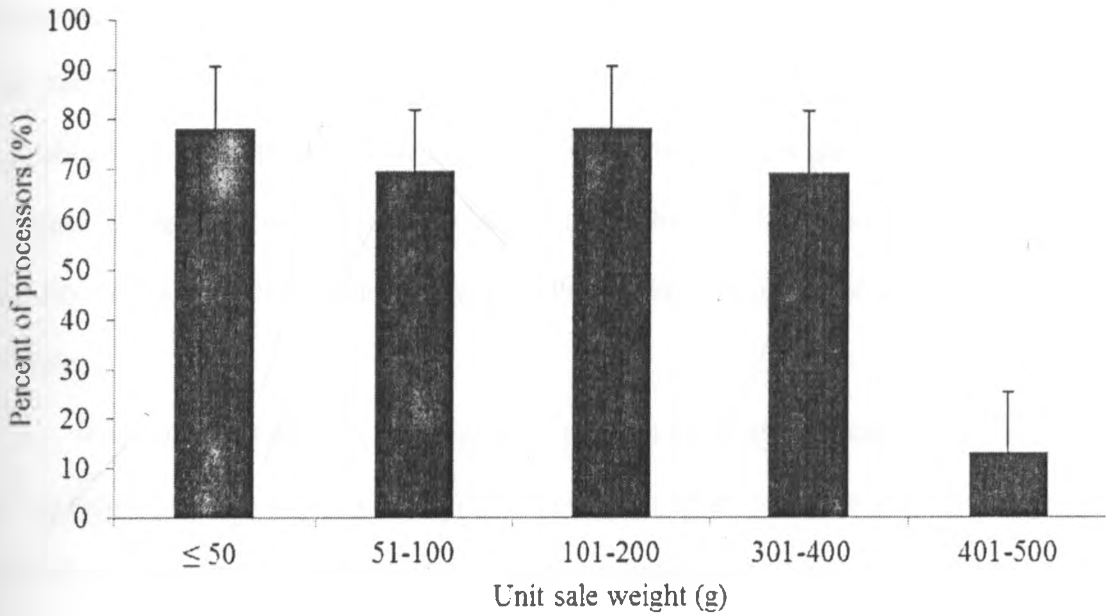

Figure 11: Unit sale weights of potato crisps processed by Kenyan industries. All values are given as mean ± standard errors

4.4.3 Potato varieties and constraints in procurement in industries

Flesh color had significant ($P \leq 0.05$) influence on the choice and procurement of raw potato to most processors. Most processors (65%) preferred the red skinned potatoes, 26% preferred white skinned potatoes, while 9% used both the red and white skinned potatoes for processing. The red skinned potatoes have been associated with good quality (golden yellow and crispy) crisps for a long time in Kenya (Walingo *et al.,* 1998; Kabira, 2002). The major potato cultivars utilized in crisps processing by Kenyan processors were Dutch Robjin (76%), Tigoni (26%) and Cangi (4%). Dutch Robjin has been the preferred potato cultivar for crisps processing for long time (Walingo *et al.*, 1998). Other cultivars such us Tigoni and Cangi have been used in processing, mainly as alternatives when cv. Dutch Robjin is in short supply.

The choice of potato cultivar for crisps processing was based on good quality of produced crisps, i.e. uniform golden yellow color (61%), availability of the potato (30%) and affordability (4.3%). The other criteria for the choice of raw potatoes were shallow eyes, smooth skin and round potato tubers since they produced good product yields because of low peeling and trimming losses. The major sources of cv. Dutch Robjin for most of the processors (62%) were Wakulima market in Nairobi and Bomet in the Rift Valley Province where the cultivar is grown in abundance. Wakulima market is a large open market centrally located in the city of Nairobi whose many processors around the city find easy access. Other markets include Nakuru town market and Kangemi markets in Nairobi.

Many of the processors (44%) procure potatoes daily, 39% procure once a week and a few (17%) procure twice a week. Only 1% procured raw potatoes once a month. These is explained by the fact that most processors are small-scale and had no adequate storage facilities and knowledge on how to prevent losses that are likely to be incurred during storage such us greening and rotting. Most large-scale processors, however, have adequate storage facilities and the necessary knowledge for proper storage, and can thus purchase potatoes on average once a month.

Raw potatoes were obtained in 110 kg gunny bags at average price of USD 19.00-26.00. This price, however, fluctuates within the year ranging from USD 19.00 to 58.00, depending on seasonal availability. The raw potatoes are plenty early in the year between February-March and also September and October during and after the two harvest seasons. During the low season between April and July, potatoes are in low supply at which time prices rise considerably. The low supply is occasioned by poor harvest during some seasons due to unpredictable drought. Political disturbances in the production areas occasionally affect supply especially during general elections.

During acquisition of raw potatoes, processors face a number of constraints. These include price fluctuation, low quality of raw potatoes, unavailability of suitable varieties throughout the year, lack of information and technology for storage, and high transport costs. A large number of processors (70%) store the raw potatoes for short periods of 2 days to 3 weeks. Other larger processing firms (30%) stored potatoes for a month or longer since they have appropriate storage structures and information. About 17% of the processors experienced losses of raw potatoes due to rotting and greening. Raw potato storage is an important step and requires absolute care and skills to maintain quality of crisps (Kabira and Lemaga, 2006). Appropriate skills and technologies should therefore be given to processors to prevent unnecessary losses.

4.4.4 Processing technology of potato crisps in Kenyan industries

The general processing operations were the same for almost all the processors and consisted of washing, peeling, slicing, washing, drying, frying, cooling and oil draining, salting or flavoring, and finally packaging. Flavoring potato crisps' has been widely adopted by processors who use a range of flavors including onion, cheese, *masala*, tomato, garlic and mixtures thereof. Slicing and frying stages of crisps processing pose a major challenge according to many processors as they determine crisp sizes and oil contents. These stages are critical in potato crisps processing for the desired quality in terms of color and amount of oil absorbed (O'Connor *et al.,* 2001; Cuesta *et al.*, 2001; Kita *et al.*, 2007; Ziaiifar *et al.*, 2008; Abong, *et al.,* 2009c).

The major type of fuel used by most of the processors (52%) who were mainly small-scale was sawdust and firewood. However, 31% used electricity and 17% used charcoal. Contrary to expectations, fewer processors were using electricity due to the current high tariffs levied on electric power in Kenya that in turn lead to higher costs of production.

Table 4 shows the types of frying oils commonly used by processors in Kenya. There was no significant ($P > 0.05$) association between processing capacity and the choice of oil used.

Table 4: Major frying oils used by potato crisps processors in Kenya

Brand	Oil type	Manufacturer	City and country	Percent of crisps Processors (%)
Rina	Vegetable oil	Kapa Oil Refineries Ltd.	Nairobi, Kenya	35
Cheff	Corn oil	Premier Oil Mills Ltd.	Nairobi, Kenya	30
Elianto	Corn oil	Bidco Oil Refineries	Thika, Kenya	30
Golden fry	Vegetable oil	Bidco Oil Refineries	Thika, Kenya	26
Ufuta	Vegetable oil	Bidco Oil Refineries	Thika, Kenya	4
Postman	Vegetable oil	Kapa Oil Refineries Ltd.	Nairobi, Kenya	4

The largest number of processors (35%) used Rina vegetable oil; a good number (30%) used Cheff and Elianto corn oils, 26% used golden fry vegetable oil while a few (4%) used Ufuta and Postman vegetable oils. None of the surveyed processors used solid fats. All the processors were conscious of quality as affected by the choice of oil, which was chosen for production of good crisps color and to prevent them from sticking together when cooled after frying. On average, the frying oil was changed after 17-24 hours. However, the spent oil was occasionally used for frying other products such as peanuts and popcorns. Potato peels were either discarded or given to farmers as animal feed.

4.4.5 Marketing and marketing constraints in potato crisps processing industries in Kenya

A majority of the processors (83%) sold their products directly to supermarkets, 13% to individuals and kiosks and 4% to wholesalers (Figure 12). Although the market channel was not significantly ($P > 0.05$) influenced by processing capacity, most kiosks and individual buyers received products mainly from small scale processors. The current findings contrast the reports of an earlier study by Walingo *et al.* (1997) that indicated a customer base of 60% supermarkets and 40% wholesalers.

The higher volume of sales to the supermarkets indicates that most of the crisps processors comply with Kenya Bureau of Standards (KEBS) quality requirements since supermarkets acceptance criterion is pegged on meeting the strict KEBS standards certificate among other factors. Most of the potato processors (91%) were aware of the standards for potato crisps as required by KEBS. This was confirmed by display of up-to-date certificates at the processing premises of individual firms.

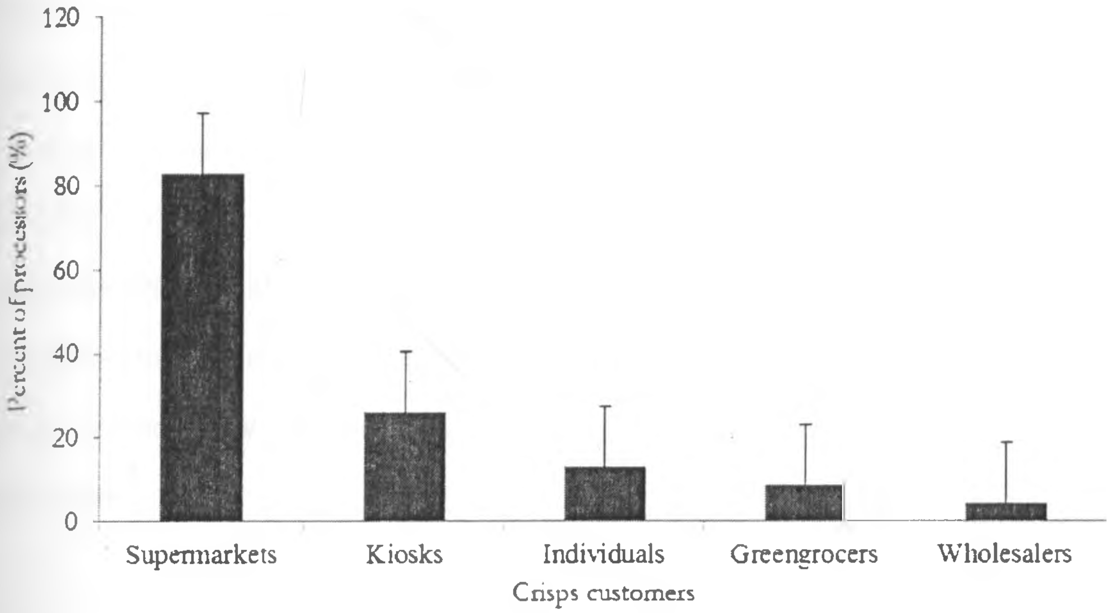

Figure 12: Major customers for potato crisps in Nairobi and Nakuru, Kenya. All values are given as mean ± standard errors

To most of the processors (61%), the market had experienced growth in terms of sales volume compared to two years ago. Results from our earlier study indicated that consumption of potato crisps in Nairobi was on the rise (Abong' *et al.*, 2010a). The demand for potato crisps was, however, noted to vary with seasons; higher sales were recorded during school holidays and during festive seasons. A few (21%), especially small-scale processors recorded higher sales during school days. This is because most of them depend on kiosks which serve school going children on school days.

Major problems encountered by processors during sales and marketing of potato crisps included cancellation of orders and increasing cost of processing (9%), obtaining of Kenya Bureau of Standards certificate (4%), high competition (30%) and ethnic bias (13%) especially when looking for orders from the shops. This indicates that many processors have to compete for the available market.

4.5 Conclusions and recommendation

The potato crisps processing industry in Kenya is dominated by small scale processors who process crisps only as one of a diversity of other products. The industry is faced with several constraints including raw potato price fluctuations, scarcity and poor quality of ware potatoes, lack of facilities, skills and information on raw potato storage. The industry relies heavily on one variety that is not always available for all the processors. A large number, mainly small scale processors stored their raw potatoes for quite a short period of time ranging from 2 days to 3 weeks due to lack of sufficient storage facilities and knowledge. It would be important to train these processors on basic storage requirements.

CHAPTER FIVE

EVALUATION OF SELECTED KENYAN POTATO CULTIVARS FOR PROCESSING INTO POTATO CRISPS

5.1 Abstract

There has been tremendous increase in the demand and consumption of potato crisps as snacks in Kenya. This has however, not been paralleled by development of appropriate raw materials. Many potato varieties and clones have been developed through breeding, but these have not been adequately evaluated for crisps processing. This study was therefore designed to evaluate the newly developed potato cultivars for processing into quality crisps. Twenty four potato cultivars including eighteen varieties and six clones were evaluated for some physico-chemical properties and crisps processing potential. Most cultivars with the exception of six of them including Roslin Tana, Desiree, Roslin Eburu, Nyayo, Tigoni Long and Kihoro had acceptable physical characteristics for processing. The specific gravity of the cultivars varied from 1.074 to 1.098 and dry matter contents ranged from 19.50 to 24.20%. Reducing sugar levels significantly ($P \leq 0.05$) varied among the cultivars and ranged between 0.07% and 0.4%. In addition to Dutch Robjin which is currently used for processing potato crisps in Kenya, the varieties Tigoni and Kenya Baraka, and the clones 393371.58, 392657.8, 391691.96 and 393385.39 were also found suitable for processing into potato crisps. They had desired physical characteristics with low levels of reducing sugars and produced crisps that were highly rated by sensory panelists. Promoting the production of these cultivars will increase the number of processing varieties for the rapidly expanding processing industry, and thus safeguard availability and quality.

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5.2 Introduction

Potatoes belong to the Solanaceae family commonly grown for starchy tubers. Potatoes are the World's most widely grown tuber crop and the fourth largest crop in terms of fresh produce after rice, wheat and maize (MoA, 2005). According to the National Policy on Potato Industry, the potato is an important food crop that plays a major role in food security and is only second to maize in terms of utilization (MoA, 2007). Production is confined to the highlands (1500-3000 m above sea level), where the crop has highest yields. The growing areas of production include Central, Rift Valley, Eastern, and to a less extent the high levels of Western and Coast provinces. Potato production is increasing due to the economic decline of competing cash crops such as maize, pyrethrum and barley, and increasing demand from consumers and processors (Kabira, 1990).

Over 60 potato varieties including Roslin Eburu, Roslin Tana, Roslin Gucha, Bvumbwe, Feldslohn, Nyayo, Kenya Sifa, Kenya Baraka, Kenya Dhamana, Desiree, Asante, Tigoni, Annet, Arka, Kenya Mavuno, Dutch Robjin and Kerr's Pink are currently grown and marketed in Kenya (MoA, 2007). In addition, the newer potato varieties developed by the National Potato Research Center (KARI-Tigoni) presumed to be superior to the existing ones in terms of disease tolerance (mainly late blight and viruses), require to be evaluated to establish their potential for processing. Among the existing varieties, the round red-skinned type Dutch Robjin has been commonly used for crisps processing in Kenya. Though limited to sensory testing, suitability of crisps processing of newer varieties Asante, Tigoni and Furaha were evaluated (Kabira, 2000; Kabira, 2002). Many advanced potato clones from the International Potato Centre, Lima-Peru have been introduced into the national potato breeding programme. They are currently undergoing multi-locational trials and at least six of them are undergoing national performance trials in collaboration with Kenya Plant Health Inspectorate Service (KEPHIS) (Kiplagat, 2008). Information on the processing characteristics of the new and promising cultivars is required in order to support the rapidly expanding potato industry with quality raw materials.

The most important products in the Kenyan potato processing industry are potato chips (ready-to-eat), crisps and frozen fries. The demand for all these products has greatly increased in the urban areas (Walingo *et al.*, 2004; Kabira, 2007). The processing of potato crisps in Kenya has undergone tremendous growth over the last three decades. In early 1980s, only five processors existed in Nairobi city (Durr and Lorenzl, 1980). In a previous study by the present authors, at least 24 processors existed in the city. The potato varieties for processing into crisps vary among processors and countries depending on the suitability and availability. Crisps therefore, vary in quality depending on country of origin and the processor (Salvador *et al.*, 2008).

The major hindrance to crisps processing in Kenya is the unavailability of sufficient quantities of appropriate quality potato cultivars (Kabira, 2007). Although potato crisps processing industry is an important outlet for Kenyan farmer's production, the country has only one variety for crisping (Maingi, 2009). Unfortunately even for this variety, the best tubers for crisps come from only one region of the country, Bomet in the Rift Valley Province. Although the variety is the most favored for processing, the tubers of Dutch Robjin have medium to deep eyes which may lead to substantial peeling and trimming losses compared with varieties such as Tigoni having shallower eyes. Furthermore, a single variety cannot be relied on to supply sufficient raw material for an expanding local and exports crisps market. Several varieties and clones have been developed which can be evaluated to expand the available appropriate raw material (Walingo *et al.*, 2007; Kiplagat, 2008; Abong' *et al.*, 2009a). Indeed, during periods of scarcity the processors underutilize their installed capacity within factories with more than 50%. During these periods also, the manufacturers use any available potato cultivars which lowers the general quality of crisps (Walingo *et al.*, 2004).

Crisps quality is influenced by tuber size, shape, eye depth, specific gravity, dry matter and levels of reducing sugars. These factors depend on cultural practices, environmental conditions, genotype and postharvest handling and storage. The genetic component, however, has the strongest influence since the traits are heritable (Kabira and Lemaga, 2006; Abong' *et al.*, 2009a). This study was therefore designed to evaluate 24 potato cultivars including 18 varieties and 6 advanced potato clones for their suitability as raw materials for processing into potato crisps.

5.3 Materials and methods

5.3.1 Potato tuber production

Six promising clones coded as 392617.54, 393371.58, 385524.9, 392657.8, 391691.96 and 393385.39 from the International Potato Center (CIP) and eighteen varieties (Tigoni, Desiree, Dutch Robjin, Kenya Karibu, Kenya Baraka, Cangi, Pimpernel, Roslin Tana, Asante, Kihoro, Kenya Furaha, Romano, Roslin Eburu, Arka, Kenya Mavuno, Tigoni Long, Nyayo and Kenya Sifa) were grown at the National Potato Research Center Tigoni (2100 m above sea level) in the year 2009/10 under standard cultural conditions (Lung'aho and Kabira, 1999). After maturity, the crop was dehaulmed two weeks before harvesting. Then, the tubers were harvested and allowed to cure in a common dark store under ambient air conditions (17-22 ^{o}C/84-92% rh) for two weeks at the National Potato Research Center in Tigoni. They were then analyzed for physical characteristics at Tigoni and for crisping property at a processing company. The dry matter content and reducing sugars levels were analyzed at the Department of Food Science, Nutrition and Technology, University of Nairobi.

5.3.2 Physical tuber characteristics

The physical tuber characteristics (shape, size, skin and flesh color, and eye depth), were determined according to the methods described by Kabira and Lemaga (2006) and Abong' *et al.* (2009c).

Tuber shape, size and eye depth

Shapes were determined by observation of 10 representative tubers from each cultivar. The shape was designated as round, elongated, oblong, long oval, pointed oval or oval. The samples were measured for size and eye depths using a vernier caliper (NSK Nippon Sokutei, Japan) and a ruler (Aim, Kenya), respectively. Size was determined in terms of diameter. Eye depth was recorded as shallow (0.00-0.20 mm), medium (0.20-0.50 mm) or deep (>0.60 mm). Round tubers with shallow or medium eye depths and of size 40-60 mm in diameter were considered suitable for processing.

Skin and flesh color

Five representative tubers were picked at random from a net bag of 10 kg of each cultivar and visually examined for skin color which was recorded as cream, red, white, pink or purple. Each tuber was then cut with a knife longitudinally and flesh colors recorded as white, yellow or cream.

Specific gravity and dry matter content

Specific gravity was determined in the raw tubers according to weight under water method as described by Ludwig (1972). Tubers with specific gravity of $\geq$ 1.080 were considered suitable for crisps processing. For determination of dry matter, five whole tubers were randomly selected from each cultivar and cut into small slices (1-2 mm) and mixed thoroughly. Dry matter contents were then determined by drying triplicate 20 g samples at 80 °C for 72 hr in a forced air oven. Tubers with dry matter contents $\geq$ 20% were considered ideal for crisps processing.

5.3.3 Reducing sugars

Reducing sugars were determined on triplicate samples by the Luff-Schoorl method number 4 of the International Federation of Fruit Juice Producers (1985). Tubers with reducing sugars contents of $\leq$ 0.25% were considered ideal for crisps processing.

5.3.4 Potato crisps preparation and evaluation

Potato tubers were peeled, and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to a uniform thickness of 1.5 mm. These slices were washed in cold tap water to remove surface starch dewatered by centrifuging (PPM No. 824, Sweden) at 3000 rpm for 3-5 min. The potato slices were then fried in an institution size, batch type, and deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) containing about 10 litres of "Cheff" corn oil maintained at a fixed temperature of 170 ^{0}C for 3-5 min. The fried slices were removed and excess oil drained off for 1 min, placed on plates, cooled and taken for evaluation.

Crisp color was determined according to PC/SFA (1987) color chart ranging from a score of 1 to a score of 5. Where one was highly acceptable (golden yellow) and 5 was highly unacceptable (dark brown) and 2.5 represented the maximum acceptability score.

For sensory evaluation, coded samples were presented to 10 panelists, all familiar with potato crisps. Panel members scored for color, texture, flavor, oiliness and overall acceptability on a 7-point hedonic rating scale with 1= dislike very much to 7 = like very much (Appendix 4). A score of 4 was the lower limit of acceptability (Larmond, 1977).

5.3.5 Data analysis

Data were subjected to analysis of variance (ANOVA) and means separated by least significant difference test using Statistical Analysis System (SAS version 9). Pearson correlation analysis was also performed to determine linear relationships if necessary.

5.4 Results and discussion

5.4.1 Physical tuber characteristics

The physical characteristics of tuber shape, size, eye depth, skin and flesh color are shown in Table 5. Majority of the cultivars tested, with exception of Roslin Tana, Desiree, Roslin Eburu, Nyayo and Tigoni Long which had long or pointed oval shapes, were round in shape. Tuber shape is an important characteristic in influencing peeling and trimming efficiency during processing. Potato tubers that are round in shape have been shown to be suitable for crisps processing for most processors because they easily make the required crisp diameters (Kulkarni and Govinden, 1994; Kabira and Lemaga, 2006). On the basis of shape alone all the cultivars with round shape had potential to be processed to crisps that conformed to specifications. The long and oval tubers, however, lend themselves easily for processing into French fries (Kabira and Lemaga, 2006; Abong' *et al.*, 2009c).

With the exception of variety Kihoro that had deep eyes, all cultivars had tubers with either shallow or medium eye depths. Deep eye depths lead to heavy losses during peeling and trimming and overall lowered yields of crisps (Smith, 1975; Kabira and Lemaga, 2006). Most cultivars had white, cream or red skin colors with the exception of clone 391691.96 that had dark-purple skin. White or red skin colors are associated with good quality by many Kenyan consumers (Kabira, 2000). The clone 391691.96 is an exception; dark purple skin color is a rare appearance and may not be popular with the consumers at the initial stages of introduction but may be accepted or rejected depending on performance.

Table 5: Physical tuber quality characteristics of twenty four potato cultivars

Cultivar	Shape	Skin color	Flesh color	Eye depth
Tigoni	Round	Cream	Cream	Shallow
Dutch Robjin	Round	Red	Cream-yellow	Medium
Kenya Karibu	Round	Deep-Red	Yellow	Medium
Kenya Sifa	Flat/round	Red-pink	Cream	Shallow/Medium
Asante	Round	Red	White	Medium
392617.54	Round	White	White	Medium
393385.39	Round	Red	White	Medium
393371.58	Round	Cream	White	Shallow
385524.9	Round	Cream	White	Shallow
392657.8	Round	Cream	White	Shallow
391691.96	Round	Dark-purple	Cream	Shallow
Kihoro	Round	Cream/yellow	Cream	Deep
Kenya Furaha	Round	Yellow	Cream	Shallow
Romano	Round	Red	White	Shallow
Roslin Tana	Long oval	White/yellow	Yellow	Shallow
Roslin Eburu	Pointed oval	White/yellow	White	Shallow
Arka	Round-oval	Red	Cream	Shallow
Pimpernel	Round	Red	Cream	Shallow
Kenya Baraka	Round	Cream	White	Shallow
Kenya Mavuno	Round	Cream/yellow	Cream-yellow	Shallow
Nyayo	Pointed oval	Cream white	Cream-yellow	Shallow
Tiglong	Long oval	Cream/white	Cream-yellow	Shallow
Desiree	Long oval	Red	Cream-yellow	Shallow
Cangi	Round	Cream	Cream-yellow	Medium

5.4.2 Tuber size, specific gravity, dry matter, reducing sugars content of selected cultivars

Tuber diameter varied significantly ($P \leq 0.05$) among the cultivars ranging from 43 mm in Tigoni Long to 56 mm in Kenya Sifa and clone 392617.54 (Table 6). All the cultivars therefore had tuber sizes within recommended range for crisps (40-60 mm in diameter). Tuber size directly influences crisp size, which in turn influences post-frying handling. Larger tubers than 60 mm in diameter yield crisps which are fragile and break easily during packaging and transport (Kabira and Lemaga, 2006). Specific gravity and dry matter contents differed significantly ($P \leq 0.05$) among the cultivars. The specific gravity of cultivars varied from 1.074 in Kenya Furaha and Tigoni Long to 1.098 in Roslin Eburu. All the cultivars except Tigoni Long, Kenya Furaha, Romano and clone 392617.54 had specific gravity greater than 1.080 that is recommended for crisps processing.

Table 6: Diameter, specific gravity, dry matter and reducing sugars content of twenty four potato cultivars

Cultivar	Diameter (mm)	Specific gravity	Dry matter content (%)	Reducing sugars (%)[1]
392617.54	56.00 ± 1.41a	1.079 ± 0.000h	20.22 ± 0.06h	0.07 ± 0.04h
385524.9	45.50 ± 0.71i	1.080 ± 0.001gh	20.75 ± 0.16hg	0.38 ± 0.18ab
392657.8	55.50 ± 0.71ab	1.082 ± 0.001f	21.00 ± 0.13ef	0.23 + 0.04cd
393371.58	53.50 ± 0.70bc	1.093 ± 0.001b	23.19 ± 0.10c	0.18 ± 0.11def
393385.39	48.00 ± 2.28ef	1.087 ± 0.000c	22.06 ± 0.07d	0.25 ± 0.00abc
391691.96	50.00 ± 0.00d	1.080 ± 0.001gh	20.82 ± 0.26gh	0.18 ± 0.11def
Arka	45.50 ± 0.71i	1.084 ± 0.003de	21.60 ± 0.58de	0.18 ± 0.12def
Asante	47.50 ± 3.53fg	1.082 ± 0.000f	21.07 ± 0.03ef	0.10 ± 0.00efg
Roslin Eburu	48.00 ± 2.83ef	1.098 ± 0.000a	24.20 ± 0.13a	0.28 ± 0.16abc
Kenya Baraka	45.50 ± 0.71i	1.092 ± 0.001b	23.10 ± 0.16c	0.10 ± 0.07efg
Desiree	54.00 ± 1.41ab	1.080 ± 0.000gh	20.70 ± 0.03h	0.20 ± 0.07cdef
Dutch Robjin	45.50 ± 0.71i	1.093 ± 0.001bc	23.26 ± 0.33c	0.10 ± 0.00efg
Kenya Furaha	46.50 ± 0.71g	1.074 ± 0.000i	19.50 ± 0.19i	0.28 ± 0.04abc
Kenya Karibu	52.00 ± 0.00cd	1.080 ± 0.000gh	20.70 ± 0.03h	0.08 ± 0.04h
Kihoro	50.50 ± 0.71d	1.085 ± 0.000d	21.57 ± 0.16de	0.05 ± 0.07i
Kenya Mavuno	46.00 ± 0.00hi	1.087 ± 0.000c	22.13 ± 0.03d	0.18 ± 0.11def
Nyayo	52.00 ± 0.00cd	1.097 ± 0.001a	24.13 ± 0.23a	0.35 ± 0.00ab
Pimpernel	50.00 ± 0.00d	1.094 ± 0.000ab	23.52 ± 0.03b	0.26 ± 0.00abc
Romano	51.00 ± 1.41cd	1.075 ± 0.001hi	19.64 ± 0.06i	0.40 ± 0.14a
Cangi	46.00 ± 0.00hi	1.080 ± 0.000gh	20.74 ± 0.00h	0.38 ± 0.17ab
Kenya Sifa	56.00 ± 0.00a	1.080 ± 0.000gh	20.70 ± 0.03h	0.18 ± 0.11def
Roslin Tana	50.25 ± 0.35d	1.085 ± 0.000d	21.80 ± 0.23de	0.23 ± 0.04bc
Tigoni Long	43.00 ± 0.00j	1.074 ± 0.008i	19.50 ± 0.51i	0.10 ± 0.00efg
Tigoni	46.00 ± 0.00hi	1.088 ± 0.000c	22.22 ± 0.16d	0.05 ± 0.07i

[1]Maximum of 0.25% is allowed; Results are means of three determinations ± standard deviation; Means with the same letter in the same column are not significantly ($P \leq 0.05$) different at 5%

Dry matter content ranged from 19.50% in Kenya Furaha and Tigoni Long to 24.20% in Roslin Eburu. Potato tuber specific gravity and dry matter content are very important characteristics in determining suitability of cultivars for crisps. Tubers with high specific gravity and dry matter have been shown to give higher yields of crisps, have lower oil absorption and better texture and therefore are more economical to process (Lulai and Orr, 1979; Burton, 1989). Potato crisps processing requires tubers with dry matter content of greater or equal to 20% and specific gravity of greater or equal to 1.080 (Kabira and Lemaga, 2006). Therefore, based on specific gravity and dry matter content selection criteria, all cultivars except Tigoni Long, Kenya Furaha, Romano and clone 392617.54 were suitable for processing.

Reducing sugars levels significantly ($P \leq 0.05$) varied among the cultivars ranging from 0.07% in clone 392617.54 to 0.4% in variety Romano. Besides factors such as environmental (such as temperature) or cultural practices (such as mineral nutrition, harvesting and storage conditions), genetic disposition has a strong influence on reducing sugar accumulation (Kumar *et al*., 2004). Reducing sugars react with amino acids in non-enzymic browning during frying of crisps to give them a golden brown color (Hamernik and Hanneman, 1998). The levels of reducing sugars and amino acids present in the potato therefore determine the extent of the brown color formation. Very high levels of reducing sugars would result in undesirable dark brown crisps as opposed to the required golden yellow color (Guar *et al*., 1999; Olsson *et al.*, 2004; Abong' *et al*., 2009a).

There was a significant ($P \leq 0.05$) correlation ($r = -0.53$) between reducing sugar contents and PC/SFA color scores that confirms the influence of reducing sugars on crisps color (Table 7). Based on reducing sugar content, all the cultivars tested in this study except clone 385524.9 and varieties Roslin Eburu, Kenya Furaha, Nyayo, Pimpernel, Romano and Cangi could be used for crisping.

Table 7: Pearson correlation coefficient (r) between PC/SFA color scores for crisps and levels of reducing sugars in twenty four raw potato cultivars

Parameters	PC/SFA color score	Reducing sugars
PC/SFA color score	1.00	-0.53[a]
Reducing sugars	-0.53[a]	1.00

[a]Significant correlation coefficient (P=0.0078). (N=24)

5.4.3 Sensory quality characteristics of potato crisps

Table 8 shows average sensory and PC/SFA color scores for crisps processed from 18 potato varieties and 6 clones. The sensory attributes of potato crisps that were evaluated differed significantly ($P \leq 0.05$) among the cultivars. Variety Roslin Eburu had the highest color score (5.68) while Cangi had the lowest score (2.73). Color has been shown to be one of the most critical sensory properties that determines acceptability of a food (Surkan *et al.*, 2009) and hence must conform to consumer requirement (Krokida *et al.*, 2001). Since there was a high correlation (r=-0.92) between PC/SFA and sensory color scores for potato crisps processed from the 24 cultivars, it therefore means that the panelists scores were in agreement with the objective color measurement (Table 9). Varieties Kenya Mavuno, Asante, Kenya Furaha, Arka, Romano and Kihoro had color scores below the acceptable limit of 4.0.

Flavor scores ranged from 3.4 in Cangi to 5.4 in Roslin Eburu. The flavor perception significantly ($P \leq 0.05$) varied among the cultivars. The low scores exhibited by Cangi may have resulted from the dark brown color and the burnt flavor due to high reducing sugar content. Flavor is influenced by genetic component of the potato cultivar and it does affect the consumer preference of potato products (Rojo and Vincent, 2008).

Textural scores differed significantly ($P \leq 0.05$) among the cultivars. The highest score was 5.41 in Roslin Eburu compared to the lowest in Cangi of 3.32. Depending on the tuber characteristics especially dry matter and processing conditions, the texture can be too hard or too soft (soggy). It is, however, noted that all the cultivars evaluated except Cangi had scores above the limit of acceptability. On oiliness, variety Cangi had the least score (3.64) compared to Kenya Sifa and clone 392617.54 which had the highest score (5.14).

Table 8: Average sensory and PC/SFA color scores for crisps processed from twenty four cultivars

Cultivar	Color[1]	Flavor[1]	Texture[1]	Oiliness[1]	Overall acceptability[1]	PC/SFA color score[2]
Dutch Robjin	4.86 ± 1.13cd	4.95 ± 1.13b	5.18 ± 1.33b	4.81 ± 1.26b	5.32 ± 1.36a	1.30 ± 0.17g
Kenya Baraka	4.82 ± 1.05d	4.95 ± 1.21b	5.05 ± 0.84b	5.05 ± 0.90a	4.95 ± 0.95b	1.38 ± 0.18f
Kenya Mavuno	3.45 ± 1.06j	4.09 ± 1.48g	4.05 ± 1.39e	3.91 ± 1.58g	3.95 ± 1.36e	2.63 ± 0.18b
Asante	3.41 ± 1.18j	4.14 ± 1.08fg	4.50 ± 1.37d	4.32 ± 1.09e	4.08 ± 1.09e	2.65 ± 0.18b
Kenya Furaha	3.73 ± 1.42j	3.95 ± 1.46g	4.09 ± 1.44e	4.05 ± 1.62f	4.09 ± 1.23e	2.55 ± 0.35b
Nyayo	4.14 ± 1.28gh	4.45 ± 1.30d	4.77 ± 0.97c	4.82 ± 1.05b	4.86 ± 1.12b	2.48 ± 0.18b
Tigoni	4.60 ± 1.17e	4.77 ± 1.30c	4.50 ± 1.37d	4.73 ± 1.49c	5.00 ± 1.29b	1.75 ± 0.35e
Arka	3.59 ± 1.67j	4.18 ± 1.50fg	4.45 ± 1.56d	4.32 ± 1.25e	4.09 ± 1.54e	2.53 ± 0.18b
Romano	3.45 ± 1.01j	4.00 ± 1.31g	4.23 ± 1.19e	4.14 ± 1.39f	4.14 ± 1.28e	2.63 ± 0.18b
Roslin Eburu	5.68 ± 0.84a	5.41 ± 0.85a	5.41 ± 0.91a	5.14 ± 0.89a	5.50 ± 1.10a	1.45 ± 0.35f
Pimpernel	4.64 ± 1.05e	4.86 ± 1.16bc	4.95 ± 0.95b	4.73 ± 1.08c	5.00 ± 1.11b	2.15 ± 0.18c
Kihoro	3.18 ± 1.36k	3.50 ± 1.44h	3.82 ± 1.44f	4.36 ± 1.17e	4.09 ± 1.23e	2.93 ± 0.18a
Desiree	4.20 ± 1.39gh	4.32 ± 1.27ef	4.52 ± 1.13d	4.55 ± 1.04d	4.61 ± 1.18c	2.13 ± 0.53c
Roslin Tana	4.50 ± 1.12ef	4.33 ± 1.32ef	4.20 ± 1.13e	4.40 ± 1.22d	4.43 ± 1.34d	2.00 ± 0.00d
Cangi	2.73 ± 1.70l	3.41 ± 1.82h	3.32 ± 1.76g	3.64 ± 1.59h	3.64 ± 1.50f	3.25 ± 0.35a
392657.8	5.27 ± 0.83b	5.18 ± 1.44b	5.27 ± 1.39b	5.00 ± 1.35a	4.90 ± 1.25b	1.75 ± 0.35e
391691.96	5.00 ± 1.19c	4.27 ± 1.28f	4.59 ± 1.10d	5.00 ± 1.07a	5.30 ± 0.97a	1.25 ± 0.35g
385524.9	4.27 ± 1.49gh	4.32 ± 1.24ef	4.73 ± 1.24c	4.68 ± 0.89c	4.86 ± 1.04b	2.23 ± 0.18c
393371.58	4.64 ± 1.50e	4.64 ± 1.43cd	4.64 ± 1.59c	4.59 ± 1.37c	4.68 ± 1.52c	2.25 ± 0.00c
392617.54	5.45 ± 0.91b	5.50 ± 1.01a	5.32 ± 1.17a	5.14 ± 1.13a	5.45 ± 1.26a	1.25 ± 0.35g
Tigoni Long	4.02 ± 1.60i	4.32 ± 1.35ef	4.68 ± 1.25c	4.45 ± 1.33d	4.55 ± 1.19c	2.35 ± 0.35c
Kenya Sifa	4.23 ± 1.41gh	4.64 ± 1.43cd	4.50 ± 1.54d	4.59 ± 1.33c	4.77 ± 1.19c	2.25 ± 0.17c
393385.39	4.36 ± 1.33g	4.95 ± 1.53b	5.05 ± 1.33b	5.14 ± 1.08a	5.32 ± 1.17a	2.33 ± 0.35c
Kenya Karibu	4.36 ± 1.56g	4.45 ± 1.59e	4.41 ± 1.33d	4.59 ± 1.86c	4.32 ± 1.86d	2.28 ± 0.18c

[1]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; [2]Scores of 2.5 and below were acceptable on a scale of 1 to 5; All figures are mean ± standard deviation; Means with the same letter in the same column are not significantly ($P \leq 0.05$) different at 5%.

Table 9: Pearson correlation coefficient (r) between PC/SFA and sensory color scores for crisps made from twenty four cultivars

Parameters	PC/SFA color score	Sensory color score
PC/SFA color score	1.00	-.92[a]
Sensory color score	-0.92[a]	1.00

[a]Significant correlation coefficient (P=0.000). (N=24)

Oiliness in crisps is as a result of the total oil absorbed or that which adheres to the surface. It depends on tuber characteristics and processing conditions. In the current study, all the cultivars except varieties Kenya Mavuno and Cangi had acceptable scores on oiliness. On overall acceptability, all the varieties and clones were generally acceptable with the exception of varieties Cangi and Kenya Mavuno that had scores of 3.64 and 3.95, respectively.

5.5 Conclusions and recommendation

Having considered the most critical characteristics including shape, eye depth, size, specific gravity, dry matter and reducing sugars of the potato tubers and sensory properties of crisps prepared from the 24 cultivars, varieties Dutch Robjin, Tigoni and Kenya Baraka and clones 393371.58, 392657.8, 391691.96 and 393385.39 were suitable for processing into potato crisps. Tubers of Dutch Robjin, Tigoni, 391691.96 and 393385.39 were, however, most suitable and could be promoted for commercial use by the potato industry. Variety Tigoni that is known to be high yielding can produce equally good quality crisps and should be promoted alongside Dutch Robjin that is the variety available currently for many crisps processors in Kenya. The advanced clones 391691.96 and 393385.39 performed farely well compared to Dutch Robjin. The National Potato Research Centre (KARI) should therefore ensure adequate production and distribution of these cultivars to farmers for supply to processors.

CHAPTER SIX

INFLUENCE OF FRYING TEMPERATURE, PACKAGING AND STORAGE TEMPERATURE ON ASCORBIC ACID CONTENTS OF CRISPS FROM FOUR POTATO CULTIVARS

6.1 Abstract

Though only as a snack, consumption of crisps is on the rapid rise in Kenya and can be considered to make considerable contribution to provision of dietary intake of nutrients. The fate of nutrients during processing of potatoes into crisps is therefore of considerable importance. This study was designed to assess the degradation of reduced ascorbic acid (RAA) during crisps processing. Reduced ascorbic acid (RAA) levels of fresh tubers was determined in four cured Kenyan potato cultivars (Dutch Robjin, Tigoni, 393385.39 and 391691.96) previously identified as suitable for processing into crisps. Tubers were processed into crisps by frying at temperatures of 160 °C, 170 °C and 180 °C. The crisps were stored in two packages; polyethylene and aluminium foil pack at three different temperatures of 25 °C, 30 °C and 35 °C. RAA was determined at intervals of 4 weeks during storage for 24 weeks. The RAA contents of the cultivars varied between 65.2 mg/100g in Dutch Robjin and 73.3 mg/100g in Tigoni and were significantly ($P \leq 0.05$) different from each other. The RAA contents of crisps varied between 40.0 and 51.5 mg/100g and were significantly ($P \leq 0.05$) different between the cultivars and frying temperatures. Package type and storage temperature significantly ($P \leq 0.05$) influenced the RAA retention by crisps during storage period. Crisps stored in aluminium foil packages at 25 °C retained the highest amount of RAA, while those stored in polyethylene bags at 35 °C retained the lowest. Low frying temperatures, aluminium package and storage at temperatures below 30 °C results in optimum retention of RAA.

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6.2 Introduction

Potato (*Solanum tuberosum L.)* is one of the most important tuber crops widely consumed in the world (Burgos *et al.*, 2009). It is ranked fifth in terms of human consumption and fourth crop after wheat rice and maize in worldwide production (Horton, 1987; Burlingame *et al.*, 2009). Apart from supply of energy and high quality protein, potato has also been known to be an important source of vitamins and minerals (Woolfe, 1987, Abong *et al.*, 2009b). Potato tubers have been reported to contain up to 46 mg/100 g ascorbic acid (in Fresh Weight Basis) depending on the variety, maturity of the tubers at harvest and the environmental conditions under which they were grown (Nourian *et al.*, 2003; Han *et al.*, 2004). The contribution of potato and its products to dietary intake of vitamin C is considerable and can therefore not be underestimated (Dale *et al.*, 2003).

Though potatoes have been popularly consumed in Kenya in various other forms including French fries and mashed mixtures, it is only recently that consumption of crisps has assumed a steep forward trend. This gives sufficient reason to start considering potato crisps as making significant contribution to dietary intake of nutrients especially by Kenyans of the middle class and high socio-economic groups living in the urban areas (Abong' *et al.*, 2010a). Many nutrients, especially vitamins are sensitive to harsh temperatures employed in deep frying of crisps. The quality of nutrients consumed in crisps could therefore be considerably low compared to the levels found in fresh tubers. The levels of nutrients even reduce further during storage of the products. A general perception of the degradation of vitamins during processing and storage of crisps can be gained by assessing the degradation of ascorbic acid (RAA) as an index.

As an antioxidant and an essential component of most living tissues, ascorbic acid (vitamin C) has been known to play an important role in protection against oxidative stress (Farvin *et al*, 2009; Badreh *et al.*, 2009). In addition, its role in enhancing the bioavailability of non-haem iron in the human body has been shown (Haase and Weber, 2003; Teucher *et al.*, 2004). Recommended daily allowance (RDA) of vitamin C varies not only with age, but also from country to country. The Food and Agriculture Organization (FAO/WHO, 2001) indicated that the recommended nutrient intake of vitamin C ranges from 25 to 70 mg/day, depending on age and that as little as 6.5-10.0 mg/day of the vitamin will prevent the appearance of scurvy on the body. In previous studies, however, based on available biochemical, clinical, and epidemiological studies, the recommended daily intake (RDI) of ascorbic acid was estimated to be 100–120 mg/day for adults to achieve optimum cellular levels that can reduce risk of heart disease, stroke and cancer in healthy individuals (Carr and Frei, 1999; Naidu, 2003).

Several authors have reported considerable reduction in the quantities of ascorbic acid during cooking with losses that vary widely according to cultivar, cooking and handling methods. During preparation and processing degradation, of vitamin C takes place by chemical and enzymatic oxidation, thermic degradation and diffusion into the preparation and processing medium. Losses of ascorbic acid were found to be 52% during processing into French fries and about 26% during crisps processing (Haase and Weber, 2003). Thermal degradation of the vitamin was noted to dominant during crisps processing because of the high temperature regimes employed.

Packaging plays critical roles of protecting food products from harsh atmospheric conditions that can lead to product damage and also provides consumers with ingredient and nutritional information. Crisps packaging can retard product deterioration extend shelf-life, and maintain or preserve quality and safety of food (Marsh and Bugusu, 2007). The major packaging material for potato crisps in Kenya is polyethylene and to a lesser extent, polyethylene lined with aluminium foil (Abong *et al.*, 2010a).

Current information on the ascorbic acid concentration of potatoes and their products during processing and storage relates mainly to commercial varieties outside Africa. In the light of the foregoing, it was therefore important to gain a general perception of the retention of ascorbic acid during processing of crisps and their storage under the prevailing conditions in Kenya. This was done by assessing the fate of ascorbic acid (RAA), one of the most important but easily degraded nutrients.

6.3 Materials and methods

6.3.1 Potato cultivars for processing

Two potato clones coded as 391691.96 and 393385.39 from the International Potato Center (CIP) and two established varieties (Tigoni and Dutch Robjin) were grown at the National Potato Research Center, Tigoni in the year 2009/10. These were grown under the standard cultural conditions as established by Lung'hao and Kabira (1999). The crops were harvested at maturity. Following harvest, the tubers were allowed to cure for 2 weeks in a naturally ventilated dark store under ambient air conditions (17-22 °C/78-90% rh). The cured tubers were analyzed for ascorbic acid contents.

6.3.2 Processing of potato crisps

Potato tubers were peeled and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to uniform thickness of 1.5 mm. The slices were thereafter washed in cold water to remove surface starch, dried with cloth towel and fried in an institution size, batch type, deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) in "Chef" corn oil (Premier Oil Mills Ltd., Nairobi, Kenya) at temperatures of 160 ^{0}C, 170 ^{0}C and 180 ^{0}C until bubbling ceased. The fried slices were removed and excess oil allowed to drain for 1 min, cooled and packaged then stored.

6.3.3 Storage of potato crisps

Potato tubers that were used for the storage trials were fried at 170 °C. The crisps from each cultivar were packaged into polyethylene bags (gauge 200 microns) and aluminium foil packs in batches of 200g each. The packaged crisps were stored at different temperatures of 25 °C, 30 °C and 35 °C. The levels of ascorbic acid (RAA) were determined at the beginning and after every 4 weeks during storage for 24 weeks.

6.3.4 Determination of reduced ascorbic acid (RAA)

Ascorbic acid was determined in duplicate by titration with 2, 6-dichlorophenolindophenol dye according to AOAC methods (AOAC, 1984).

6.3.5 Data analysis

Analysis of variance (ANOVA) and least significant difference test for the variables was conducted using the Statistical Analysis System (SAS version 9). Differences at $P \leq 0.05$ were considered significant.

6.4 Results and discussion

6.4.1 Influence frying temperature on Ascorbic acid content of potato crisps

The variation of ascorbic acid content in potato crisps made from four cultivars under different frying temperatures is shown in Table 10.

Table 10: Retention of RAA[1] in potato crisps from four cultivars after frying at different temperatures

Cultivar	Fresh tubers	Frying temperature (°C)		
		160	170	180
391691.96	69.81 ± 0.66c	42.93 ± 0.85d	41.40 ± 0.41d	40.01 ± 0.43c
393385.39	71.76 ± 0.47b	51.15 ± 0.37a	48.42 ± 0.27a	48.41 ± 0.42a
Dutch Robjin	65.17 ± 0.56d	48.66 ± 0.38b	46.78 ± 0.42b	45.41 ± 0.22b
Tigoni	73.31 ± 0.48a	45.91 ± 0.12c	45.12 ± 0.33c	44.22 ± 0.34b

[1]Determined in mg/100 g Dry Weight Basis; Values are mean ± SD; Means with the same letters within the same column are not significantly different at 5%.

The levels of RAA in fresh tubers significantly ($P \leq 0.05$) varied among the cultivars ranging from 65.17 mg/100g in Dutch Robjin to 73.31 mg/100g and Tigoni. There was significant ($P \leq 0.05$) reduction in the levels of RAA in all the cultivars when tubers were fried into crisps. The reduction was highest in variety Tigoni while it was lowest in Dutch Robjin. The reduction levels were significantly ($P \leq 0.05$) higher at 180 °C than at 160 °C. There was, however, no significant ($P > 0.05$) reduction when frying temperature was increased from 170 to 180°C.

Ascorbic acid levels in fresh potato tubers are mainly determined by cultivar's genetic make-up (Hemavathi, *et al.*, 2010). Different workers from different parts of the world have reported wide variation in concentration of RAA. Burgos *et al.* (2009) evaluated 25 Andean cultivars and reported a range of 22.2 to 121.4 mg/100 g on a dry weight basis (DW) and from 6.5 to 36.9 mg/100 g on a fresh weight basis (FW). Working on 9 Czech potato varieties, Hamouz *et al.* (2009) reported ascorbic acid levels ranging from 14 to 24 mg/100 g on a fresh weight basis (FW). The ascorbic acid levels on fresh weight basis ranged from 8 to 36 mg/100 g for American varieties (Augustin *et al.*, 1978), 10–17 mg/100 g for Indian varieties (Mishra, 1985) while in Norwegian and Korean varieties it varied from 8.4 to 20 mg/100 g and 16 to 46 mg/100 g, respectively (Nordbotten *et al.*, 2000; Han *et al.*, 2004). Odukoya *et al.* (2007) reported RAA ranging from 13 to 187 mg/100 g on dry weight basis in green leafy vegetables. Some fruits and vegetables may have higher RAA levels than the average levels in potato tubers. The contribution of dietary ascorbic acid from potatoes to the human diet could, however, be higher since in some places potato is a staple food as opposed to vegetables and fruits that are usually complementary components of the diet. The fruits which are major suppliers of the vitamin are rarely eaten by a large part of the population in developing world due to limited supply and high costs. Besides, potato crisps are regularly consumed especially in major urban centers (Abong' *et al.*, 2010a). In the present study, the concentrations of RAA in the cultivars therefore fall within the range reported in other parts of the world. Even though the levels of ascorbic acid in Kenyan potato cultivars differed from other varieties reported in the world, the ranges in the past studies are generally large. The potato family is similar and hence the close relationship all over the world.

In the present study, there was an average reduction of 45% in the RAA due to frying which is comparable to those reported by Burgos *et al.* (2009) on baked and microwaved potatoes. The average retention levels of 55% in ascorbic acid were, however, higher than 26% that was reported by Haase and Weber (2003) in potato crisps. Boiling the tubers was reported to reduce ascorbic acid by about 30% (Hagg *et al.*, 1998). During processing, higher frying temperature regimes (> 100 °C) have been known to determine level of thermal degradation of ascorbic acid in potato crisps. Higher frying temperatures lead to higher degradation of the vitamin (Sahin *et al.*, 1999; Pirone *et al.*, 2007).

6.4.2 Influence of packaging and storage temperature on ascorbic acid content of potato crisps

Cultivar variation of ascorbic acid levels with package and temperature during storage is presented in Table 11. Levels of ascorbic acid in fried crisps differed significantly ($P \leq 0.05$) with cultivar ranging from 40.99 to 49.42 in cultivar 391691.96 and 393385.39, respectively. Cultivar 393385.39 had the highest retention of the vitamin followed by Dutch Robjin, Tigoni and 391691.96 in that order.

Packaging type significantly ($P \leq 0.05$) influenced retention of ascorbic acid during storage. There was no significant ($P > 0.05$) variation of the vitamin content within eight weeks of storage in crisps packaged in polyethylene bags and aluminium foil packs. However, after eight weeks of storage significant ($P \leq 0.05$) reduction of ascorbic acid was noted in all the cultivars. Crisps packaged in aluminium foil pack retained higher levels of ascorbic acid (78%) compared to those in polyethylene bags which retained 58% after 24 weeks of storage.

Storage temperature had a significant ($P \leq 0.05$) effect on ascorbic acid retention; there was higher reduction of the vitamin levels at higher temperatures. There was significant ($P \leq 0.05$) temperature, packaging and time interaction on vitamin C retention; there was higher retention at storage temperature of 25°C in crisps packaged in aluminium foil pack while the least retention was noted in crisps stored in polyethylene bags at 35°C. The results are in agreement with findings of Hagg *et al.* (1998) who reported that storage of potato products at elevated temperature degraded ascorbic acid levels by 10% on average.

Table 11: Effect of packaging and storage temperature on RAA (mg/100 g DW) in potato crisps from four cultivars

Cultivar	PKG[1]	ST[2]	Storage time (weeks)						
		°C	0	4	8	12	16	20	24
391691.96	AF[3]	25	42.43 ± 0.41e	40.61 ± 0.78e	40.62 ± 0.14d	39.52 ± 0.30e	36.80 ± 0.28f	35.24 ± 0.23e	33.33 ± 0.18e
		30	41.30 ± 0.40e	40.71 ± 1.46e	40.27 ± 0.14d	38.89 ± 0.63ef	36.70 ± 1.87f	34.02 ± 1.53f	31.41 ± 1.62g
		35	41.35 ± 0.43e	41.38 ± 0.42e	39.71 ± 0.66de	39.00 ± 1.07e	36.38 ± 1.56f	34.02 ± 1.53f	29.96 ± 1.62g
	PE[4]	25	40.99 ± 0.41e	41.12 ± 0.14e	38.61 ± 1.60e	38.07 ± 0.59ef	33.82 ± 1.04h	30.92 ± 1.52h	28.10 ± 0.82h
		30	41.43 ± 0.41e	40.61 ± 0.55e	38.76 ± 0.37e	37.29 ± 0.56f	33.66 ± 0.93h	29.56 ± 0.62h	24.24 ± 0.95j
		35	42.40 ± 0.44e	41.03 ± 2.07e	40.90 ± 0.30d	40.06 ± 2.91e	35.81 ± 2.28f	31.00 ± 1.41h	24.88 ± 1.21j
393385.39	AF[3]	25	49.42 ± 0.37a	48.99 ± 0.01a	48.66 ± 0.26a	47.36 ± 0.47a	45.48 ± 0.72a	43.14 ± 0.70a	40.88 ± 0.75a
		30	49.38 ± 0.37a	49.10 ± 0.58a	48.31 ± 0.26a	47.00 ± 0.17a	43.79 ± 0.81b	41.17 ± 0.84b	38.51 ± 0.67b
		35	49.41 ± 0.37a	49.30 ± 0.33a	47.67 ± 0.88a	47.33 ± 0.47a	43.13 ± 0.13b	41.17 ± 0.84b	37.06 ± 0.67c
	PE[4]	25	49.37 ± 0.37a	49.16 ± 0.26a	44.86 ± 0.35b	42.78 ± 0.06c	38.16 ± 0.23d	34.94 ± 0.06f	29.43 ± 0.07g
		30	49.41 ± 0.73a	48.25 ± 0.35a	44.94 ± 0.06b	42.78 ± 0.56c	37.61 ± 0.55d	33.99 ± 0.01f	27.86 ± 0.11h
		35	49.36 ± 0.37a	49.34 ± 0.48a	45.07 ± 0.90b	43.18 ± 0.38c	37.27 ± 1.03d	32.54 ± 0.20g	26.62 ± 0.01i
Dutch Robjin	AF[3]	25	46.48 ± 0.42b	45.94 ± 0.33b	44.95 ± 0.62b	44.90 ± 0.40b	43.50 ± 0.71b	41.39 ± 0.86b	38.92 ± 0.36b
		30	46.78 ± 0.42b	46.50 ± 0.71b	44.70 ± 0.62b	43.70 ± 0.22bc	40.05 ± 0.09c	37.76 ± 0.34c	35.46 ± 0.33d
		35	46.58 ± 0.42b	46.69 ± 0.45b	43.80 ± 0.58bc	43.46 ± 0.07bc	40.27 ± 0.04c	37.76 ± 0.34c	34.01 ± 0.33d
	PE[4]	25	46.73 ± 0.42b	45.67 ± 0.62bc	42.90 ± 0.55c	42.82 ± 0.36c	39.27 ± 0.38c	35.84 ± 0.04e	31.07 ± 0.05f
		30	46.66 ± 0.41b	45.95 ± 0.78b	42.56 ± 0.59c	41.78 ± 0.27e	37.49 ± 0.72d	33.43 ± 0.80f	30.04 ± 0.28g
		35	46.78 ± 0.42b	45.78 ± 0.83bc	39.97 ± 0.97de	39.61 ± 0.54e	34.88 ± 0.24g	31.81 ± 0.83h	27.75 ± 0.63h
Tigoni	AF[3]	25	46.01 ± 0.38b	45.01 ± 0.14bc	43.61 ± 0.15bc	43.47 ± 0.35c	41.98 ± 0.02c	40.06 ± 0.22b	38.22 ± 0.35b
		30	44.97 ± 0.38c	44.21 ± 0.33c	43.36 ± 0.15bc	42.20 ± 0.28c	38.77 ± 0.32e	36.42 ± 0.51d	33.72 ± 0.67e
		35	45.32 ± 0.33c	45.02 ± 0.32c	42.94 ± 0.39c	42.22 ± 1.10c	39.20 ± 0.39c	36.42 ± 0.52d	32.27 ± 0.67f
	PE[4]	25	45.52 ± 0.33c	44.33 ± 0.15cd	40.61 ± 0.76d	39.29 ± 0.25e	34.10 ± 0.12g	30.26 ± 0.74h	25.42 ± 0.73i
		30	45.12 ± 0.38c	44.31 ± 0.02cd	41.09 ± 0.16d	40.20 ± 1.03e	36.38 ± 0.54f	33.02 ± 0.49g	30.25 ± 1.13g
		35	45.18 ± 0.39c	44.59 ± 0.84cd	40.81 ± 0.30d	39.74 ± 1.05e	35.94 ± 0.71f	31.67 ± 0.47h	27.43 ± 0.77h

PKG[1]=Packaging type; ST[2]=Storage temperature; AF[3] =Aluminium foil pack; PE[4]=Polyethylene; Values are means ± SD; Means with the same letters within the same column are not significantly different at 5% level of significance

Like any other food product, the role of packaging in potato crisps is to protect it damage and to provide consumers with ingredient and nutritional information. The goal of food packaging is to safety, and minimizes environmental impact (Marsh and Bugusu, 2007). Packaging in aluminium foil pack provided the best protection leading to increased ascorbic acid retention compared to polyethylene bag.

6.5 Conclusions

Potato cultivar, frying temperature, packaging type and storage temperature were found to greatly influence the levels of ascorbic acid in raw tubers and processed crisps. Frying crisps from the four cultivars at all temperatures significantly reduced the levels of ascorbic acids irrespective of the cultivar. The reduction was highest in variety Tigoni while it was lowest in Dutch Robjin. Lower frying temperatures and packaging of crisps in aluminium Foil Pack and storage at temperatures less than 30°C will ensure maximum RAA retention in potato crisps.

CHAPTER SEVEN

EFFECTS OF FRYING TEMPERATURE AND SLICE THICKNESS ON OIL UPTAKE AND SENSORY QUALITY OF POTATO CRISPS PROCESSED FROM FOUR KENYAN CULTIVARS

7.1 Abstract

The effects of cultivar, frying temperature and slice thickness on oil uptake and sensory quality of crisps were investigated in four Kenyan cultivars. Potato tubers were peeled, washed and cut into slices of thickness 1.0 mm, 1.5 mm and 2.0 mm. Each size was fried at a constant temperature of 170 °C for 3-5 minutes. For frying temperature evaluation, the potatoes for all cultivars were cut into a uniform thickness of 1.5 mm and fried at temperatures of 160, 170 and 180 °C for 2-5 minutes.

Crisps made from the four cultivars differed significantly ($P \leq 0.05$) in oil absorbed which ranged from 35.12% in Dutch Robjin to 36.52% in clone 391691.96. Tuber dry matter differed significantly ($P \leq 0.05$) among the cultivars ranging from 20.99% in clone 391691.96 to 25.29% in variety Dutch Robjin. Tuber dry matter content was found to be negatively correlated to oil content of crisps; oil content increased with decrease in dry matter content. For each cultivar, the oil content of crisps differed significantly ($P \leq 0.05$) with temperatures and was higher at frying temperatures of 160 °C and lowest at 180 °C, respectively. The oil content was significantly ($P \leq 0.05$) higher in slices of 1.0 mm thick than in slices of 1.5 mm and 2.0 mm; the amount of oil absorbed decreased with increase in slice thickness. There was significant correlation ($P \leq 0.05$, $r=-0.834$) between oil content as determined in the laboratory and sensory scores. Results showed that high dry matter, slice thickness and temperature of frying resulted in reduced oil absorption by crisps during processing.

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7.2 Introduction

Potato crisps are popular fried snacks in the world. They are increasingly becoming important snack foods to many Kenyans and especially those living in major urban centers (Abong' *et al.*, 2010a). Potato crisps are among the most important products in the Kenyan potato processing industry. The demand for crisps increases rapidly, especially during festive seasons (Walingo *et al.,* 2004). The amount of oil absorbed during deep frying of crisps is becoming important (Hagenimana *et al.*, 1997). The amount of oil absorbed is a major influence of the number of calories supplied by the food. Fried foods may contain very high amounts of oil that in some cases is more than 40% of the weight of the total product (Gamble *et al.,* 1987; Kita *et al.*, 2007). French fries made from Kenyan cultivars, for example, were found to contain on average 12% oil content (Abong' *et al.,* 2009d) and crisps can contain oil contents of up to 45% depending on potato cultivar, and processing parameters (Hagenimana *et al.*, 1997; Kita *et al.*, 2007, Abong' *et al.*, 2010a). Consumption of crisps is therefore of concern to nutritionists and health practitioners who advocate a decreased or increased oil intake in diets depending on the part of the World they are based. Crisps with low oil content and desirable sensory attributes are therefore expected to be accepted by the increasing numbers of health conscious consumers (Hagenimana *et al.*, 1997).

Many factors have been reported to affect the oil content of French fries and crisps including oil quality, frying temperature and duration, slice thickness, product shape and composition in terms of moisture, solids and fat content, pre-frying techniques such as blanching, drying and frying and any added coating such as methylcellulose or colloids (O'Connor *et al.*, 2001; Garc'ia *et al.*, 2004; Garmakhany *et al.*, 2008; Ziaiifar *et al.*, 2008). Gamble *et al.* (1998) found the loss of moisture and the oil uptake in French fries during frying to be interrelated; a reduction of the initial moisture content by drying was recommended to reduce the oil uptake into potatoes. Deep-fat frying of potato slices for crisps production has been shown to involve an initial, very short period of heating at high moisture level resulting in gelatinization of starch followed by a rapid dehydration period to a final moisture content of about 2% (Ufheil and

Escher, 1996). There exists a close contact between the frying oil and the surface of the potato slices that ensures high heat and mass transfer rates. In addition, the frying oil is taken up by the potato slices to a final oil content of approximately 35% for most industrial manufactured crisps (Ufheil and Escher, 1996).

The frying process as a function of time has been well described (Baumann and Escher, 1995). It has been noted that the residence time of frying determines the amount of oil absorbed by the potato slices; the longer the time, the greater the amount of oil absorbed. Literature information on the relation of cultivar, dry matter content, frying temperature and slice thickness to final oil content vary and to some extent is contradictory. In earlier investigation by Ufheil and Escher (1996), an increase of fat content with decreasing initial dry matter, decreasing slice thickness, decreasing oil temperature and increasing frying time was found, the relative influence of these four factors being different from each other.

Selection of appropriate variety and proper control of process parameters are important in determining the oil uptake by crisps (Kabira and Lemaga, 2006). The present study was therefore designed to investigate the influence of potato cultivar, frying temperature and slice thickness on oil content and sensory quality of crisps processed from four Kenyan potato cultivars.

7.3 Materials and methods

7.3.1 Potatoes for processing

Two potato clones coded as 391691.96 and 393385.39 from the International Potato Center (CIP) and two varieties (Tigoni and Dutch Robjin) were grown at the National Potato Research Center Tigoni (2100 m above sea level) in the year 2009/10. These were grown under the standard cultural conditions (Lung'hao and Kabira, 1999). After maturity, the crop was dehaulmed two weeks before harvesting. Then, the tubers were harvested and allowed to cure in a common dark store under ambient air conditions (17-22 °C/84-92% rh) for two weeks at the National Potato Research Center in Tigoni. They were then analyzed for dry matter content and processed into crisps in Tigoni and the products analyzed for oil content in our laboratories in the Department of Food Science, Nutrition and Technology, University of Nairobi.

7.3.2 Potato crisps processing

Potato tubers were peeled, and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to uniform thicknesses of 1.0 mm, 1.5 mm and 2.0 mm. The slices were washed in cold water to remove surface starch, dried with a cloth towel and fried at a constant temperature of 170 ^{0}C for 3-5 min in an institution size, batch type, deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) containing about 7 litres of "Cheff" corn oil (Premier Oil Mills Ltd., Nairobi, Kenya). For frying temperature evaluations, the potatoes for all cultivars were cut into a uniform thickness of 1.5 mm and triplicate samples of 100 g slices were fried in oil heated at temperatures of 160 ^{0}C, 170 ^{0}C and 180 ^{0}C for 2-5 min. The fried slices were removed and excess oil drained off for 1 min, placed on plates, cooled ready for evaluation.

7.3.3 Determination of moisture and dry matter content

The moisture contents of the fresh tubers and processed products were determined by standard analytical method (AOAC, 1984). Triplicate samples of approximately 5 g were accurately weighed in aluminum dishes and dried in an air-oven at 105 ^{o}C to constant weight. The dried samples were cooled in a dessicator to room temperature and weighed. Loss of weight due to drying was converted to percent moisture and dry matter content obtained.

7.3.4 Oil content determination

After drying, potato crisps were finely ground in a blender and triplicate 5 g samples were accurately weighed and placed into thimbles. They were extracted in 16-hr Soxhlet apparatus using analytical grade petroleum ether (boiling point 40-60 ^{o}C) as described by Lulai and Orr (1979). The petroleum ether was evaporated away in a rotary vacuum evaporator and the residual oil dried in an air-oven at 80 ^{o}C for 2 hrs. The weight of the residue was calculated as percent oil content.

7.3.5 Sensory evaluation of potato crisps

For sensory evaluation, coded samples were presented to 20 panelists, all familiar with potato crisps. Panel members scored for flavor, oiliness and overall acceptability on a 7-point hedonic rating scale varying from 1(dislike very much) to 7 (like very much). A score of 4 was the lower limit of acceptability (Larmond, 1977).

7.3.6 Data analysis

All these experiments were replicated three times, and the average values are reported. Analysis of variance (ANOVA) and least significant difference test for the variables were conducted using the Statistical Analysis System (SAS version 9). Correlation analysis was performed to determine linear relationship between tuber dry matter content and oil content, and also between oil content determined in laboratory and sensory scores. Differences at $p \leq 0.05$ were considered significant.

7.4 Results and discussion

7.4.1 Influence of tuber dry matter on oil content of potato crisps

Influence of tuber dry matter content on oil content of crisps is illustrated in Figure 13.

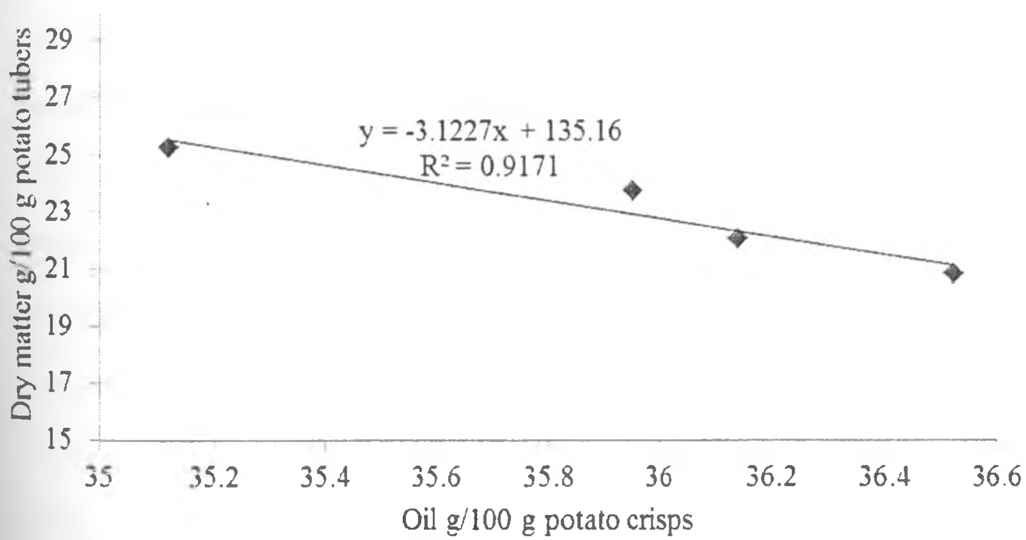

Figure 13: Correlation between dry matter in raw potato cultivars and oil content of crisps

Tuber dry matter differed significantly ($P \leq 0.05$) among the cultivars. Dry matter content ranged from 20.99% in clone 391691.96 to 25.29% in variety Dutch Robjin. Crisps made from the potato tubers differed significantly ($P \leq 0.05$) in oil content which ranged from 35.12% Dutch Robjin to 36.52% in clone 391691.96. Tuber dry matter content was found to be negatively correlated to oil content of crisps; oil uptake increased with decrease in tuber dry matter. The range of dry matter content, 20.99% to 25.29%, in potato tubers is within the recommended levels for crisps processing in Kenya and East Africa (Kabira and Lemaga, 2006). On the basis of dry matter content as a selection criterion, therefore, all the cultivars were suitable for crisps processing. Potato tuber dry matter content is a very important characteristic in determining suitability of cultivars for processing into crisps.

Significantly ($P \leq 0.05$) more oil was absorbed in crisps processed from tubers of clone 391691.96 compared to Dutch Robjin due to variation in dry matter contents. There was a significant ($P \leq 0.05$) correlation between the oil content of crisps and dry matter content of potato tubers. The regression line $Y = -3.123X + 135.16$ was developed to estimate oil content of crisps (Y) on the basis of dry matter content (X) in a potato tuber. In earlier studies of oil uptake by potato crisps, Gravoueille (1996) noted that dry matter was a major factor for the potato processing industry, and proposed the required levels to be between 23 and 25% in order to minimize the oil uptake and improve yields.

Ufheil and Escher (1996) found a close relationship between dry matter and oil content of potato crisps whereby the oil content decreased with increase in dry matter content. Potatoes with high dry matter (>20%) have been shown to produce high yield of French fries with lower oil content than those of lower dry matter contents (Abong' *et al.,* 2009d). Hagenimana *et al* (1996) working on sweet potatoes cultivars found a linear relationship between dry matter content and oil uptake in thin sliced crisps, with oil content decreasing with increase in dry matter content. Tubers with high dry matter are known to give high yields of crisps with low oil absorption and hence more economical to process (Burton, 1989).

7.4.2 Effects of frying temperature and slice thickness on oil content of potato crisps of crisps from selected potato cultivars

Table 12 shows variation of oil content of crisps processed from the four potato cultivars, depending on the frying temperature. For each cultivar, the oil content of crisps fried at different temperatures differed significantly ($P \leq 0.05$). There was also a significant ($P \leq 0.05$) interaction in oil uptake between cultivar and frying temperature. The oil content was significantly ($P \leq 0.05$) higher at 160 °C than at 170 °C and 180 °C, respectively. The oil content decreased with increase in frying temperature. On average, the oil content decreased by 2.2% between 160 and 170 °C, and also between 170 and 180 °C, respectively. It therefore indicates that there was a decrease of about 4% of oil absorbed by the potato cultivars when temperature was increased from 160 °C to 180 °C. These results slightly compare to the findings of Kita *et al.* (2007) who observed that with every 20 °C increase in frying temperature, oil absorption was reduced by 3%, on average, irrespective of the type of oil used in frying crisps.

Table 12: Effect of frying temperature on oil content (%) of potato crisps from four cultivars

Cultivar	Frying Temperature(°C)		
	160	170	180
391691.96	38.42 ± 0.00a	36.51 ± 0.01a	34.32 ± 0.02a
393385.39	38.14 ± 0.08a	36.13 ± 0.07a	34.03 ± 0.09a
Dutch Robjin	37.12 ± 0.06b	35.12 ± 0.05b	33.08 ± 0.06b
Tigoni	38.15 ± 0.04a	35.95 ± 0.04ab	33.45 ± 0.03b

Values with the same letters in the same column are not significantly different at $P \leq 0.05$; Values are means of triplicate samples ± standard deviation.

Many factors have been reported to affect oil uptake by crisps including oil quality, frying temperature and duration, product shape, moisture content, solids content, coating agents and slice thickness (Pinthus, 1995; Esturk *et al.*, 2000; Garmakhany *et al.*, 2008; Garc'ia *et al*

2004). Ziaiifar *et al.* (2008) agree that oil uptake is a complex phenomenon resulting from interactions between oil and products that undergo numerous physical, chemical, and structural transformations during frying. Frying temperature has been reported to be one of the most important factors affecting the quantity of fat absorbed by potato crisps (Kita *et al.*, 2007). In the present study the oil uptake by crisps was indirectly correlated with the frying temperatures among the cultivars; the oil content being significantly ($P \leq 0.05$) higher at 160 °C than at 170 °C and 180 °C, respectively. This behavior agrees with results of similar study by Moyano and Pedreschi (2006) who worked on a potato variety Panda under different treatments and found that higher frying temperatures lead to lower oil absorption by crisps. Similar results were also reported by Pedreschi and Moyano (2005b). Kita *et al.* (2007) compared oil content of crisps fried at different temperatures in different vegetable oils and found oil uptake to reduce with increase in temperature irrespective of the type of oil. Crust formation on crisps occurs on the surface of the potato slice during frying and as it becomes thicker, resistance to evaporation of water from the inner part of the crisp increases. The rate of evaporation has been shown to reduce with crust formation thereby reducing oil uptake; as frying temperatures increase, the rate of crust formation increases due to a higher rate of evaporation which in turn decreases the amount of oil absorbed by crisps (Sahin *et al.*, 1999).

Variation in amount of oil absorbed by crisps with slice thickness is summarized in Table 13. For each cultivar, the oil content of crisps differed significantly ($P \leq 0.05$) with slice thickness. There was a significant ($P \leq 0.05$) interaction in oil uptake between cultivar and slice thickness. The oil content was significantly ($P \leq 0.05$) higher in 1.0 mm thick slices than in 1.5 mm and 2.0 mm thick slices; the amount of oil absorbed decreased with increase in slice thickness. Clone 391691.96 and Dutch Robjin were most affected by slice thickness variation. Increasing slice thickness from 1.0 mm to 1.5 mm decreased the amount of oil absorbed by 10% on average, while from 1.5 mm to 2.0 mm it decreased by about 4%. There was therefore a large decrease

(14%) in oil absorbed by the potato cultivars when slice thickness was increased from 1.0 mm to 2.0 mm.

Table 13: Influence of slice thickness on oil content (%) of potato crisps from four cultivars

Cultivar	Slice thickness (mm)		
	1.0	1.5	2.0
391691.96	48.54 ± 0.04a	36.52 ± 0.00a	33.52 ± 0.17a
393385.39	44.64 ± 0.15c	36.14 ± 0.08a	33.27 ± 0.26a
Dutch Robjin	46.49 ± 0.01b	35.12 ± 0.06b	29.80 ± 2.36c
Tigoni	43.01 ± 0.55d	35.95 ± 0.04ab	32.23 ± 0.25b

[1]Values with the same letters in the same column are not significantly different at $P \leq 0.05$; [2]Values are means of triplicate samples ± standard deviation.

Potato crisps vary in slice thickness depending on the processors and countries. In United Kingdom, for example, crisps are very thin pieces (1.27–1.78mm thick) of sliced raw potatoes that are fried to a final oil content of 33–38 g/ 100 g (wet basis) (Moyano and Pedreschi, 2006). In Kenya, slice thickness is regulated to range from 1.0 mm to 1.5 mm. It therefore means that processing any of the four cultivars into crisps with slices of 1.0 mm thickness will produce crisps with higher oil content than the required maximum 40% as stipulated by Kenya Bureau of Standards (KEBS, 2007).

Oil content and surface area of crisps have been well related in past studies; the larger the surface area, the higher the oil content of the product (Gamble and Rice, 1988). Thinner slices have been shown to absorb significantly more frying oil compared to large slices due to their larger surface area to volume ratio (Kita *et al.*, 2007). Baumann and Escher (1995) also noted that slice thickness is inversely related to oil uptake since most oil in crisps is deposited on the surface; the surface area to volume ratio and specific surface for oil absorption decreases with increase in slice thickness.

7.4.3 Sensory quality characteristics of potato crisps fried at selected temperatures

Effect of frying temperature on flavor, oiliness and overall acceptability for crisps processed from 4 cultivars is presented in Table 14.

Table 14: Effect of frying temperature on sensory quality characteristics of crisps from four cultivars

Cultivar	Frying temperature	Flavor[1]	Oiliness[1]	Overall acceptability[1]
Dutch Robjin	160 °C	5.5 ± 1.44a	4.5 ± 0.67cb	5.3 ± 0.96a
	170 °C	5.2 ± 0.70a	4.8 ± 0.62b	5.2 ± 0.72ab
	180 °C	5.3 ± 0.86a	5.5 ± 0.90a	5.6 ± 0.90a
393385.39	160 °C	5.4 ± 0.79a	4.4 ± 1.24bc	4.9 ± 1.24b
	170 °C	4.5 ± 0.52c	4.9 ± 1.24b	5.2 ± 0.83ab
	180 °C	5.4 ± 1.38a	5.4 ± 1.34a	5.3 ± 1.22a
391691.96	160 °C	4.2 ± 0.72d	3.8 ± 1.03d	4.3 ± 1.15c
	170 °C	4.4 ± 1.00cd	4.4 ± 1.24bc	4.9 ± 0.90b
	180 °C	4.2 ± 1.11d	4.4 ± 1.31bc	4.0 ± 0.85c
Tigoni	160 °C	4.3 ± 0.65d	3.6 ± 0.49d	4.8 ± 1.05b
	170 °C	4.9 ± 1.08b	4.1 ± 0.51c	4.5 ± 1.31c
	180 °C	5.1 ± 1.08ab	5.5 ± 0.79a	5.6 ± 1.24a

[1]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; All figures are mean ± standard deviation. Values with the same letters in the same column are not significantly different at $P \leq 0.05$.

Crisps from all the 4 cultivars were acceptable to the panelists notwithstanding the frying temperature. Significant ($P \leq 0.05$) differences were noted in flavor and overall acceptability with variations in temperature among the cultivars. Scores on flavor did not show an apparent pattern as compared to overall acceptability in which case there were higher scores in crisps fried at 180 °C. Analysis of variance for the sensory attributes for each separate frying temperature indicated that there were significant ($P \leq 0.05$) differences in scores for all the evaluated attributes of crisps made from different cultivars. In oiliness, there was a significant ($P \leq 0.05$) higher score for crisps processed at 180 °C than at 170 and 160 °C, respectively.

The highest score for oiliness was observed in Dutch Robjin (4.9), while clone 391691.96 had the lowest score (4.2). Significant correlation ($P \leq 0.05$, $r = -0.834$) between oil content as determined in the laboratory and sensory scores on oiliness were observed in crisps indicating that the amount of oil absorbed by a cultivar would be detected by the consumer and hence influence acceptability; crisps with low oil content are highly rated compared to those with high oil content.

Effect of slice thickness on sensory quality characteristics of flavor, oiliness and overall acceptability for crisps processed from 4 potato cultivars are presented in Table 15.

Table 15: Effect of slice thickness on sensory quality characteristics of crisps from four cultivars

Cultivar	Slice thickness	Flavor[1]	Oiliness[1]	Overall acceptability[1]
Dutch Robjin	2.0 mm	5.4 ± 1.08b	5.6 ± 1.24a	5.3 ± 0.98cb
	1.5 mm	5.0 ± 1.35cb	5.3 ± 1.30ab	5.5 ± 1.17b
	1.0 mm	5.1 ± 1.16cb	5.3 ± 1.05ab	5.9 ± 0.67a
393385.39	2.0 mm	6.0 ± 0.60a	6.1 ± 0.66a	6.2 ± 0.39a
	1.5 mm	5.2 ± 1.11bc	5.6 ± 0.90a	5.8 ± 0.62bc
	1.0 mm	4.8 ± 1.11c	5.0 ± 1.21b	5.3 ± 0.66cb
391691.96	2.0 mm	5.1 ± 0.90cb	5.6 ± 0.79a	5.6 ± 0.90a
	1.5 mm	5.8 ± 0.97a	5.6 ± 1.08a	5.8 ± 0.93a
	1.0 mm	4.8 ± 0.75c	5.6 ± 1.24a	5.8 ± 0.75a
Tigoni	2.0 mm	5.0 ± 1.44cb	5.7 ± 0.98a	5.2 ± 1.29cb
	1.5 mm	5.5 ± 1.17a	5.2 ± 1.27b	5.5 ± 1.31b
	1.0 mm	5.3 ± 1.07ba	5.8 ± 1.28a	5.6 ± 1.00b

[1]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; All figures are mean ± standard deviation; Values with the same letters in the same column are not significantly different at $P \leq 0.05$.

Crisps from all the 4 cultivars were acceptable to the panelists. Significant ($P \leq 0.05$) differences were noted in flavor and overall acceptability with variations in slice thickness among crisps made from the cultivars. Except in cv. 393385.39, scores on overall acceptability were higher in slice thickness of 1.0 mm than 1.5 and 2.0 mm. this may have been due to the brittle and crispy nature of small sliced crisps. In oiliness, there were significant higher ($P \leq 0.05$) scores for crisps of slice thickness 2.0 mm than 1.5 mm and 1.0 mm, respectively, indicating that consumers are able to differentiate crisps, depending on the amounts of absorbed oil.

7.5 Conclusion

Variety, frying temperature and slice thickness are important factors influencing oil uptake by crisps processed from all the four Kenyan potato cultivars studied. There is a need for processors to wisely choose the potato cultivar in order to produce crisps with desired oil content. All the four cultivars produced acceptable crisps, especially when processed at moderately higher temperature (170-180 °C) and slice thickness (1.5-2.0 mm) that would ensure moderate retention of oil and hence much lower oil contents of crisps.

CHAPTER EIGHT

EFFECT OF FRYING TEMPERATURE AND SLICE THICKNESS ON TEXTURE, COLOR AND ORGANOLEPTIC PROPERTIES OF CRISPS FROM FOUR KENYAN POTATO CULTIVARS

8.1 Abstract

The objective of this work was to study the performance of four Kenyan potato cultivars in terms of objective texture and color measurements, and organoleptic properties of potato crisps processed at different slice thickness and frying temperatures. Potato tubers were peeled, washed and cut into slices of thickness 1.0 mm, 1.5 mm and 2.0 mm. Each cut was fried at a constant temperature of 170 °C for 2-5 minutes. For frying temperature evaluation, the potatoes for all cultivars were cut into a uniform thickness of 1.5 mm and fried at temperatures of 160, 170 and 180 °C for 2-5 minutes. There was no significant ($P > 0.05$) variation in crisps texture among the four cultivars at different frying temperatures. Texture significantly ($P \leq 0.05$) increased with increase in frying temperature and slice thickness. Potato cultivar and slice thickness significantly ($P \leq 0.05$) influenced the lightness (L*), redness (a*) and yellowness (b*) color parameters. Redness and yellowness parameters significantly ($P \leq 0.05$) decreased with increase in frying temperature. Potato cultivar significantly ($P \leq 0.05$) influenced sensory scores on crisps color, flavor, texture and overall acceptability. Notably, frying temperature did not significantly ($P > 0.05$) affect sensory scores. Color scores significantly ($P \leq 0.05$) decreased with increasing slice thickness. The effects of variety, frying temperature and slice thickness on potato crisps quality are apparent, and hence the need for crisps processors to properly select not only the cultivars but also these critical processing parameters.

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8.2 Introduction

Worldwide consumption of potato and potato products has been increasing in the last few decades. Potato crisps, for instance, have become popular snacks commonly consumed worldwide (Kulkarni and Govinden, 1994; Kita, 2002; Knol *et al.*, 2009). In terms of utilization, potato is the fourth food crop in the world (Yasmin, 2006; Ali, 2007) while it occupies the first position both in acreage and production among vegetable crops in the Far East countries such as Bangladesh (Chowdhury, 2002).In sub-Saharan Africa, including Kenya, consumption of crisps has increased rapidly in the last decade (Abong' *et al.*, 2010a).

Potato crisps can be defined as thin potato slices that are dehydrated by deep-fat frying to a moisture content of $\geq$ 2%. Crisps can also be defined as thin slices of peeled and washed potato tubers, deep-fried until crunchy and to which edible salt or permitted food grade spices, color and flavor may be added (EAS, 2010; Salvador *et al.*, 2009). Depending on the processor, there are therefore many different types of crisps targeting different consumer preferences.

Frying of food products is often used as a means of creating unique flavors, colors and textures in processed foods with the intention of improving palatability. In processing of potato crisps, the most important quality characteristics that manufacturers endeavor to control are texture and color. Changes in texture of potato slices during frying in both the initial tissue softening process and crust development process have been shown to be influenced by temperature (Pedreschi and Moyano, 2005b). Higher temperatures were shown to accelerate textural changes. However, neither the temperature nor the pre-treatment such as blanching had a significant effect on the final texture of the fried potato crisps from Chilean cv. Panda (Pedreschi and Moyano, 2005b). Kita *et al.* (2007) found no significant influence of frying temperature on the texture of potato crisps fried in sunflower, soybean, palm and the two modified oils. Crisps fried in rapeseed and peanut oils, however, exhibited harder and less crispy texture when they were fried at 150 compared to 180 °C. Most variable texture, depending on frying temperature, was in crisps fried in olive oil; it was hardest at lower frying temperature and crispy at highest.

Crisps that are too hard and less crispy may result in rejection of the products by customers and hence the need to monitor texture during processing.

Color has been shown to be one of the most important quality parameter of fried potato products strictly related to consumer perception (Segnini *et al.*, 1999; Krokida *et al.*, 2001; Pedreschi *et al.*, 2005a; Santis *et al.*, 2007). It is always critically evaluated by consumers and in most cases forms the basis for selection or rejection of a brand of crisps. Potato crisps color is the result of Maillard reaction, which depends on the content of reducing sugars and proteins, temperature and time of frying. Reducing sugars levels are especially critical when crisps color is to be desirable (Mendoza *et al.,* 2007) and is the concern of not only the farmers, but the processors of potato products (Sharma, 2011).

Frying in hot oil at temperatures between 160 and 180 °C is normally characterized by very high drying rates that are critical for ensuring favorable structural and textural properties of the final product. These frying conditions have, however, been shown to produce crisps with different characteristics which affect acceptability depending on the potato cultivar used (Baumann and Escher, 1995). Potato crisps have an oil content that ranges from 30% to 45% (wet basis) that gives the product the unique and desirable texture-flavor combination (Mellema, 2003). In products with relatively high content of starch, such as potatoes, the major influence on texture has been attributed to gelatinization of starch, dehydration, protein denaturation and oil uptake during heating. The crispy structure of crisps results from changes at the cellular and sub-cellular level in the outermost layers of the product (Andersson *et al.*, 1994; Bouchon *et al.*, 2001). The crispy/crunchy character is an important sensory characteristic on which consumers base their appreciation (Vliet *et al.*, 2007).

The objective of this work was to determine the performance of four Kenyan potato cultivars in terms of texture, color and sensory properties when crisps are processed in different slice thickness and frying temperature.

8.3 Materials and methods

8.3.1 Potatoes

Two potato clones coded as 391691.96 and 393385.39 from the International Potato Center (CIP) and two established varieties (Tigoni and Dutch Robjin) were grown at the National Potato Research Center Tigoni, Kenya in the year 2010 under the standard cultural conditions (Lunghao and Kabira, 1999). After maturity, the crop was dehaulmed two weeks before harvesting. Following harvest, the tubers were allowed to cure in a common dark store under ambient air conditions (17-22 ^oC/84-92% rh) for two weeks at the National Potato Research Center in Tigoni. They were then processed into crisps and analyzed for color, texture and organoleptic. The potato tubers and crisps were also analyzed for sugar contents.

8.3.2 Potato crisps processing

Duplicate 10 potato tubers from each cultivar were peeled and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to uniform thicknesses of 1.0 mm, 1.5 mm and 2.0 mm. The slices were washed in cold water to remove surface starch, dried with a cloth towel and fried at a constant temperature of 170 ^0C for 2-5 min in an institution size, batch type, deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) containing about 7 litres of "Chef" corn oil (Premier Oil Mills Ltd., Nairobi, Kenya). For frying temperature evaluations, ten tubers from each cultivar were cut into a uniform thickness of 1.5 mm and duplicate samples of 200 g slices were fried in oil heated at temperatures of 160 ^0C, 170 ^0C and 180 ^0C for 2-5 min. The fried slices were removed and excess oil drained off for 1 min, placed on plates and cooled before evaluation.

8.3.3 Analytical methods

8.3.3.1 Color measurements

Crisps color was measured using a color spectrophotometer (NF 333, Nippon Denshoku, Japan) using the CIE Lab L*, a* and b* color scale. The 'L*' value is the lightness parameter indicating degree of sample lightness varying from 0=black to 100=white. The 'a*' which is the chromatic redness parameter whose value means red color when positive (+) and green color when negative (-). The 'b*' is yellowness chromatic parameter corresponding to yellow color when positive (+) and blue color when negative (-). Each sample consisted of 10 crisps pieces, each of which was measured twice.

8.3.3.2 Measurement of potato crisps texture

Crisps texture measurements were performed at room temperature (23 °C) by a puncture test using a Texture Analyzer (Sun rheometer Compac 100, Sun scientific Co. Ltd, Japan) equipped with a wedge probe imitating front teeth. Maximum force (N) needed at a penetration rate of 100 mm/min was recorded. Maximum Force (MF) is defined as the force at which the wedge penetrates the outer layer of the surface of the fried potato slices (Segnini *et al.*, 1999). Each measurement was conducted on 10 potato crisps as described by Vliet *et al.* (2007).

8.3.3.3 Determination of sugars

Approximately 10 g of homogenized potato slices and finely ground crisps were weighed into a 250 ml conical flask and 50 ml of 96% alcohol was added and mixed well. The mixture was refluxed at 100 °C for 1 hour, stirring occasionally. The resultant slurry was filtered and the filtrate collected. The conical flask was rinsed 3 times with 5 ml of 80% alcohol. The filtrate was transferred into 150 ml pear-shaped flask and the solvent evaporated to dryness at 60 °C. Approximately 10 ml of distilled water was added to the dried sample. Thereafter the dissolved sample was placed in duplicates of 2 ml into a test tube and 2 ml of diethyl ether added. The mixture was vigorously shaken and allowed to stand before removing the ether layer. This was repeated 3 times. Excess ether was flashed off using a vacuum (Heraeus, RVT 360, Germany). Equal amounts of acetonitrile were added to the samples before being stored at 5 °C ready for determination of sugars using HPLC.

The samples were micro-filtered to remove any debris before injecting 20 µl into a HPLC, SCL-10A (Shimadzu, Japan) fitted with a Refractive Index Detector, RID-6A (Shimadzu, Japan). Chromatographic conditions included a mobile phase of acetonitrile: water (75:25) pumped through a reverse phase column, $NH_2$100R 250 x 4.6 mm, 5 μm at a working maximum pressure of 150 kgf/cm^2 and flow rate of 1.0 ml/min. Oven temperature was set at 30 °C. Using working standards of sucrose, fructose and glucose, the sugars in the samples were identified and calculated. The results are means of duplicate determinations and are given as fructose, glucose and sucrose in g/100 g dry weight (dw). Tubers of reducing sugars levels $\leq$ 0.25% were considered acceptable for processing.

8.3.3.4 Sensory evaluation of potato crisps from four cultivars

Coded samples were presented in duplicates to 20 panelists, all familiar with potato crisps. Panel members scored for flavor, oiliness and overall acceptability on a 7-point hedonic rating scale varying from 1(dislike very much) to 7 (like very much). A score of 4 was the lower limit of acceptability (Larmond, 1977) (Appendix 4).

8.3.4 Data analysis

One-way analysis of variance (ANOVA) and least significant difference test for the variables was conducted using the Statistical Analysis System (SAS version 9). Correlation coefficients (ANOVA) were performed to determine relationship between color and texture determined by laboratory and sensory scores on the parameters. Differences at $P \leq 0.05$ were considered significant.

8.4 Results and discussion

8.4.1 Influence of temperature and slice thickness on texture of potato crisps from four cultivars

There was no significant ($P > 0.05$) variation in crisps texture among the four cultivars that were evaluated (Table 16). Cultivar-temperature interaction had no significant ($P > 0.05$) effect on texture. Texture, however, significantly ($P \leq 0.05$) increased with increase in frying temperature. The effect of temperature on texture was minimal in cv. Dutch Robjin and 391691.96 when compared to cv. Tigoni and 393385.39 that had greater changes. These results slightly differ from those reported by Kita *et al.* (2007) who worked on a potato cv. Karlena and observed that frying temperatures had no significant influence on the texture of potato crisps fried in sunflower, soybean, palm and modified oils. This contrast may be attributed the nature and number of raw materials such as potato cultivars and type of frying oil used. Whereas the authors used one potato variety to carry out the experiments, this study looked at four different cultivars. Their study, however, indicated that, depending on frying temperature, crisps fried in olive oil were hardest at lower frying temperature and crispy at highest.

Table 16: Average texture (N) depending on frying temperature for crisps from four potato cultivars

Cultivar	Temperature (°C)		
	160	170	180
	Mean ± SD[1]	Mean ± SD[1]	Mean ± SD[1]
391691.96	0.24 ± 0.03a	0.25 ± 0.03a	0.25 ± 0.04a
393385.39	0.21 ± 0.03ab	0.25 ± 0.07a	0.27 ± 0.08a
Tigoni	0.19 ± 0.01ab	0.22 ± 0.08ab	0.27 ± 0.08a
Dutch Robjin	0.26 ± 0.05a	0.26 ± 0.02a	0.27 ± 0.02a

[1]Standard deviation of the mean; Means with the same letters in the same column are not significantly ($P \leq 0.05$) different at 5%.

Notably, there were no significant ($P \geq 0.05$) differences between texture of crisps fried at 170 and 180 °C. This means that frying at either temperature will not influence the texture of potato crisps. This finding is important with regard to acrylamide formation in potato crisps. It is possible to reduce acrylamide content of potato crisps without adverse effect on the textural quality, by decreasing frying temperature (Pedreschi *et al.*, 2005a).

There was no significant ($P > 0.05$) correlation ($r = 0.07$) between sensory texture scores and maximum force (N) measured by Texture Analyzer. This means that consumers may not be able to detect any textural differences in crisps made from the four potato cultivars. Potato crisps texture has been shown to be influenced among other factors with dry matter content and processing temperature; the higher the temperature, the less the oil absorbed and the higher the water which is evaporated from crisps slices and hence less harder the slices become (Lisinska and Golubowska, 2005). The presence of oil in a cellular solid crispy material, for instance, was shown to greatly affect the sound emitted on fracture at least for shorter ageing times (Vliet *et al.*, 2007). Results of the present study strongly agree with these findings due to the fact that the maximum force (texture) increased with increase in frying temperature.

Table 17 summarizes the textural scores of crisps from four Kenyan cultivars as influenced by slice thickness.

Table 17: Average texture (N) as affected by slice thickness of potato crisps from four cultivars

Cultivar	Slice thickness (mm)		
	1.0	1.5	2.0
	Mean ± SD[I]	Mean ± SD[I]	Mean ± SD[I]
391691.96	0.06 ± 0.01c	0.22 ± 0.01a	0.34 ± 0.15a
393385.39	0.06 ± 0.03c	0.20 ± 0.02b	0.27 ± 0.02bc
Tigoni	0.12 ± 0.01a	0.19 ± 0.05bc	0.24 ± 0.09d
Dutch Robjin	0.09 ± 0.02b	0.21 ± 0.08ab	0.29 ± 0.07b

[I]Standard deviation of the mean; Means with the same letters in the same column are not significantly ($P \leq 0.05$) different at 5%.

The four cultivars significantly ($P \leq 0.05$) varied in texture when processed at different slice thicknesses. Cultivar-size interaction had no significant ($P > 0.05$) effect on texture. Crisps from cv. Tigoni were the hardest (force (N) =0.12) at 1.0 mm while those from 391691.96 were the hardest at 1.5 mm (force (N) =0.22) and 2.0 mm (force (N) =0.34). The maximum force (N) to break the crisps significantly ($P \leq 0.05$) increased with increase in slice thickness. There was, however, no significant ($P > 0.05$) correlation coefficient ($r = 0.22$) between objective texture determined in the laboratory and sensory scores indicating that panelists could not detect the existing differences in texture as affected by slice thickness and any crisps size would be acceptable so long as they are attractive.

8.4.2 Influence of frying temperature and slice thickness on color of potato crisps from four cultivars

Potato cultivar significantly ($P \leq 0.001$) influenced the lightness (L*) parameter; it was highest in crisps of cv. 391691.96 (70.90) followed by Tigoni (67.30) and Dutch Robjin (67.111, while it was lowest in cv. 393385.39 (63.00) (Table 18).

Table 18: Effect of frying temperature on color parameters of potato crisps from four cultivars

Cultivar	Temperature (°C)	Lightness (L*)	Redness (a*)	Yellowness (b*)
391691.96	160	70.34 ± 2.56a	-1.43 ± 0.21h	23.15 ± 0.93a
	170	70.90 ± 3.35a	-0.27 ± 0.10e	22.89 ± 1.58ab
	180	64.44 ± 1.00c	-0.21 ± 0.42e	22.90 ± 2.05a
393385.39	160	60.05 ± 2.49d	-0.12 ± 0.43c	18.00 ± 0.82e
	170	58.63 ± 5.20de	0.19 ± 0.56a	17.79 ± 1.62f
	180	63.00 ± 1.66cd	0.69 ± 0.39b	19.97 ± 0.87d
Dutch Robjin	160	63.15 ± 2.29cd	-0.96 ± 0.53fg	18.43 ± 2.06e
	170	64.59 ± 4.61c	-0.73 ± 0.32f	23.56 ± 2.36a
	180	67.11 ± 0.91b	-0.25 ± 0.22e	21.26 ± 0.66c
Tigoni	160	60.05 ± 2.49d	-0.17 ± 0.43d	18.00 ± 0.81e
	170	59.12 ± 4.95ab	0.19 ± 0.42a	18.31 ± 0.72e
	180	67.30 ± 2.91b	1.23 ± 1.28a	20.07 ± 0.83d

Values are means ± SD; Means with the same letters in the same column are not significantly ($P \leq 0.05$) different at 5%.

Frying temperature, however, did not significantly ($P>0.05$) influence the lightness parameter and the cultivar-temperature interaction had no significant influence on lightness. Crisps from the four cultivars significantly ($P \leq 0.001$) differed in redness parameter (a*); cv. Tigoni and 393385.39 tended towards red (positive values) while with negative values of crisps from 391691.96 and Dutch Robjin tended towards green. The parameter was significantly ($P \leq 0.001$) affected by cultivar-temperature interaction; crisps color tended towards red (browning) in all the cultivars as temperature increased from 160 to 180 °C, respectively. Redness or crisps darkening which increases with increase in frying temperatures is mainly due to formation of acrylamide contents which utilizes the available reducing sugars (Pedreschia *et al.*, 2004).

Yellowness (b*) parameter significantly ($P \leq 0.001$) differed with potato cultivars, it was highest in variety Dutch Robjin (23.56) followed by clone 391691.96 (23.15) and variety Tigoni (20.07) while it was lowest in clone 393385.39 (19.97). All the cultivars produced crisps which tended towards yellow color. Yellowness significantly ($P \leq 0.01$) increased with frying temperature in Tigoni and 393385.39 while it did not have a definite trend in 391691.96 and Dutch Robjin. This behavior can be explained by the fact that higher frying temperature requires less time compared to lower temperatures which could.

The differences in the behavior of the cultivar may also have resulted from the difference in composition especially in reducing sugars of the cultivars (Table 19). Color of potato crisps is an important parameter to be controlled during processing together with other parameters such as crispness, oil uptake and acrylamide content. Potato crisps color, just like flavor and aroma compounds, is formed by the maillard reaction between reducing sugars and amino acids which occur naturally at different levels in potatoes depending on variety (Pedreschi *et al.*, 2005a; Santis *et al.*, 2007; Williams, 2005; Hassanpanah *et al.*, 2011). The tendency to brown or darken in crisps increases at higher levels of reducing sugars (Olsson *et al.*, 2004; Viklund *et al.*, 2010).

The four cultivars had acceptable reducing sugar levels (≤0.25%). However, Dutch Robjin and clone 391691.96 had lower sugars compared to Tigoni and 393385.39 and are therefore expected to have good fry colors. In industrial processing of potato crisps, potato slices are normally deep fried at 150-180 °C for 2-5 minutes, during which time the moisture content decreases from approximately >75% to < 2%. Apart from sugars and amino acids which influence crisps' tendency to darken, high frying temperatures can also lead to production of dark colored crisps as shown by crisps tending towards redness (Viklund *et al.*, 2007b).

Table 19: Variation in sugars levels (%) in four potato cultivars as affected by three frying temperatures

Cultivar	Treatment	Fructose	Glucose	Sucrose	Reducing sugars
Dutch Robjin	Raw	0.034 ± 0.000c	0.101 ± 0.000a	0.055 ± 0.001c	0.135 ± 0.003c
	160 °C	0.001 ± 0.001f	0.041 ± 0.003d	0.041 ± 0.001d	0.063 ± 0.003e
	170 °C	0.001 ± 0.001f	0.036 ± 0.001e	0.035 ± 0.000e	0.052 ± 0.006f
	180 °C	ND	0.019 ± 0.000g	0.028 ± 0.003g	0.037 ± 0.004h
391691.96	Raw	0.047 ± 0.013b	0.076 ± 0.002b	0.056 ± 0.002c	0.123 ± 0.002d
	160 °C	0.021 ± 0.001e	0.032 ± 0.000f	0.036 ± 0.003e	0.068 ± 0.003e
	170 °C	0.013 ± 0.001e	0.020 ± 0.000g	0.029 ± 0.001g	0.051 ± 0.000f
	180 °C	0.001 ± 0.000f	0.009 ± 0.001i	0.015 ± 0.008h	0.017 ± 0.011i
393385.39	Raw	0.050 ± 0.002b	0.050 ± 0.008c	0.250 ± 0.053a	0.168 ± 0.042b
	T160 °C	0.013 ± 0.001e	0.020 ± 0.000g	0.005 ± 0.001i	0.037 ± 0.001h
	T170 °C	0.001 ± 0.001f	0.001 ± 0.000j	0.003 ± 0.000ij	0.004 ± 0.001j
	T180 °C	0.001 ± 0.000f	ND	0.001 ± 0.000j	0.002 ± 0.001j
Tigoni	Raw	0.113 ± 0.003a	0.076 ± 0.001b	0.131 ± 0.001b	0.193 ± 0.005a
	160 °C	0.021 ± 0.001e	0.015 ± 0.002h	0.014 ± 0.000h	0.049 ± 0.004g
	170 °C	0.020 ± 0.000e	0.012 ± 0.000hi	0.004 ± 0.000i	0.035 ± 0.001h
	180 °C	0.025 ± 0.007d	0.001 ± 0.001j	0.002 ± 0.000j	0.034 ± 0.009h

Values are means ± SD; ND= Not detected; Means with the same letters in the same column are not significantly (P ≤ 0.05) different at 5%.

The color parameters of crisps from selected four cultivars as affected by slice thickness are shown in Table 20. The cultivars varied significantly ($P \leq 0.001$) in lightness (L*) parameter; cv. 393385.39 had the highest average value (63.72) followed by Tigoni (60.28) and 391691.96 (58.70) while Dutch Robjin had the lowest value (58.39).

Table 20: Color parameters of potato crisps made from four potato cultivars depending on slice thickness

Cultivar	Slice thickness (mm)	Lightness (L*)	Redness (a*)	Yellowness (b*)
391691.96	1.0	66.61 ± 1.85b	-2.57 ± 0.53d	23.70 ± 2.08a
	1.5	57.02 ± 3.50d	-0.14 ± 1.50b	21.00 ± 2.16b
	2.0	52.45 ± 3.49ef	0.51 ± 0.80b	15.76 ± 1.38d
393385.39	1.0	71.49 ± 3.58a	0.23 ± 1.46b	23.90 ± 3.17a
	1.5	62.69 ± 3.27c	1.12 ± 0.72a	19.81 ± 0.67c
	2.0	56.98 ± 3.32d	0.19 ± 0.84b	17.45 ± 2.59d
Dutch Robjin	1.0	58.32 ± 2.01d	-0.46 ± 0.63	22.56 ± 1.05a
	1.5	62.28 ± 2.96c	-0.67 ± 0.15b	23.35 ± 4.30a
	2.0	54.55 ± 2.71e	-1.11 ± 1.13c	20.19 ± 1.27c
Tigoni	1.0	64.21 ± 1.83b	-0.21 ± 0.39b	19.07 ± 3.59c
	1.5	62.08 ± 3.34c	0.02 ± 1.05b	15.64 ± 0.82d
	2.0	54.55 ± 1.69e	1.26 ± 0.73a	14.94 ± 0.80d

Values are means ± SD; Means with the same letters in the same column are not significantly ($P \leq 0.05$) different at 5%.

Lightness values significantly ($P \leq 0.01$) decreased with increasing slice thickness in all the cultivars indicating significant cultivar-size interaction. Redness (a*) value significantly ($P \leq 0.05$) differed in crisps depending on cultivar; cv. 393385.39 and Tigoni produced crisps with colors tending towards red compared to cv. 391691.96 and Dutch Robjin which tended towards green. Redness parameter significantly ($P \leq 0.05$) increased with increase in slice thickness. Thin slices may have had very little amounts of precursors combined with short frying times that lead to reduced redness or darkening of crisps. The degree of yellowness (b*) varied significantly ($P \leq 0.05$) with cultivar; it was highest in cv. Dutch Robjin followed by 393385.39 and 391691.96, respectively. Variety Tigoni had the lowest values. Yellowness value significantly ($P \leq 0.05$) decreased with increase in slice thickness.

8.4.3 Sensory quality properties of crisps produced from four potato cultivars fried at different temperature and slice thickness

Potato cultivar significantly ($P \leq 0.05$) influenced crisps color, flavor, texture and overall acceptability (Table 21).

Table 21: Sensory properties of crisps from four potato cultivars as affected by frying temperatures

Cultivar	Frying temperature (°C)	Color[2]	Flavor[12]	Texture[2]	Overall acceptability[1,2]
Dutch Robjin	160	6.0 ± 1.12a	5.5 ± 1.44a	5.6 ± 0.99a	5.3 ± 0.96a
	170	5.7 ± 0.98a	5.2 ± 0.70a	5.2 ± 0.72ab	5.2 ± 0.72ab
	180	5.5 ± 0.79ab	5.3 ± 0.86a	5.1 ± 0.71b	5.6 ± 0.90a
393385.39	160	4.9 ± 1.08c	5.4 ± 0.79a	4.7 ± 0.96bc	4.9 ± 1.24b
	170	4.6 ± 1.07c	4.5 ± 0.52dc	4.8 ± 0.83b	5.2 ± 0.83ab
	180	5.2 ± 1.33bc	5.4 ± 1.38a	5.3 ± 1.21a	5.3 ± 1.22a
391691.96	160	4.0 ± 0.85c	4.2 ± 0.72d	4.3 ± 1.21d	4.3 ± 1.15c
	170	4.5 ± 0.78c	4.4 ± 1.00dc	4.6 ± 0.99c	4.9 ± 0.90b
	180	4.0 ± 0.80d	4.2 ± 1.11d	4.3 ± 1.29d	4.0 ± 0.85c
Tigoni	160	4.9 ± 1.44ab	4.3 ± 0.65d	5.2 ± 0.71ab	4.8 ± 1.05b
	170	4.4 ± 1.31c	4.9 ± 1.08b	4.6 ± 1.30c	4.5 ± 1.31c
	180	5.6 ± 1.44a	5.1 ± 1.08ab	5.3 ± 1.28ab	5.6 ± 1.24a

[1]Source: Abong' *et al.* (2011); [2]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; Values are means ± SD.

Variety Dutch Robjin had the highest color score (> 5) while clone 391691.96 had the lowest score (4.0) at all the frying temperatures. Frying temperature did not significantly ($P > 0.05$) affect potato crisps color and flavor in all the cultivars. Scores for texture were significantly ($P \leq 0.05$) higher in Dutch Robjin and Tigoni than in clones 393385.39 and 391691.96. Even though panel scores were generally higher at frying temperatures of 180 °C, crisps texture did not follow any specific pattern; frying temperature did not significantly ($P > 0.05$) influence scores on texture. These results agree with Rojo and Vincent (2008) who worked on three commercial potato crisps.

Table 22 summarizes sensory properties of potato crisps as influenced by slice thickness. All the cultivars produced acceptable potato crisps. Potato cultivar did not significantly ($P > 0.05$) influence the scores of crisps color, flavor and texture when slices of different thickness were fried. Slice thickness, however, significantly ($P \leq 0.05$) influenced color scores of the potato crisps; the smaller the slice, the higher the score. There was, however, no significant effect of thickness on flavor and texture of crisps. Color of the food surface is the first quality parameter evaluated by consumers and it has been shown to be critical in the acceptance of the product, even before it is eaten (Santis *et al.*, 2007). It is therefore important to select slice thickness that will produce products with acceptable color and other sensory attributes taking into account that oil as a major crisps ingredient is expensive.

Table 22: Sensory properties of crisps from four potato cultivars as affected by slice thickness

Cultivar	Slice thickness (mm)	Color[2]	Flavor[12]	Texture[2]	Overall acceptability[1,2]
Dutch Robjin	2.0	5.3 ± 1.12b	5.4 ± 1.08b	5.3 ± 1.36b	5.3 ± 0.98bc
	1.5	5.0 ± 1.60bc	5.0 ± 1.35c	5.6 ± 0.99a	5.5 ± 1.17b
	1.0	4.9 ± 1.31c	5.1 ± 1.16bc	5.3 ± 1.28b	5.9 ± 0.67a
393385.39	2.0	6.3 ± 0.45a	6.0 ± 0.60a	5.8 ± 0.58a	6.2 ± 0.39a
	1.5	5.5 ± 0.79b	5.2 ± 1.11bc	5.5 ± 0.80a	5.8 ± 0.62a
	1.0	4.9 ± 1.31c	4.8 ± 1.11bc	5.0 ± 1.21b	5.3 ± 0.96bc
391691.96	2.0	5.7 ± 1.30ab	5.1 ± 0.90c	5.6 ± 0.79a	5.6 ± 0.90b
	1.5	5.6 ± 1.00b	5.8 ± 0.97a	5.6 ± 0.75a	5.8 ± 0.93a
	1.0	4.7 ± 0.75c	4.8 ± 0.75cb	5.6 ± 0.90a	5.8 ± 0.75a
Tigoni	2.0	5.0 ± 1.41bc	4.6 ± 1.44c	4.8 ± 1.21c	4.8 ± 1.29bc
	1.5	5.8 ± 1.40a	5.5 ± 1.17b	5.3 ± 1.30b	5.5 ± 1.31b
	1.0	5.0 ± 1.13bc	5.3 ± 1.07b	5.6 ± 1.16a	5.6 ± 1.00b

[1]Source: Abong' *et al.* (2011); [2]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; Values are means ± SD.

8.5 Conclusion

Cultivars Dutch Robjin and 391691.96 performed better in comparison to 393385.39 and Tigoni in terms of texture, color and organoleptic properties. Frying at temperatures of 170 and 180 °C produced better results compared with 160 °C. Slice thickness significantly effect of on texture, color and organoleptic properties. Processors should therefore properly select not only the cultivars, but also the frying temperature and slice thickness in order to produce attractive and acceptable potato crisps.

CHAPTER NINE

EFFECT OF PACKAGING AND STORAGE TEMPERATURE ON THE SHELF LIFE OF CRISPS FROM FOUR KENYAN POTATO CULTIVARS

9.1 Abstract

Consumption and demand for potato crisps as snacks in Kenya has been on the rise. Deep-oil fried foods such as potato crisps absorb high levels of oil that is not only important nutritionally but also has a marked bearing on the flavor. It is, however, important to note that oils used to process snack foods such as crisps undergo reactions including thermo-oxidative and hydrolytic alterations which may have profound negative effects on consumers, especially when crisps are consumed after prolonged storage. This study was designed to determine changes in the levels of peroxides, free fatty acids and moisture as influenced by packaging and temperature during storage of crisps processed from four Kenyan potato cultivars. Potato tubers were processed into crisps of 1.5 mm thickness at a frying temperature of 170 °C for 3.5 min. The crisps were packaged into aluminium foil pack and polyethylene bags commonly used by Kenyan industries and stored at 25, 30 and 35 °C for a period of 24 weeks.

The results showed that aluminium foil pack was the most effective in controlling increase in moisture content, peroxide values and free fatty acid levels. Potato cultivar significantly ($P \leq 0.05$) influenced the formation of peroxides. Crisps from Cv. 391691.96 had the lowest peroxide values compared to the other cultivars. The products stored at 35 °C had significantly ($P \leq 0.05$) shorter shelf life compared to those stored at 25 and 30 °C. The flavor, aroma and acceptability of the crisps significantly ($P \leq 0.05$) varied with cultivar and storage temperature. The scores decreased with storage duration. Scores in all the attributes for crisps made from Cv. 391691.96 were, however, acceptable in the entire storage period.

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A significant ($P \leq 0.05$) negative correlation was noted between sensory attributes and peroxide values. Shelf-life of potato crisps was therefore influenced not only by the potato cultivar (used as a raw material) but also the packaging material and storage temperature. Storage of crisps in aluminium foil packs at lower temperatures is desirable to maintain product acceptability for longer storage period.

9.2 Introduction

Among the world's snack foods, potato crisps are consumed by millions of people of diverse cultural backgrounds in many countries (Knol *et al.*, 2009; Lachman *et al.*, 2009). Notably, there has been a worldwide increase in consumption of potato products, crisps included, indicating the need to pay more interest on consumer behavior and innovations in the sector (Buono *et al.*, 2009). According to Shiroma and Rodriguez-Saona (2009), potato crisps are some of the most important products in the snack industry and are the top choice for between-meal snacks for American adults and children.

The consumption of crisps in Kenya, especially in major urban centers, has increased tremendously in the past five years with the main consumers being children under 15 years of age (Abong' *et al.*, 2010a). Deep fried foods such as crisps absorb high levels of oil that is not only important nutritionally but also has a marked bearing on the flavor, calories supplied and shelf life. Depending on product, potatoes absorb varied amounts of cooking oil, crisps having oil contents ranging from 25 to 45% (Abong' *et al.*, 2010a; Kita *et al.*, 2007; Debnath *et al.*, 2009). On the other hand, French fries have on the average 12% (Abong' *et al.*, 2009d). It is, however, important to note that oils used to process foods such as crisps undergo reactions including thermo-oxidative and hydrolytic alterations which may have profound negative effects on consumers, especially when products are stored for a long time at high temperatures.

Just like any other food product intended for sale, packaging protects potato crisps from atmospheric conditions and damage. It provides consumers with ingredient and nutritional information. Packaging also retards product deterioration, adds value and extends as well as ensuring quality and safety of food (Marsh and Bugusu, 2007). Consumer demand for food products with high quality has increased generally increased. Food packaging has, therefore assumed outstanding importance in maintaining product quality while offering protection from microbial and chemical contamination, as well as from oxygen, water vapor and light (Silva *et al.,* 2004).

Apart from oil content, other crisps quality attributes that require attention during storage include fat oxidation, flavor alteration, peroxide, free fatty acids and moisture buildup. Most of these factors are affected by among other factors the variety of potato because of the variation in chemical composition (Pant and Kulrestha, 1994; Abong' *et al.,* 2009b). Different kinds of off-flavor volatile compounds are normally developed and their concentration increase during storage of potato crisps (Melton *et al.*, 1993). Processing and storage conditions also strongly influence the final quality of potato crisps (Lisinska and Leszczynski, 1989). The objective of this study was therefore to investigate the effect of packaging and temperature on moisture content, peroxide value and free fatty acids during storage of crisps made from four Kenyan potato cultivars.

9.3 Materials and methods

9.3.1 Processing of potato crisps

Potato tubers from four cultivars (Tigoni, Dutch Robjin 391691.96 and 393385.39) previously shown to be the most suitable for processing into crisps (Abong' *et al.*, 2010c) were used for this study. These were peeled and sliced using an automatic electric slicer (Hitech Systems, Saudi Arabia) to a uniform thickness of 1.5 mm. The slices were washed in running tap water to remove surface starch, dried with cloth towel and fried in an institution size, batch type, deep oil fryer (E 6 ARO S.A., La Neuveville, Switzerland) containing about 7 litres of "Chef" corn oil

(Premier Oil Mills Ltd., Nairobi, Kenya) at a temperature of 170 ^{0}C for 3.5 min. The fried slices were removed and excess oil drained off for 1 min, cooled and packaged.

9.3.2 Storage of potato crisps

Approximately 150 g of crisps from each cultivar were packaged into polyethylene bags (gauge 150 microns) and aluminium foil packs. The major packaging material for potato crisps in Kenya is polyethylene and to a lesser extent aluminium foil packs (Abong' *et al.,* 2010b). The packaged crisps were stored at 25, 30 and 35^{o}C. As a measure of shelf life, the crisps were analyzed for moisture, peroxide value and free fatty acids immediately and thereafter at 4 week intervals during storage for 24 weeks. The flavor, aroma and acceptability were determined initially and at 12 week intervals during the same period.

9.3.3 Analytical methods

9.3.3.1 Determination of moisture content

The moisture content of potato crisps was determined by the standard AOAC method (1984). Triplicate samples of approximately 5 g were accurately weighed in aluminum dishes and dried in an air-oven at 105 ^{o}C to a constant weight. The dried samples were cooled in a dessictor to room temperature and weighed. Loss of weight due to drying was converted to percent moisture content.

9.3.3.2 Determination of peroxide value

Duplicate samples of potato crisps were analyzed for peroxide values in potato crisps according to standard AOAC Methods (1984).

9.3.3.3 Determination of free fatty acids

Duplicate samples of potato crisps were analyzed for free fatty acids according to standard AOAC Methods (1984).

9.3.3.4 Sensory evaluation of potato crisps

Coded samples were presented to 20 panelists, all familiar with potato crisps. Panel members scored for flavor, aroma and overall acceptability on a 7-point hedonic rating scale varying from

1 (dislike very much) to 7 (like very much). A score of 4 was the lower limit of acceptability (Larmond, 1977) (Appendix 4).

9.3.3 Data analysis

All the experiments were arranged in a completely randomized block design with a factorial structure of main treatments of packaging and storage temperature. The sub-treatments were the two types of packaging material (transparent polyethylene and aluminium foil packs), three different storage temperatures (25, 30 and 35 °C) and seven lengths of storage, (from 0 to 24 weeks). The experiments were replicated twice. Analysis of variance (ANOVA) and least significant difference (LSD) test for the variables was conducted using the Statistical Analysis System (SAS version 9). Differences at $P \leq 0.05$ were considered significant.

9.4 Results and discussion

9.4.1 Influence of packaging and storage temperature on moisture content of potato crisps from four selected cultivars

The average moisture content of potato crisps stored in polyethylene bags and aluminium foil packs at three different temperatures is shown in Figures 14 and 15, respectively. Moisture content of potato crisps stored in polyethylene bags at 25 and 30 °C did not increase significantly ($P>0.05$) for the first 8 weeks of storage. The levels of moisture, however, increased significantly ($P \leq 0.05$) from 12 to 24 weeks at these temperatures from 1.5% up to a maximum of 4.7%. Levels of moisture for crisps stored at 35°C increased significantly beginning from the first week from 1.5 to 5.7% after 24 weeks of storage. The higher temperatures may have contributed to polyethylene extension thereby increasing its pores leading to higher levels of moisture beyond the stipulated limits of 4.7% (KEBS, 2007).

Crisps stored at 25°C in aluminium foil had no significant increase in moisture levels up to 12 weeks of storage while those stored at 30 and 35 °C increased from the 4th week reaching a maximum of 4.5% after 24 weeks of storage.

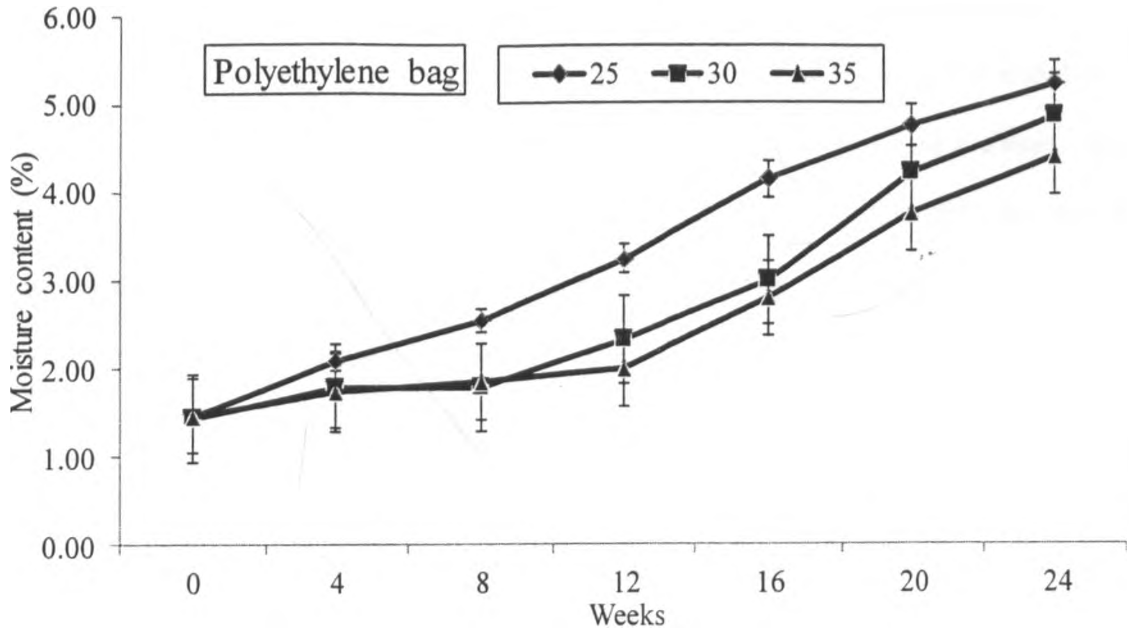

Figure 14: Moisture content of potato crisps stored in polyethylene bags at three different temperatures. The bars indicate standard errors.

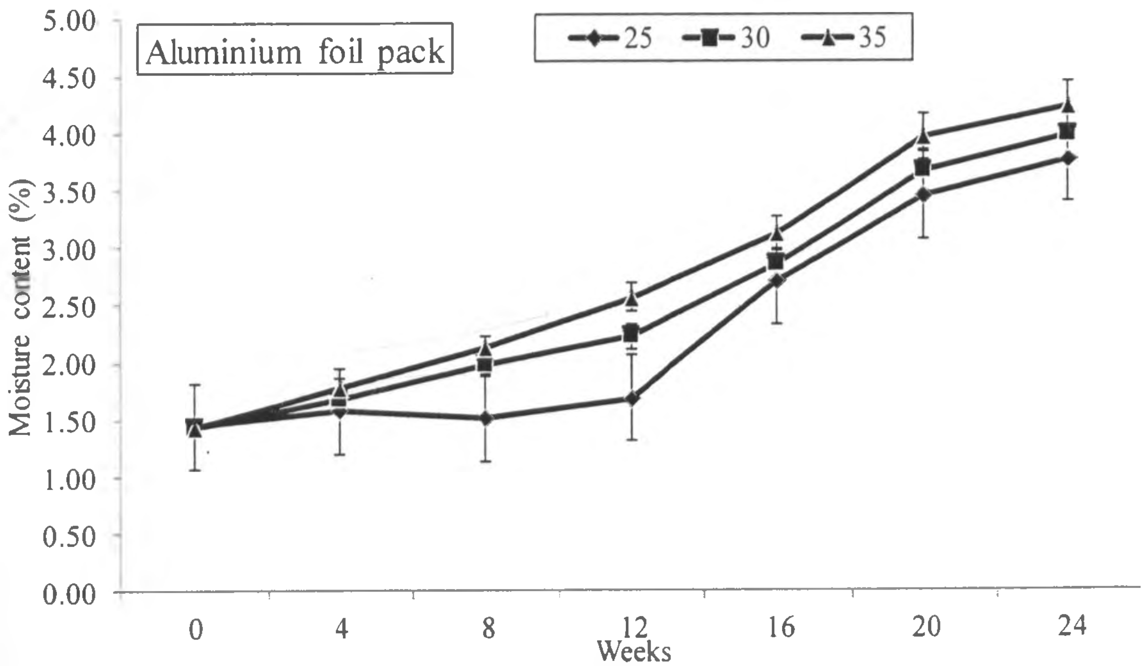

Figure 15: Moisture content of potato crisps stored in aluminium foil pack at three different temperatures. The bars indicate standard errors.

Aluminium foil pack was the most effective in controlling the moisture content of potato crisps compared to polyethylene bag which allowed the highest moisture ingression in the stored crisps. The products stored at 35 °C had significantly ($P \leq 0.05$) higher increase in moisture content compared to those stored at 25 and 30 °C. The difference in relative humidity was high and would be responsible for the high overall moisture content of crisps. A similar trend was reported by Vanhanen and Savage (2006).

Deep-fat frying of potato crisps has been shown to be a drying process in which rapid moisture loss occurs and crisps acquire minimal moisture content (Esturk *et al.,* 2000). The levels of moisture depend among other factors on packaging and storage conditions (Vanhanen and Savage, 2006). Moisture content is an important shelf-life determinant; the higher the level of moisture the higher the rate of microbial spoilage of food products, and the faster the breakdown of oils in stored products. The effectiveness of storage conditions has been assessed in many instances by measuring the moisture content (Vanhanen and Savage, 2006). Crisps, being food products that can be stored for up to 6 months, require that moisture levels be kept as low as possible. According to East African Food Standards, potato crisps must have maximum moisture level of 4.7% (EAS, 2010). In the current study, aluminium foil pack maintained moisture levels below the maximum limit in all the storage conditions even after 24 weeks of storage. Polyethylene bags on the other hand, maintained the required moisture for only up to 16th week of storage at 35 °C. At 30 °C the moisture limit was maintained up to 20 weeks, while at 25°C the levels were acceptable for the whole storage period.

Like any other snack, potato crisps require protection against moisture uptake during storage usually ranges between 1-3% when well packaged, but if these levels increase to 4–5%, the product becomes unacceptable (Silva *et al.*, 2004). In this study, potato crisps stored in aluminium packs minimized the increase in moisture as opposed to transparent polyethylene bags.

9.4.2 Effect of packaging and storage temperature on free fatty acids of potato crisps from four selected cultivars

Packaging and storage temperature significantly ($P \leq 0.05$) affected the levels of free fatty acids in potato crisps, depending on duration of storage (Figures 16 and 17). The highest increase was observed in crisps packaged in polyethylene bags. There was, however, no significant ($P > 0.05$) varietal difference in the levels of free fatty acid. After 24 weeks of storage free fatty acids had accumulated to 1.6% in polyethylene bags compared to 1.3% in aluminium foil pack when the products were stored at 35 °C. The crisps stored at 35 °C had significantly ($P \leq 0.05$) higher increase in free fatty acids compared to those stored at 25 and 30 °C. Notably, in both packages, there was no significant ($P \leq 0.05$) increase in free fatty acid levels until 16 weeks of storage.

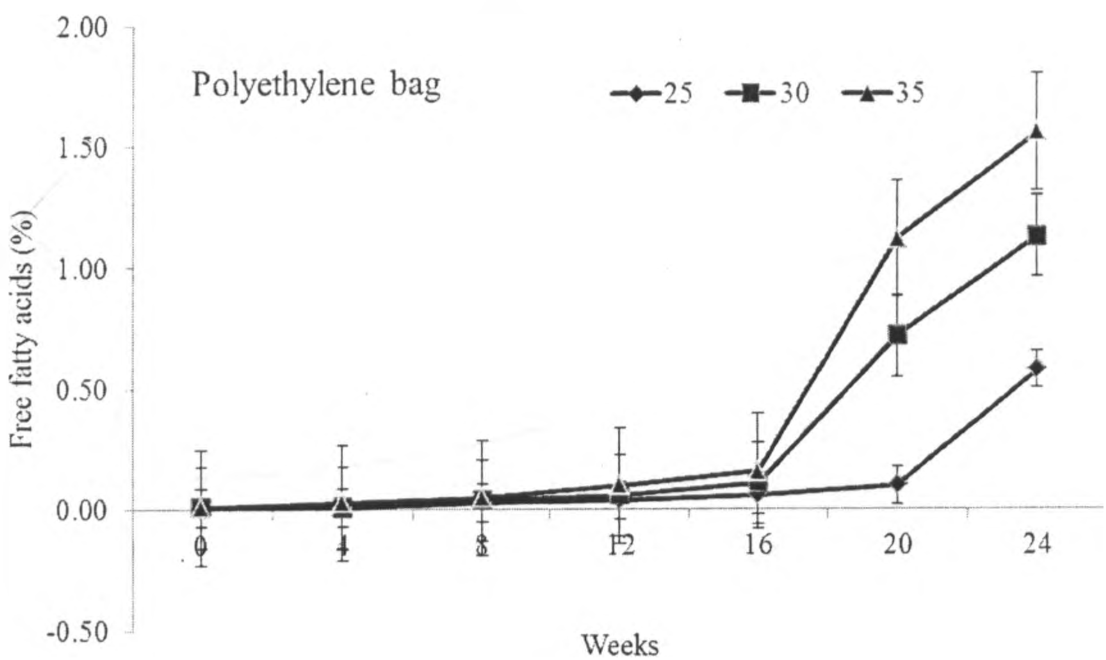

Figure 16: Variation of free fatty acid levels in crisps stored in polyethylene bags at three different temperatures. The bars indicate standard errors.

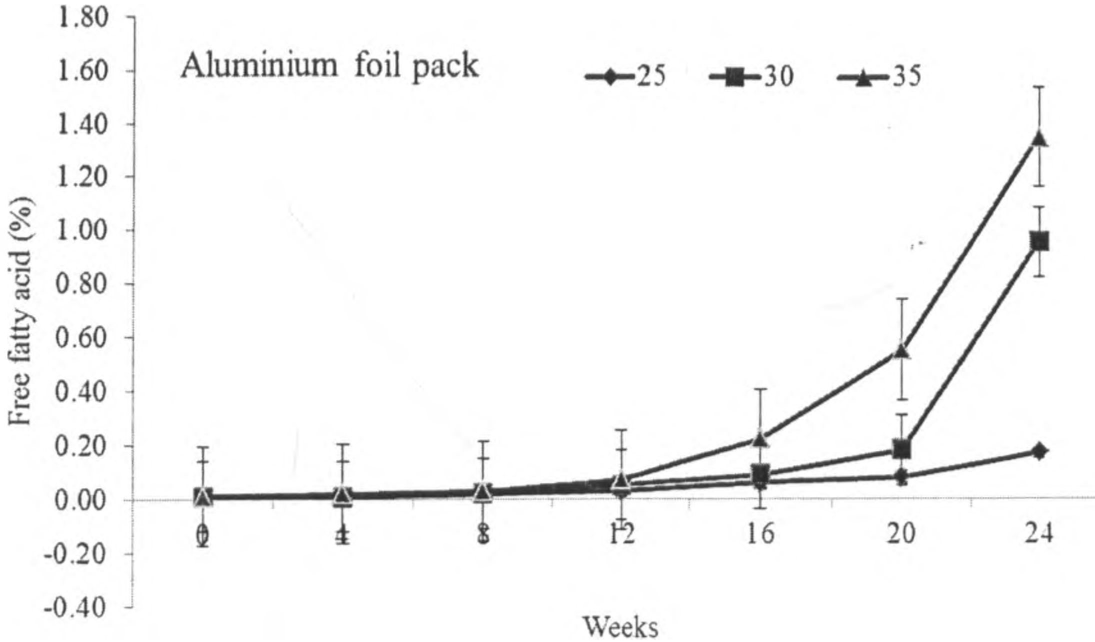

Figure 17: Variation of free fatty acid levels in crisps stored in polyethylene bags at three different temperatures. The bars indicate standard errors.

Free fatty acids result from fat or oil breakdown due to either enzyme activity and oxidation or use of high frying temperatures. The accumulation of free fatty acids is accelerated by storage at high temperatures. Therefore, total fatty acid change has been found to be a useful tool for determining optimum frying and storage studies (Cuesta *et al.*, 2001).

9.4.3 Effect of packaging and storage temperature on peroxide value of potato crisps from four selected cultivars

Table 23 shows variation of peroxide value with packaging and storage temperature in four potato cultivars. Potato cultivar significantly ($P \leq 0.05$) influenced the formation of peroxides. Crisps from cv. 391691.96 had the lowest peroxide values compared to the three other cultivars. Generally, aluminium foil pack was the most effective in controlling the formation of peroxides in potato crisps compared to polyethylene bags. The products stored at 35 °C had significantly ($P \leq 0.05$) higher increase in peroxides compared to those stored at 25° and 30°C after 24 weeks of storage. There was no significant ($P > 0.05$) increase in peroxide values until 12 weeks of storage. The peroxides then accumulated steadily reaching the highest level of 7.4% in crisps stored at 35 °C. A similar trend was reported on walnut flour stored at five different temperatures using three different packages (Vanhanen and Savage, 2006).

Deep-oil frying is one of the most popular methods of preparation of food due to the fact that it is easy to use, fast, and relatively cheap and results in palatable foods preferred by many consumers. The oil does not only function as a medium for heat transfer from the heating source to the food, but also enhances flavor, responsible for the typical smell and taste of the fried products (Matthäus, 2007). However, due to high temperatures used in frying (170 °C) undesirable off-flavors occur if deteriorated oil is used or if the oil is used over a long period of time. Among the reactions that occur during frying and storage are oxidation and hydrolysis (Cuesta *et al.*, 2001; Jia *et al.*, 2010). The stability of the product will depend on its nature, type of oil used and storage duration (Aminlari *et al.*, 2005; Chiou *et al.*, 2009). In the present study, a stable corn oil was used in preparation of crisps from each of the four cultivars in equal proportion and conditions.

Potato cultivars differ in both physical and chemical constituents. Extracts from some potato cultivars have been shown to contain anti-oxidant properties (Singh and Rajini, 2004). Mohdaly *et al.* (2010) demonstrated potato peels were potent sources of natural antioxidants that might be explored to prevent oxidation of vegetable oils. In the present study, cultivar 391691.96 had the least increase in peroxide value indicating that it could have constituents with antioxidant properties which require further research. Crisps from this cultivar would store for a sufficient longer period.

Snacks such as crisps with oil content higher than 30% not only require protection against moisture but also light and oxygen to prevent oil oxidation in stored crisps (Silva *et al.*, 2004; Lennersten and Lingnert, 1998). Air is known to be a pro-oxidant agent, and proper packaging is necessary for longer shelf life of the products (Silva *et al.*, 2004). In this study, potato crisps stored in opaque aluminium packs minimized the influence light in comparison to transparent polyethylene bags. Alternative and innovative packaging method with oxygen absorbents, which decreases the residual oxygen concentration and modified atmosphere packaging, have been used in some circumstances even though these pose many challenges including high costs (Silva *et al.*, 2004; Del Nobile, 2001). Use of aluminium foil pack provides an easy way of packaging while ensuring safety of products in storage. The cost of aluminium foil pack is, however, higher than that of polyethylene and should be considered.

Table 23: Variation in peroxide value (mEq kg-[1] dwb) with packaging and storage temperature in crisps from four potato cultivars

Cultivar	PKG[1]	ST[2]	Storage period (weeks)						
			0	4	8	12	16	20	24
391691.96	AF[3]	25	ND	ND	0.00 ± 0.00	0.12 ± 0.01	0.14 ± 0.01	0.19 ± 0.00	0.38 ± 0.03
		30	ND	ND	0.01 ± 0.00	0.17 ± 0.03	0.59 ± 0.08	0.75 ± 0.11	1.11 ± 0.05
		35	ND	ND	0.01 ± 0.00	0.28 ± 0.01	0.80 ± 0.05	1.01 ± 0.07	1.47 ± 0.17
	PE[4]	25	ND	ND	0.02 ± 0.02	0.17 ± 0.05	0.26 ± 0.13	0.39 ± 0.17	0.78 ± 0.24
		30	ND	ND	0.03 ± 0.01	0.22 ± 0.01	0.66 ± 0.01	1.09 ± 0.01	1.86 ± 0.02
		35	ND	ND	0.02 ± 0.01	0.42 ± 0.00	0.98 ± 0.03	1.49 ± 0.05	2.27 ± 0.03
393385.39	AF[3]	25	ND	ND	0.05 ± 0.01	0.92 ± 0.06	1.61 ± 0.04	1.64 ± 0.06	1.93 ± 0.10
		30	ND	ND	0.07 ± 0.00	1.16 ± 0.03	1.55 ± 0.09	2.04 ± 0.13	2.41 ± 0.05
		35	ND	ND	0.08 ± 0.00	1.53 ± 0.07	2.01 ± 0.07	2.51 ± 0.11	3.03 ± 0.19
	PE[4]	25	ND	ND	0.05 ± 0.01	1.25 ± 0.08	2.17 ± 0.29	4.53 ± 0.38	5.26 ± 0.58
		30	ND	ND	0.09 ± 0.00	1.34 ± 0.03	2.54 ± 0.07	3.72 ± 0.09	5.59 ± 0.14
		35	ND	ND	0.10 ± 0.00	1.44 ± 0.00	2.84 ± 0.04	4.09 ± 0.07	6.45 ± 0.06
Dutch Robjin	AF[3]	25	ND	ND	0.07 ± 0.00	0.83 ± 0.02	1.63 ± 0.06	2.57 ± 0.08	2.98 ± 0.12
		30	ND	ND	0.06 ± 0.00	1.57 ± 0.20	2.55 ± 0.05	2.87 ± 0.06	3.45 ± 0.17
		35	ND	ND	0.09 ± 0.00	1.83 ± 0.00	2.93 ± 0.03	3.52 ± 0.05	4.97 ± 0.09
	PE[4]	25	ND	ND	0.08 ± 0.00	1.54 ± 0.02	3.03 ± 0.05	3.89 ± 0.06	5.59 ± 0.10
		30	ND	ND	0.09 ± 0.01	1.49 ± 0.02	2.90 ± 0.07	3.70 ± 0.08	5.50 ± 0.15
		35	ND	ND	0.10 ± 0.00	1.55 ± 0.02	3.36 ± 0.03	4.76 ± 0.06	6.57 ± 0.01
Tigoni	AF[3]	25	ND	ND	0.07 ± 0.00	0.43 ± 0.00	1.76 ± 0.00	2.33 ± 0.00	2.65 ± 0.00
		30	ND	ND	0.12 ± 0.48	1.92 ± 0.00	2.02 ± 0.42	2.42 ± 0.39	2.99 ± 0.16
		35	ND	ND	0.08 ± 0.00	1.63 ± 0.00	2.44 ± 0.05	2.74 ± 0.06	3.62 ± 0.36
	PE[4]	25	ND	ND	0.6 ± 0.59	1.91 ± 0.66	2.74 ± 0.81	4.15 ± 0.88	5.97 ± 1.03
		30	ND	ND	0.10 ± 0.00	1.53 ± 0.02	2.40 ± 0.08	4.34 ± 0.11	6.72 ± 0.16
		35	ND	ND	0.11 ± 0.00	1.64 ± 0.01	2.71 ± 0.07	4.95 ± 0.10	7.44 ± 0.08

PKG[1]=Packaging type, ST[2]=Storage temperature (°C), AF[3] =Aluminium foil pack, PE[4]=Polyethylene bag, ND=Not detected, Values are mean ± SD

9.4.4 Sensory characteristics of potato crisps from four cultivars as affected by packaging and storage temperature

Changes in sensory flavor, aroma and acceptability

Crisps flavor, aroma and acceptability significantly ($P \leq 0.05$) varied with cultivar and storage temperature, depending on storage duration (Table 24). Scores in all the attributes for crisps made from Cv. 391691.96 were acceptable. Flavor and aroma perception significantly reduced with storage time reaching unacceptable levels after 24 weeks of storage, especially for crisps in polyethylene bags under higher temperatures. Higher reductions on scores were noted in crisps stored at 35 °C compared to 25 °C. A significant ($P \leq 0.05$) negative correlation was noted between sensory attributes and the peroxide and free fatty acid levels (Table 25)

Storage of crisps at higher temperatures increased the levels of peroxides, indicating the significant role of heat in oil oxidation. It therefore follows that similar products in hot areas will develop rancidity faster compared to those in cold areas. The development of rancidity in deep-fried foods during storage is often the factor that limits the shelf-life of the products (Vanhanen and Savage, 2006; Asap and Augustin, 1986). The onset of rancidity is usually a consequence of oxidative reactions of the lipids present in the food and can be minimized by proper choice of storage conditions. The decrease in scores of sensory attributes indicates that consumers are able to detect changes that occur in stored crisps. Proper packaging and storage of crisps in appropriate conditions is necessary in order to maintain acceptability of products in the market.

Table 24: Variation in sensory attributes with packaging and storage temperature in crisps from four cultivars

Cultivar	PG[1]	ST[2]	Storage period (weeks)								
			0			12			24		
			Flavor[5]	Aroma[5]	Accep[5,6]	Flavor[5]	Aroma[5]	Accep[5,6]	Flavor[5]	Aroma[5]	Accep[5,6]
391691.96	AF[3]	25	6.0 ± 0.0	6.0 ± 0.0	6.5 ± 0.7	5.5 ± 0.0	5.5 ± 0.7	5.8 ± 0.5	5.2 ± 0.5	4.7 ± 0.3	4.8 ± 0.5
		30	6.0 ± 0.0	6.0 ± 0.1	6.5 ± 0.5	5.8 ± 0.21	5.2 ± 0.4	5.5 ± 0.6	4.7± 0.5	4.7 ± 0.1	4.7 ± 0.3
		35	6.0 ± 0.0	6.0 ± 0.0	6.5 ± 0.3	5.5 ± 0.6	4.7 ± 0.3	5.0 ± 0.2	4.7 ± 0.4	4.5 ± 0.1	4.5 ± 0.5
	PE[4]	25	6.0 ± 0.0	6.0 ± 0.0	6.5 ± 0.2	5.2 ± 0.7	5.8 ± 0.4	5.3 ± 0.4	4.6 ± 0.1	5.0 ± 0.1	4.5 ± 0.4
		30	6.0 ± 0.0	6.0 ± 0.0	6.5 ± 0.7	5.8 ± 0.2	5.3 ± 0.2	5.2 ± 1.1	4.5 ± 0.6	4.4 ± 0.4	4.0 ± 0.0
		35	6.0 ± 0.2	6.0 ± 0.0	6.5 ± 0.8	5.3 ± 0.5	4.9 ± 0.1	5.2 ± 0.9	4.5 ± 0.5	4.3 ± 0.4	4.1 ± 0.1
393385.39	AF[3]	25	6.0 ± 0.0	5.5 ± 0.5	6.0 ± 0.0	5.0 ± 0.0	4.9 ± 0.1	5.0 ± 0.0	5.0 ± 0.0	4.8 ± 0.4	4.8 ± 0.3
		30	6.0 ± 0.0	5.5 ± 0.3	6.0 ± 0.0	5.7 ± 0.3	4.8 ± 0.6	5.4 ± 0.8	4.5 ± 0.9	4.2 ± 0.2	4.2 ± 0.4
		35	6.0 ± 0.0	5.5 ± 0.3	6.0 ± 0.0	4.5 ± 0.0	4.4 ± 0.2	5.3 ± 0.3	4.2 ± 0.3	4.3 ± 0.2	4.0 ± 0.0
	PE[4]	25	6.0 ± 0.0	5.5 ± 0.4	6.0 ± 0.0	4.5 ± 0.7	4.4 ± 0.5	5.0 ± 0.0	3.7 ± 0.3	4.0 ± 0.1	4.2 ± 0.2
		30	6.0 ± 0.0	5.5 ± 0.6	6.0 ± 0.0	4.7 ± 1.6	4.3 ± 0.2	4.9 ± 0.1	3.7 ± 0.4	3.3 ± 0.2	3.9 ± 0.1
		35	6.0 ± 0.0	5.5 ± 0.3	6.0 ± 0.0	4.2 ± 03.	4.1 ± 0.2	5.0 ± 0.0	3.6 ± 0.1	3.2 ± 0.2	3.7 ± 0.3
Dutch Robjin	AF[3]	25	5.5 ± 0.6	5.5 ± 0.3	6.0 ± 0.0	5.0 ± 0.0	5.2 ± 0.5	5.7 ± 0.3	4.5 ± 0.4	4.2 ± 0.3	5.1 ± 0.6
		30	5.5 ± 0.8	5.5 ± 0.7	6.0 ± 0.0	5.3 ± 0.4	4.6 ± 0.1	5.5 ± 0.1	4.5 ± 0.4	4.0 ± 0.0	4.3 ± 0.0
		35	5.5 ± 0.3	5.5 ± 0.6	6.0 ± 0.0	4.7 ± 0.4	4.4 ± 0.1	5.0 ± 0.0	3.9 ± 0.2	4.1 ± 0.1	4.1 ± 0.2
	PE[4]	25	5.5 ± 0.2	5.5 ± 0.6	6.0 ± 0.1	4.8 ± 0.2	5.0 ± 0.0	5.3 ± 0.3	3.8 ± 0.2	4.0 ± 0.1	4.3 ± 0.4
		30	5.5 ± 0.7	5.5 ± 0.7	6.0 ± 0.0	5.1 ± 0.6	4.4 ± 0.4	5.0 ± 0.0	3.8 ± 0.3	3.4 ± 0.6	3.9 ± 0.1
		35	5.5 ± 0.6	5.5 ± 0.5	6.0 ± 0.2	4.5 ± 0.2	4.2 ± 0.2	4.8 ± 0.3	3.3 ± 0.3	3.5 ± 0.2	3.8 ± 0.5
Tigoni	AF[3]	25	6.0 ± 0.0	6.0 ± 0.0	6.3 ± 0.2	5.9 ± 0.2	5.4 ± 0.5	5.7 ± 0.3	4.2 ± 0.3	4.2 ± 0.3	4.9 ± 0.1
		30	6.0 ± 0.3	6.0 ± 0.0	6.2 ± 0.3	5.5 ± 0.7	4.8 ± 0.2	5.2 ± 0.4	4.5 ± 0.6	3.8 ± 0.2	3.8 ± 0.2
		35	6.0 ± 0.2	6.0 ± 0.0	6.2 ± 0.3	4.7 ± 0.4	4.5 ± 0.3	5.2 ± 0.2	4.1 ± 0.1	4.2 ± 0.5	4.0 ± 0.0
	PE[4]	25	6.0 ± 0.0	6.0 ± 0.0	6.2 ± 0.3	5.3 ± 0.5	5.3 ± 0.5	5.2 ± 0.3	5.3 ± 0.4	5.3 ± 0.5	5.3 ± 0.4
		30	6.0 ± 0.7	6.0 ± 0.2	6.3 ± 0.2	4.5 ± 0.8	4.3 ± 0.4	5.3 ± 0.4	3.5 ± 0.8	3.8 ± 0.4	4.0 ± 0.0
		35	6.0 ± 0.0	6.0 ± 0.0	6.3 ± 0.5	4.5 ± 0.7	4.2 ± 0.2	5.0 ± 0.6	3.5 ± 0.7	3.5 ± 0.4	3.9 ± 0.1

PKG[1]=Packaging type; ST[2]=Storage temperature (°C); AF[3] =Aluminium foil pack; PE[4]=Polyethylene bag; [5]Evaluation was done on 7-point hedonic scale. A score of 4 was the acceptable lower limit; [6]Accep=Acceptability; Values are mean ± SD.

Table 25: Pearson correlation coefficient (r) between peroxide value, free fatty acids and sensory attributes for crisps made from four potato cultivars

Parameters	Sensory attributes		
	Flavor	Aroma	Acceptability
Peroxide value	-0.76***	-0.66**	-0.43*
Free fatty acids	-0.53**	-0.52*	-0.78***

Levels of significance: * $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; NS= not significant, $P > 0.05$. NA= Not applicable

9.5 Conclusions

Depending on the cultivar, shelf life of potato crisps is influenced by packaging and storage temperature. Compared to the popular polyethylene bags, aluminiu foil packs extended shelf life of crisps. Storage of crisps at lower temperatures is desirable to maintain product acceptability. It is therefore advisable, that for longer storage duration (> 5 months) processors should consider the use of aluminium foil packs and prevailing weather conditions in the product destination.

CHAPTER TEN

GENERAL CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

Kenyan potato crisps market consists of local and imported brands. Imported crisps were found to have better quality in terms of oil content and product uniformity. The consumption of potato crisps in Nairobi depends on gender, occasion, season of the year, and availability of disposable income. Except in the sizes and uniformity, most brands with a few exceptions had crisps characteristics that conformed to the national standards.

The potato crisps processing industry is dominated by small to medium scale processors who process crisps only as one of a diversity of products. The industry is, however, faced with several constraints including raw potato price fluctuations, scarcity and poor quality of suitable processing potatoes, lack of improved equipment, skills and information on raw potato storage. The industry relies heavily on potatoes from one variety, Dutch Robjin grown in one part of the country only and due to low production there is inadequate supply to processors.

The screening process established three varieties, Dutch Robjin, Tigoni and Kenya Baraka, and three clones 393371.58, 392657.8, 391691.96 and 393385.39 as suitable for processing into crisps. Deep frying of crisps significantly reduced the level of ascorbic acid irrespective of the selected four cultivars that were tested. The reduction was highest in variety Tigoni while it was lowest in Dutch Robjin.

Oil uptake, texture and color of potato crisps were influenced by potato cultivar, slice thickness and frying temperature. Depending on the cultivar, the keeping quality of potato crisps was influenced by packaging and storage temperature. Aluminium foil packs and low storage temperatures extended shelf life more compared to the popular polyethylene bags.

10.2 RECOMMENDATIONS

Even though most marketed crisps met the maximum oil content set at 40% by the Kenyan standards body, this limit is quite high and could be reduced to about 35%. This value was achieved by 55% of the brands evaluated. Proper choice of appropriate potato cultivars and processing parameters would ensure that the limit is achieved as shown by selected cultivars that were tested.

It would be important to train processors, most of who own small to medium scale processing units, on basic post-harvest handling and storage requirements for processing ware potatoes for quality crisps manufacture.

Variety Tigoni that is known to be high yielding can produce equally good quality crisps and should be promoted alongside Dutch Robjin that is the variety available currently for many processors in Kenya. The advanced clones 391691.96 and 393385.39 performed well compared with Dutch Robjin. In order to solve the problem of lack adequate suitable raw material for crisps processing, the National Potato Research Centre (KARI) should therefore ensure adequate production and distribution of the identified cultivars to farmers for supply to processors. The Ministry of Agriculture could develop a potato production policy that will enhance production of processing potato cultivars in areas of suitability.

Cultivar 391691.96 showed presence of anti-oxidant as indicated by lower levels of peroxides. Evaluation of the nature and activity of the anti-oxidant is necessary. It is advisable, that for longer storage duration (> 5 months) processors should consider not only the use of aluminium foil packs as opposed to polyethylene bags, but also the prevailing weather conditions at the product destination. It is important for all the manufacturers to declare on the package labels the required storage conditions in addition to expiry date of their products for consumer safety.

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CHAPTER TWELVE: APPENDICES

Appendix 1: Questionnaire for crisps consumption pattern in Nairobi

Information from crisp consumers in Nairobi, Kenya

Date of interview…………………………………………………..
Name of the outlet…………………………………………………
Location…………………………………………………………….
Name and gender of the interviewee…………………………………………

Q1. How many times do you buy potato crisps in a month? ____________________

Q2. Which brands of crisps do you often buy? What reasons?

Brand	Flavors				Reasons
	Onion	chilly	garlic	others	
1.					
2.					
3.					
4.					
5.					

Q3. What are the unit packages of the most popular crisps that you buy? State reasons.

Unit packaging (g or kg	Prices	Package type	reasons
1.			
2.			
3.			

Q4. Do you buy the crisps for your own consumption? If no, for whom do you buy? ______

Q5. Are there seasons when you buy less/more crisps? State them with probable reasons

Seasons (months)	Low/High	Reasons for preference
1.		
2.		
3.		

Q6. What criterion do you use to choose crisps to buy? ________________________

______________________ ____

Q7. What complaints, if any, have you ever raised on the crisps you buy? List in order of common complaints

1) ____
2) ____
3) ____

Q8. What reasons make you buy crisps? sweetness_____ hunger____attractiveness____

Q9. Can you describe your trend of crisps consumption over time? Give reasons.

	Trend (increasing/decreasing)	Reasons
Consumption		

Appendix 2: Questionnaire for diversity and characteristics of potato crisps in Nairobi

Information on crisps processed and sold in supermarkets in Nairobi city, Kenya

Date of interview...

Name of the outlet...

Location...

Name and title of the interviewee...

Q1. Does your shop sell potato crisps? _______

Q2. What other products of potato do you sell? ___________ _________ ______________

Q3. How many times do you buy potato crisps in a month? _____________________

Q4. Which brands of crisps do you sell/buy and what quantities? What reasons?

Brands	Processor	Qty/month	reasons
1.			
2.			
3.			
4.			
5.			

Q5. What are the unit packages and prices of crisps that you sell/buy? State reasons.

Unit packaging (g or kg	Prices	Package type/material	reasons
1.			
2.			
3.			
4.			
5.			

Q6. Which brand (s) of crisps is the most popular in your shop? Give reasons where possible

Brands	Company		Preference	Reasons for preference
	local	Foreign		
1.				
2.				
3.				
4.				
5.				
6.				

Q7. Of the brands you sell, state the percentage of imported and locally produced_____________

If there are imports, are there price differences between imported and local crisps? (Provide price list). What reasons are advanced for this difference? _______. (See attached sheet)

Q8. Which groups of consumers purchase crisps?

Consumer group	Rate of purchase (tick)
Parents	Highly/average/low
Children	Highly/average/low
Youths	Highly/average/low
Any other (specify)	Highly/average/low

Q9. Are there seasons of low or high sales? State probable reasons

Seasons (months)	Reasons for preference
1.	
2.	
3.	
4.	

Q10. What complaints, if any, are raised by customers on the crisps you sell? List in order of priority

4) ____
5) ____
6) ____
7) ____

Q12. What conditions are crisps displayed on shelves for sale?____________________
Q13. How are your crisps transported from the supplier to your stores? How are they bulk packaged? ____
Q14. How long do the crisps store before they are sold (weeks or months)?___________
Q15. What is the criterion for accepting a crisp supplier?_______ ____________________
Q16. Do you experience any loss? What approximate percent? _____________________
Categorize the losses.

Category	Percent loss
1. expiry	
2. microbial spoilage (fungi/bacteria)	
3. insects	
4. rodents	
5. change of smell/taste	
6. spillage	
7. Others	

Q17. Do you experience any scarcity? ___ If yes, what factors are major contributors to this scarcity?

1) __________________________________
2) __________________________________
3) __________________________________

Q18. What is the trend of prices and consumption of crisps in Kenya? Give reasons.

	Trend	Reasons
Price		
Consumption		

Q19. What portion of the shelves is occupied by crisps? _______________________

Appendix 3: Questionnaire for characteristics of the industry, constraints in processing, and marketing of potato crisps

Survey of Processed Potato Crisps

Date of the interview: ______________________________

Questionnaire number: ______________________________

Name and address of establishment: ______________________________

____

Name of the owner of the establishment: ______________________________

Name and function of person interviewed: ______________________________

____

A-1 Identification of the establishment

1) Type of establishment

1. Industry ____
2. Other (specify) ______________________________

2) Number of employees: Total______

B-2 History of the establishment/ owner

3) How long has this establishment been in operation?1. less than 1 year 2. 1-2 years 3. 2- years 4. Over 3 years

4) What are your main products? 1.____________ 2.____________3. ____________

4. ____________ 5. ____________ 6. ____________

5) How do you rank the potato crisps amongst other products?...

6) What is (are) the unit sale weight and prices of your crisps?...

Unit sale weight	Price
1.	
2.	
3.	
4.	

7) How frequently do you manufacture the crisps in a week? ____________________

7.1 What quantity on each occasion? ______________________________

7.2 How much fresh potatoes do you use on each occasion? ______________________________

____

8) Why don't you produce more crisps (if crisp production is low)?

1. Lack of customers __ 4. Lack of raw potatoes __
2. Lack of equipment __5. Poor quality potatoes__
3. Lack of money__

9) Do you produce your crisps on order?

1. Yes __ 2. No ___ 3. Not applicable ___

10) What is the production cost of 100 kg crisps?

1. Don't know __ 2. Kshs. 1000 and below 3. Ksh.1000-2000 4. Ksh.2000-3000 5. Other______

11) How many persons are involved in the production/packaging of crisps?

1. Don't know __ 2. ____________________

12) Who are your main customers?

1. Individuals __ 2. Wholesaler __
3. Supermarket __ 4. Kiosk __
5. Outside catering __ 6. Other ________

13) How does the market now compare to one year ago?

1. Same 3. Worse
2. Improved 4. Don't know

14) Does the demand for crisps vary with season?

1. Yes ___ 2. No ___ 3. Don't know ___

14.1) If yes, specify:

1. Not applicable ___ 2. High in Jan-Mar 3. High on school days 4. High on school holidays 5. Low in Jan-Mar 6. Low on school days 7. Low on school holidays

15) What problems do you experience in selling your products? ________________

____

C-1 Variety and Quality

16) For the production of your crisps, do you use red- or white-skinned potatoes? 1. Red_ 2. white_

17) Which varieties do you use for your potato crisps?

1. Don't know 2. Dutch Robjin 3. Tigoni 4. Any other (specify)____

17.1) Why do you use this particular variety (s)? 1. Cheap 2. Readily available 3. Don't know 4. Produce good quality crisps

C-2 Supply: source/frequency/ quantity/price/transport

18) What are the sources, frequency and quantities of fresh potatoes? How are they transported?

Sources (place and name of supplier)	Frequency (tick)	Quantity (tons/kg)	Means of transport
1.	1. daily— 2. once a week__ 3. twice a week__ 4. Once a month__ 5. other (specify)_	1. less than 100kg_ 2. between 100-500kg__ 3. 1 ton__ 4. 1-2 tons__ 5. other__	1. lorry__ 2. handcart__ 3. pick up__ 4. other___
2.	1. daily— 2. once a week__ 3. twice a week__ 4. Once a month__ 5. other (specify)_	1. less than 100kg_ 2. between 100-500kg__ 3. 1 ton__ 4. 1-2 tons__ 5. other__	1. lorry__ 2. handcart__ 3. pick up__ 4. other___

20) Give reasons for buying from the above source?_______________ ________________

________________ ____________________ __________________ _______________

21) How are your fresh potatoes packaged? 1. Gunny bags__ 2. Plastic bags__3. Other___

22) Have you a purchase contract?

1.Yes __ 2. No __

23) If no, what are the reasons you don't have a purchase contract? ___________________

____

24) What unit measure do you use to buy fresh potatoes? State the current prices and variations in within the year..

Unit measure	Price	Variation within the year (minimum and maximum)
1. 50 kg		
2. 110kg		
3. Other (specify)		

25) Is there fluctuation in supply of potatoes during the year?

1. Yes __ 2. No __ 3. Don't know __

26) If yes, which month (s) and how does it vary?

Month (period)	Unit weight
1. jan-april	1. 50 kg
2. may- july	2. 110kg
3. sept-december	3. Other (specify)

27) What are the reasons for the flactuations?

1.Not applicable __ 2. Don't know __

3. Drought__ 4. Rainy season 5.___________

28) What problems do you experience in acquiring your raw materials? Rank in order of importance.

1.Transport __ 5. Quality of raw material __

2. Storability ___ 6. Other ___

3.Availability __ 7. None __

4. Price ___ 8. Doesn't know __

D- Transformation: storage/ process/ equipment

D-I Storage

29) Do you store your potatoes before use?

1.Yes __ 2. No __

30. If yes, how long do you store them before processing?

1. up to 5 Days __ 2. Up to 3 Weeks __ 3. 1 Month and more __

31) Where and in what type of packages?

1. Not applicable ___ 2. ___________________________

32) Do you experience any losses of raw potatoes in storage? No.__ yes__. If yes what type of losses? a) Greening__ b) rotting__ c) hollow heart__ d) other (specify)__________

D-2 Process/equipment

33) What are your processing procedures for potato crisps?

Stages	Description (mechanized or Manual- show temp/time)	Stages	Description
1.		4.	
2.		5.	
3.		6.	

34) Do you encounter any problems in the process, which kind and at what stage?

Type of problems	Stage of processing
1.	1.
2.	2.

35) Do you intend to expand your operations in crisp processing in the near future? How

1. Yes __ 2. No __. ____

36) What type of fuel do you use?

1.Gas __ 2. Electricity __

3. Charcoal __ 4. Kerosene/paraffin __5. Other ____________________

37) How much does the fuel cost in a month?

1. Don't know __ 2. __________________________________

38) What type of oil/fat do you usually use for frying crisps? Give quantity and cost per month?

Oil type	Quantity/processing	Cost per month	Reasons for use
	1. Less than 50kg/L		1. Cheap
	2. 50-100kg/L		2. Readily available
	3. More than 100kg		3.Good quality 4.Don't know 5. other

39) How long does it take to change the oil during frying of crisps?

1. Don't know __ 2. 10 hrs__ 3. 10-16hrs 4. 20-24hrs__ 5. 2 days__ 6. 3-4 days__

40) What other products do you fry in this oil?

1. None ___ 2. ______________________

3. __________________ 4. ______________________

41) How do you dispose the potato peels? (Specify end-use if any).

1. For sale __ 2. Discard __ 3. Other ___________________

42) What kind of material do you use in packaging crisps? 1. Polythene 2. Plastic cans 3. Aluminium foil 4. Other (specify)

43) What kind of package do you use for crisps? a) Plastic bags under atmospheric air______________ b) plastic bags under vacuum_____ c) aluminium foil under vacuum____

44) How long (shelf-life) does the product keep?

1. Don't know __ 2. 2 months and below____ 3. 3-5 months__4. 6-7 months___5 7 months and above___________

45) Is this shelf life indicated on the package? 1. Yes___ 2. No___

46) Are you aware of the standards for crisps? Which ones? ____________________________

____

Sign............................

George O. Abong'
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Dept. Food Science, Nutrition and Technology
University of Nairobi
Mobile: 0735 50855

Sign..

Interviewee....................................
Industry..
Tel..
Mobile..

Appendix 4: Sensory evaluation score sheet

Date of evaluation...............................

Product evaluated................................

Name of evaluator................................

Please evaluate the food samples provided and indicate the degree of your liking for color, flavor, texture, oiliness and overall acceptability. Please do not communicate or consult with anyone while scoring.

Use the numerical scores from the scoring card provided. Enter your score under the sample in the scoring sheet.

7-point Hedonic scale

Quality	**Score**
Dislike very much	1
Dislike	2
Dislike slightly	3
Fair	4
Like slightly	5
Like	6
Like very much	7

The scoring card

Sample code	1	2	3	4	5	6	7	8	9	10	11	12
Color												
Flavor												
Texture												
Oiliness												
Overall acceptability												