Quality Attributes of French Fries: Factors Affecting Thereon A Review

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ABSTRACT

French fries are consumed by millions of people worldwide and this has contributed to the vast growth and development of industries and businesses dealing with their production. Numerous processes are carried out to obtain French fries with the desired quality attributes. Over the past few decades, a wealth of information about the health effects of consumption of fried foods has been gathered and now consumers are more cautious about oil content of fried foods.

The present review sheds a light on the processes carried out and other conditions considered during the production of French fries and their effects on some quality attributes of the finished product. Such processes and conditions include: storage conditions of fresh potato tubers, blanching, pre-fry dehydration and deep fat frying.

This review also focuses on the various factors that affect the oil content of the fried potato products and their effects on other quality attributes like colour and texture of the fried products. Such factors include; coating with edible materials, nature of frying oil, frying temperature and time.

Key words: pre-fry dehydration, edible coatings, deep fat frying, frying temperature, frying time, oil content of fried potato products.

INTRODUCTION

The potato, *Solanum tuberosum* L., was originally cultivated in Peru and from there it spread to Spain, Portugal and to other parts of Europe in the late 1500. Within the next two centuries, it was exported to America, Australia, China and elsewhere (Ames & Spooner, 2007, Pringle *et al*., 2009). In Egypt, potato was introduced in 1800s and its production was on small scale. Large scale potato production was promoted by the British colonialists to provide food for their troops during the First World War. Initially potato cultivation was concentrated in the Nile delta but in 1961, it expanded to other regions. Between 1990 and 2007, the annual potato production rose from 1.6 to 2.6 million tonnes. Egypt ranks among the leading potato exporters in the world and in 2004, more than 380,000 tonnes of fresh potatoes and 18,000 tonnes of frozen potato products were exported to European markets (FAO, 2008).

The physical and chemical quality attributes like colour, shape and nutrient composition of potato tubers were reported to vary with variety. Talburt & Smith (1967) reported that potato tubers in Peru had colours ranging from golden yellow, purple, pink, pale lilac and blue while their shapes were round, oblong, crenated and cylindrical. Lachman *et al*. (2013) compared six potato varieties (HB Red, Rote Emma, Blaue St Galler, Valfi, Violette and Agria) and found that they had purple, red and yellow coloured flesh. Different potato varieties have also been noted to have different chemical compositions and quality attributes. Numerous potato varieties exist but not all varieties are suitable for French fry and crisps production. Vinci *et al.* (2012) reported that varieties for French fry production must generally be large, long and oval with relatively high dry matter and low reducing sugar levels. Varieties for crisp production must be of medium size, oval with higher dry matter and much lower reducing sugar contents.

Before potato tubers are harvested, the soils are dampened so as to minimize damaging the tubers. Tubers are then mechanically harvested and this enables removal of clods of soil and other field wastes. The harvested tubers are exposed to warm temperatures to enable wound healing. Thereafter, the tubers are cooled to ambient storage temperature. For prolonged storage, the temperature is maintained at 3-4°C as this prolongs dormancy and slows down the development of diseases but results in accumulation of reducing sugars. Potato tubers for the production of French fries and chips must be stored at 8-12^{0}C to ensure minimum accumulation of reducing sugars during storage although this makes them susceptible to rotting, disease development and shortens the dormancy period. The stores must be well ventilated to dry out the soils adhering to the tubers during wound healing, to get rid of respiration heat and prevent condensation of moisture onto the tubers during storage. Ventilation also lowers carbon dioxide levels since high amounts of carbon dioxide result in the black heart defect (Pringle *et al.*, 2009).

Physical Properties of Potato Tubers

Tuber size

Potato tuber size is considered when determining final product of production. Long, oval, medium to large sized tubers are generally used for French fries production while production of crisps requires medium sized tubers (Steyn *et al.,* 2009, Vinci *et al.*, 2012). The tubers must be uniform size in order to eliminate the need for size grading, rejection of tubers or cutting large specimens before processing (Torres & Parreno, 2009). Small sized tubers are undesirable for the production of potato crisps.

Specific gravity

The specific gravity of potato tubers varies depending on the variety, pre-harvest conditions and post-harvest conditions. Russet Burbank potatoes obtained from different farms in Oregon had different values of specific gravity (Lyman & Mackey, 1961). Specific gravity of potato tubers affects some quality attributed of fried products. Potato tubers of higher specific gravity yielded light coloured chips (Lyman & Mackey, 1961) while French fries were more rigid and crispy with a mealy interior (Sayre *et al.*, 1975).

Chemical Composition of Potato Tubers

The chemical composition of potato varies widely depending on variety, area of growth, cultural practices, tuber maturity at harvest, storage conditions, and other factors (Talburt & Smith, 1967, Bradshaw & Ramsay, 2009).

Moisture and dry matter content

There is an inverse relationship between moisture content and dry matter content of food materials. The distribution of moisture within the tubers was found to differ since more moisture and lower dry matter were observed in the pith area compared to the cortex region (Sayre *et al.*, 1975, Marquez & Anon, 1986). Subramanian *et al.* (2011) reported a dry matter content of 10% in the pith region and 24% in the periphery of the tuber. The moisture content of potato tubers changes depending on pre and post-harvest conditions. Basuny *et al.* (2009) reported that the moisture content of six potato varieties grown for chip production in Egypt ranged from 75.35 to 83.27%. According to Mehta *et al.* (2011), immature potatoes have lower dry matter (higher moisture) amounts compared to mature tubers. Food materials with high dry matter content require less time to evaporate moisture during frying.

Carbohydrate content

Potatoes are excellent sources of carbohydrates with amounts ranging from 13.3 to 30.53% (Torres & Parreno, 2009). Basuny *et al.* (2009) reported that Osina, Glactica, Valour, Lady valour, Sponta and Hana varieties grown for chip production in Egypt had total carbohydrate content varying from 15.30-18.70%. Starch is dominant carbohydrate constituent of the tubers and varies between 65 and 80% of the dry weight of the potato tuber (Torres & Parreno, 2009).The sugar content of potato tubers varies with variety and post-harvest storage conditions.

Reducing sugar content

Potato tubers of different varieties have dissimilar reducing sugar contents (Mehta & Kaul, 1988). The amount of reducing sugars in six potato varieties (Osina, Galactica, Valour, Lady valour, Sponta and Hana) commonly grown in Egypt for chip production ranged from 0.32 to 1.11% (Basuny *et al.,* 2009). The reducing sugar content of potato tubers varies depending on a variety of factors. Marquez & Anon (1986), Mehta & Kaul (1988) and Viklund *et al.* (2008) studied the effect of storage temperature on the total reducing sugar content and found that storage of tubers under low temperatures resulted in elevated reducing sugar contents. Similar results were obtained in a study by Mehta *et al.* (2011) when potatoes stored at room temperature and in evaporative cooled stores showed lower levels of reducing sugars compared to those stored in a refrigerator. Marquez & Anon (1986) reported about the participation of both reducing sugars and amino acids in the development of colour in fried potato products and concluded that reducing sugars were the limiting factor in the colour forming reactions. The same study also showed that the addition of fructose increased colour of French fries more than addition of an equal amount of glucose.

Non reducing sugar content

Viklund *et al.* (2008) observed that the sucrose content of potato tubers was affected by the storage temperature. Tubers stored at 4°C showed higher amounts of sucrose compared to those stored at 8°C. Marquez & Anon (1986) noted that there was no change in the sucrose content of French fries as a result of frying.

Protein content

Nitrogenous materials in potato tubers range between 0.4 and 2.8% and rarely exceed 2.25%. They consist of albumin, globulin, tuberin (a peculiar protein), amino acids and salts. It was observed that 49% of the nitrogenous materials are in form of protein while 51% is non-protein nitrogen. The protein in the flesh of the tuber is about 1.5% while the peel contains about 1.7%. Therefore, peeling results in a slight loss of protein. The nitrogen content of potato tubers is directly proportional to the moisture content. Young tubers have more juice and more protein compared to mature tubers. The crude protein content of Osina, Galactica, Valour, Lady valour, Sponta and Hana potato varieties was found to range from 1.50 to 2.73% (Basuny *et al.,* 2009). Viklund *et al.* (2008) noted that storage of potato tubers at 4°C resulted in significantly higher amounts of asparagine compared to tubers stored at 8°C. Amino acids in potatoes take part in the Maillard reaction which is responsible for the colour of fried products but their participation is rarely the limiting factor for this reaction (Marquez & Anon, 1986, Rodriguez-Saon & Wrolstad, 1997).

Ash and mineral contents

The total amount of minerals in the potato tubers is affected by the soil conditions in which the tubers were grown. Subramanian *et al.* (2011) reported about the variation of some specific minerals within the potato tuber. Tuber surface layers contain higher concentrations of most minerals than the flesh region.

Technological Aspects of Potato

The production of processed potato products involves multiple technological processes starting from harvesting, transportation, storage and production of the final product. Several factors and conditions must be followed to ensure that the quality of potato tubers is maintained till production of the desired end product.

Storage conditions

The conditions in which potato tubers are stored affect the physical and chemical composition of tubers which in turn affect the quality parameters of the processed potato products. Lyman & Mackey (1961) noted that the potato tubers stored at 50°F produced lighter coloured chips than tubers stored at 40°F. Marquez & Anon (1986) observed that when potatoes were stored at 3°C, the reducing sugar content steadily increased after 1 week of storage while storage at 10°C did not greatly change the soluble sugar content. The increase in reducing sugar content resulted in potato slice of lower colour quality from tubers previously stored at 3°C. Another study by Viklund *et al.* (2008) found that potatoes stored at 4°C had higher amounts of glucose and fructose than those stored at 8°C. Bradshaw & Ramsay (2009) stated that cold storage (2-4°C) of potato tubers controls sprouting, maintains low respiration rates and results in excessive accumulation of reducing sugars (senescent sweetening). Therefore, it is suitable for seed potatoes but not tubers meant for frying. Mehta & Kaul (1988) reported that potato tubers stored at room temperature showed higher weight losses compared to those stored in a refrigerated store. This is attributed to high storage temperature and low relative humidity which promote increased respiration rates.

Conditioning

Conditioning refers to maintaining potato tubers at room temperature after cold storage. It lowers the reducing sugar content of the tubers which in turn improves the colour of fried potato products. Lyman & Mackey (1961) reported that unconditioned tubers produced darker coloured chips compared to conditioned tubers. The same study also found a relationship between the storage periods, the duration of conditioning and colour of chips. In that, when the duration of cold storage was prolonged, the conditioning time was shortened to one week in order to obtain chips of desirable colour.

Peeling

Steam, lye and abrasion are the peeling techniques that are commonly used in potato processing. Lye peeling utilizes chemicals at concentrations between 15 and 25% and heat to uniformly loosen the skins of tubers. Abrasion peeling ensures minimum weight loss for tubers with shallow eyes, while tubers with deep eyes showed high weight losses and required trimming to yield an acceptable product (Feustel & Harrington, 1957). Peeling losses decrease with increase in tuber size since large tubers have a lower surface area to volume ratio (Weaver *et al.*, 1979). Lachman *et al.* (2013) reported that peeling of potatoes decreased the total steroid glycoalkaloid content.

Cutting

Cutting causes mechanical damage to outer cells of food materials. The size of cut food pieces was observed to affect some quality attributes of food products. Gamble & Rice (1988), Krokida *et al.* (2000) and Dana & Saguy (2006) reported that potato products of smaller size lost more moisture and absorbed more oil than larger ones during frying. Product size also affects the core temperature of the food material. Mellema (2003) reported that the core temperature of large food materials like French fries and meat balls does not rise above 100°C while it raised above 100°C for thin food materials like crisps.

Blanching

This treatment enables inactivation of enzymes, softening of tissue and has been found to lower the amount of reducing sugars present in potato products (Vinci *et al.*, 2012). Blanching treatments may either be dry or wet (in solution). The quality of blanched food materials varies depending on the blanching temperature, time and the solution used. The temperature and duration of blanching determine the texture of food products. Potato strips became tender as blanching continued at higher temperatures while temperatures lower than 73.9°C had no effect on texture of the strips irrespective of the blanching time (Liu & Scanlon, 2007). Pedreschi & Moyano (2005) reported that the blanching treatment did not significantly affect the texture of fried potato slices. Blanching treatments have been noted to affect the dry matter and moisture content of food materials. Rimac-Brncic *et al.* (2004) observed that blanching in water, citric acid and calcium chloride solution decreased the dry matter content of potato strips.

Research studies on the effect of blanching treatment on the final oil content of fried food products were carried out and the following results were obtained. Rimac-Brncic *et al.* (2004) noted that fried potato strips that were previously blanched in water containing citric acid and calcium chloride had less oil than those blanched in water. A study by Pedreschi & Moyano (2005) showed that blanched potato slices contained more oil when fried than non-blanched slices. Vinci *et al.* (2012) reported that blanching causes leaching out of precursors of acrylamide, a possible carcinogen found in fried food products.

Pre-frying treatments

Several treatments are carried out during the preparation of food materials for frying. Among these treatments is dehydration by either oven drying or soaking in sugar or salt solutions and coating with edible coating materials like cellulose derivatives such as methylcellulose (MC), carboxymethyl cellulose (CMC), hydroxypropylmethyl cellulose (HPMC), pectin coatings, whey proteins, soy protein isolate, zein, gellan gum and others. The effects of these pre-frying treatments on the quality attributes of fried products were analyzed by different researchers who obtained different results.

Dehydration

Frying is considered as a dehydration process since it utilizes high temperatures which cause evaporation of water from food materials. Several techniques have been used to reduce the moisture content of food materials before frying and the effect of pre-fry dehydration on the quality attributes of fried food products has been studied by different researchers. Pre-fry dehydration was observed to lower the final moisture content of fried food products. Debnath *et al.* (2003) noted that when an extruded chickpea snack was pre-dried for 40 mins or less before frying, the final moisture content decreased with elongation in the dehydration period. Prolonged drying for 60 mins or more had slight effect on the equilibrium moisture content after frying.

The final oil content of fried products is affected by the initial moisture content of food products before frying. Debnath *et al.* (2003) reported that the final oil content of an extruded chickpea snack decreased with elongating in the pre-fry dehydration period up to 40 mins. Tran *et al.* (2007) observed that potato crisps which pre-dried and later dipped in a sugar solution showed a significant reduction in oil content compared to those without dipping. Duran *et al.* (2007) noted that potato slices that were blanched in sodium chloride solution had lower oil content compared to those blanched in water. Pedreschi *et al.* (2007b) obtained similar results with potato slices soaked in sodium chloride solution. The pre-drying method used also affects the final oil content of fried food products. Tajner-Czopek *et al.* (2008) found that potato strips pre-dried by the conventional hot air method absorbed more oil than those pre-dried by vacuum microwave method.

The effect of pre-fry dehydration on the microstructure of food products was studied and the results showed that pre-fry dehydration results compactness of the food product microstructure (Debnath *et al.*, 2003). Another study by Tajner-Czopec *et al.* (2008) reported that the conventional hot air dehydration method of potato strips resulted in strips with an irregular structure with deformed cells while strips dehydrated by vacuum microwave method had a regular structure with shrunk cells.

Debnath *et al.* (2003) found that a pre-fry dehydration of 60 mins affected the appearance of the extruded chickpea snack while other sensory attributes were not affected by this treatment. Pedreschi *et al.* (2007b) observed that dehydration by soaking potato chips in sodium chloride solutions improved the colour and increased the crispness of the chips. Tajner-Czopek *et al.* (2008) reported that pre-dried potato strips had higher colour values of greenness, yellowness and lightness compared to non-pre-dried strips.

Coating with edible biomolecules

Numerous biological molecules have been extensively used as coatings in the area of food processing, agriculture and pharmacology. Coating materials used in food products must be nontoxic and should not significantly affect the organoleptic properties of the food materials. The use of edible coatings in food processing has been found to offer added benefits like improved shelf life of fruits and vegetables, reduced final oil content of fried products and some coating have antibacterial properties. When studying the effect of edible coating on quality attributes of fried food products, several factors have to be put into consideration. The nature of coating materials, concentration, solubility and the addition of plasticizers affect the efficiency of coating materials.

The moisture content of fried food materials was influenced by coating treatments. Garcia *et al.* (2002) and Rimac-Brncic *et al.* (2004), reported that coated food materials had higher moisture content than uncoated materials. French fries coated with MC retained more moisture than those coated with HPMC (Garcia *et al.*, 2002). Meanwhile, Freitas *et al.* (2009) obtained similar results when fingers from reformed cassava puree were coated with whey protein, pectin and soy protein isolate. Kilincceker (2011) reported that chicken nuggets coated with soy protein isolate retained more moisture than those coated with zein. The high moisture content is due to the fact that the coating materials limit the migration of moisture from food products during frying.

Edible coatings were noted to affect the oil content of fried food products. Coated food samples had lower oil content than uncoated samples. In a study by Garcia *et al.* (2002), uncoated French fries had more oil than MC and HPMC coated samples. Coating with MC had a higher oil reduction effect than coating with HPMC. Bajaj & Singhal (2007) also noted that the addition of gellan gum to an extruded chick pea snack ‘sev’ reduced the oil content and the reduction effect increased with increase in concentration of gellan gum. Freitas *et al.* (2009) observed that coating of reformed cassava fingers with pectin, whey protein and soy protein isolate reduced the final oil content of fried fingers. According to Pahade & Sakhale (2012), coating French fries with HPMC resulted in a higher oil reduction effect compared to coating with MC, guar gum and xanthan gum. Contrary to such results, significantly higher oil content values were obtained in potato chips coated with HPMC compared to uncoated chips (Duran *et al*., 2007). The effect of using more than one coating material was studied by Bajaj & Singhal (2007) and the results showed that using gellan gum alone gave a higher oil reduction effect than when it was combined with sodium alginate or CMC or soy protein isolate.

The use of edible coating materials in the field of food processing has been shown to contribute other beneficial effects. Alak (2012) reported that coating of fish fillet with chitosan films prolonged the storage life. Coating with chitosan films delayed the growth of aerobic bacteria and also offered antioxidant properties.

The texture of coated food products was analyzed and it was observed that coating French fries with MC had no effect on its texture (Garcia *et al.,* 2002). Notwithstanding, Bajaj & Singhal (2007) reported that addition of gellan gum to an extruded chick pea snack 'sev' had no significant effect on product's texture. Contrary to such results, Hua *et al.* (2015) found that potato chips coated with MC were brittle and their brittleness decreased with elevation in concentration of MC.

Frying Treatments

Several frying techniques are used in the preparation of fried products. All frying techniques involve use of frying oil and high temperatures to achieve the desired quality attributes of the fried products. Among these techniques is the simple and popular deep fat frying and air frying method which may be carried out under different conditions of temperature, pressure and time duration.

Deep fat frying

Deep fat frying is described as one of the oldest and popular way of preparing tasty foods quickly (Mellema 2003, Choe & Min, 2007). This technique involves immersion of food into heated oil which results in rapid increase in surface temperature of the food material and a slight decrease in oil temperature depending on the food to oil ratio. The drop in oil's temperature is rapidly compensated by convection since the frying oil is continuously heated.

The high temperatures of frying oil usually 150-190°C (Choe & Min, 2007) cause the water at the surface of the food material to rapidly boil and evaporate. Therefore, frying is considered as a dehydration process (Dana & Saguy, 2006, Pedreschi *et al.,* 2007b). Moisture loss from food products during frying is reported to occur by diffusion (Gamble *et* al., 1987, Gamble & Rice, 1988). During frying, the evaporation of moisture from the food material results into shrinkage, development of pores on the surface of the product and increase in surface roughness (Mellema, 2003). As frying continues, the amount of moisture lost from the food product diminishes due to development of a crust which acts as barrier to moisture loss. Crust development is responsible for the desirable crispy texture of fried food products.

Mellema (2003) reported that the core temperature of large food materials like French fries and meat balls does not rise above 100°C while that for thin materials like potato crisps will be higher. When frying, the product surface temperature rises above the boiling temperature of water, so several physicochemical changes such as surface dehydration, starch retrogradation and Maillard reactions occur. Such changes are responsible for the desirable organoleptic properties of fried foods (Mellema, 2003, Dana & Saguy, 2006).

The quality of any deep fried product depends mainly on the frying temperature, duration of frying and nature of food material. Frying at high temperatures for extended periods of time results in undesirable darker and harder food surfaces with a greasy texture while frying at lower temperatures for shorter time results in under-fried foods with partially cooked centers and less developed colour, flavour and less crispy texture (Choe & Min, 2007)

Frying oil

During deep fat frying, the oil is used as a medium through which heat is transferred to the food products and is also responsible for the texture and flavour of fried products (Choe & Min, 2007). The frying oil together with other factors like composition and nature of food material, frying conditions and the type of fryer used affect the quality attributes of any fried food products.

Moreira *et al.* (1997) studied the effect of oil quality on the total amount of oil absorbed by tortilla chips and the results showed that the total amount of oil absorbed by the chips was not affected by oil quality. The same research also reported that most of the degraded oil was concentrated on the surface due to higher viscosity while more fresh oil was absorbed into the tortilla chips. Mellema (2003) stated that frying oils of high viscosity not only hinder oil uptake during cooling due to the small size of the pores but also minimizes drainage of oil when the food material is taken out of the frying oil.

In another research by Krokida *et al.* (2000), the effect of oil type on fat absorption and moisture content were studied, results showed that oil type had a negligible effect on the final oil content and moisture content of French fries. Similar results were obtained by Rimac-Brncic *et al.* (2004) when sunflower oil, palm oil and vegetable oil were used to study their effect on oil absorption. Contrary to the aforementioned results, Kita *et al.* (2007) reported that the various oils used for frying largely influenced the oil content of potato crisps.

Furthermore, Kita *et al.* (2005, 2007) observed that the fatty acid composition of frying oil affected the texture of fried potato products. Oils containing 30 to 60% oleic acid gave less hard but crispier potato crisps while oils containing higher amounts of saturated fatty acids and trans-isomer fatty acids gave French fries of higher hardness values.

Frying oil degrades as the number of frying cycles increases. Choe & Min (2007) mentioned that hydrolysis, oxidation and polymerization are reactions which occur during deep fat frying and contribute to degradation of oil. Basuny *et al.* (2009) found that oil viscosity, acid value, peroxide value, thiobarbituric acid value and polar compounds increased during the frying process. Oil degradation is minimized by addition of food grade chemicals to frying oil. Mellema (2003) reported that the addition of poly dimethyl siloxanes minimizes penetration of oxygen into the oil during frying. Choe & Min (2007) stated that the addition of tocopherols, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG) and tert-butylhydroquinone (TBHQ) to frying oils led to slow oxidation of oil at room temperature.

Frying temperature

The frying temperature is one of the factors that significantly contribute to the quality of fried products since it not only affects the organoleptic properties of the fried products but also affects the nutritional aspects of fried products. When the food material is immersed into the hot frying oil, several processes and reactions occur yielding both the desirable and undesirable qualities of the fried product. The final oil content of fried products is partly determined by frying temperatures. According to Moreira *et al.* (1997), the effect of oil temperature on the final oil content was studied when optimum baked tortilla chips were fried for 60 secs at 130, 160 and 190°C and the results showed a significant difference between frying temperature and final oil content. That is, the final oil content increased with the elevation in frying temperature.

In another study by Krokida *et al.* (2000), potato strips of different cross section areas were fried at 150, 170 and 190°C for various times. The results showed a positive relationship between frying temperature and final oil content for similar frying times. Also when Debnath *et al.* (2003) fried extruded chickpea flour-based ribbons at 150, 175 and 200°C for different times, the results showed an increase in equilibrium oil content from 0.198 to 0.278 (kg/kg dry basis) as the temperatures increased. Similar results were obtained by Yagua & Moreira (2011) when potato slices were vacuum fried and the oil content increased with elevation in frying temperatures 120, 130, 140°C. Bingol *et al.* (2012) obtained the same results with French fries fried at 146, 160 and 174°C.

Contrary to such findings, Garayo & Moreira (2002) reported that final oil content was not significantly affected by frying temperature when potato chips were vacuum fried at different temperatures (118, 132 and 144°C). Pedreschi *et al.* (2007b) found that increasing the frying temperature reduced the amount of oil absorbed when blanched potato slice were soaked in NaCl solutions and fried at 120, 140, 160 and 180°C. Furthermore, Kita *et al.* (2007) reported that when potato crisps were fried in different oils at 150, 170 and 190°C, the results showed that every 20°C rise in temperature reduced fat absorption by 3% for all oils studied.

During frying, the evaporation of water from the food material depends on the frying temperature. So, the final moisture content of any fried products is partly determined by the frying temperature. Krokida *et al.* (2000) reported that moisture content decreased with increase in frying temperature when French fries of different sizes were fried for different times at 150, 170 and 190°C. Similar results were obtained by Garayo & Moreira (2002) when potato chips were vacuum fried at 118, 132 and 144°C. Debnath *et al.* (2003), observed a decrease in equilibrium moisture content from 0.07 to 0.003 (kg/kg dry basis) when an extruded chick pea snack was fried at 150, 175 and 200°C.

Oil temperatures during frying affect the colour of fried products because Maillard reactions which are responsible for colour development in fried products depend on temperature. According to Pedreschi *et al.* (2007b), higher frying temperatures resulted in darker potato chips. Another study by Romani *et al.* (2009) found that increasing the frying temperature decreased lightness and increased redness and yellowness when potato chips were fried at 170, 180 and 190°C. Closely related, the Maillard reaction is also responsible for the formation of acrylamide, a carcinogenic compound found in fried foods. Pedreschi *et al.* (2007a) and Pedreschi & Zuniga (2009) reported that acrylamide contents increased with increase in frying temperatures from 150 to 170 and 190°C.

In addition to the aforementioned findings, the frying temperature contributes to the overall texture of the fried food products. Garayo & Moreira (2002) noted that the hardness increased with increase in oil temperature when potato chips were vacuum fried at 118, 132 and 144°C. Pedreschi & Moyano (2005) and Pedreschi *et al.* (2007b) observed that increasing the oil temperature caused faster softening of potato tissues and rapid hardening of the crust when potato chips exposed to different pre-frying treatments were fried at 120, 140, 150, 160 and 180°C. Kita *et al.* (2007) noted that frying temperature had no significant effect on texture of potato chips fried in different oils at 150, 170 and 190°C.

Frying time

The duration of frying enormously affects the various quality attributes of fried food materials. It is worth noting that all quality aspects of fried food materials are predominantly determined by the frying temperature and time. The final moisture content of any fried product is affected by the duration of frying. Longer frying times are associated with more evaporation of water from the food materials. Gamble & Rice (1988) reported that the moisture content reduced when potato slices were fried for longer times 3, 3.5, 4, 4.5 and 5 mins. Debnath *et al.* (2003) obtained identical results when an extruded chick pea snack was fried for different times. Mellema (2003) explained that prolonged frying caused increased moisture loss till complete drying of the food surface. Kilincceker (2011) obtained similar results when coated chicken nuggets were fried for 2, 4 and 6 mins.

Closely related, the frying time was also observed to affect the final oil content of fried products. It was noted that final oil content increased significantly with elongation in frying time when potato strips were fried under normal atmospheric conditions (Krokida *et al.,* 2000) and also when potato chips were vacuum fried for various times (Garayo & Moreira, 2002). Similar results were obtained by Debnath *et al.* (2003) when an extruded chick pea snack was fried for different times till 120 secs. Mellema (2003) explained that prolonged frying of small food substances caused complete drying of the crust which in turn results in increased uptake of oil during frying. Rimac-Brncic *et al*. (2004) and Pedreschi & Zuniga (2009) stated that oil absorption increased with frying time in a non-linear trend. Coated chicken nuggets revealed a similar moisture loss trend when frying was done at 2, 4 and 6 mins (Kilincceker, 2011).

The attractive colour of any fried product is due to non-enzymatic (Maillard) reaction which is determined by the frying temperature and duration of frying. Romani *et al.* (2009) observed that prolonged frying times resulted in reduced lightness and increased yellowness and redness values of potato chips. Almost similar results were obtained when coated crusts were fried for 60, 120 and 180 secs. The lightness and yellowness decreased while redness increased significantly with frying time (Ansarifar *et al.*, 2012). Closely related to the aforementioned findings, Bingol *et al.* (2012) detected a slight decrease in lightness, redness and yellowness at the start of frying and explained that it was due to changes in the surface characteristics of French fries. But later on, they increased with extending the frying time.

It is worth noting that elongation of the frying time results in development of a hard crust and causes toughening of meat tissues as shown by reduced penetrometer values (Kilincceker, 2011). The crispness of coated crusts increased with elongation of frying time due to increased surface drying and this was observed to protect tenderness of the inner parts (Ansarifar *et al.*, 2012).

The duration of frying to some extent is determined by the composition of food materials. Mehta *et al.* (2011) stated that French fries with high dry matter content (low moisture content) required relatively lower frying time to dehydrate their surfaces during frying. Pedreschi & Zuniga (2009) mentioned that frying time contributed to the formation of acrylamide which is a carcinogenic compound formed as a result of the non-enzymatic browning reaction in fried food materials.

Lastly, the use of frying oils for extended periods of time contributes to deterioration of oils due to hydrolysis, oxidation and polymerization reactions that occur during frying. Such reactions result in the formations of undesirable compounds which not only affect the viscosity of frying oil but also the quality attributes of fried products (Dana & Saguy, 2006, Choe & Min, 2007).

Post-frying Treatments

Post frying treatments are carried out immediately after the food products are removed from the frying oil. Such treatments like shaking and blotting with paper have been found to reduce the final oil content of fried foods. Dana & Saguy (2006) reported that hot air and superheated steam can be used to blow away excess oil from food surfaces. This treatment maintains the product temperature while preventing surface oil from being sucked into the product. So, the oil easily drains from the surface when blown. The duration of shaking of the food products immediately after frying has been found to affect the oil content of fried products. Bingol *et al.* (2012) noted that shaking French fries for 180 secs after frying reduced the oil content by 11.73% compared to shaking for 10 secs.

Oil content and distribution in fried products

The frying process involves utilization of food grade oils and high temperatures for short periods of time. Immersion of the food material into hot oil causes evaporation of moisture and adsorption of oil on to the surface of the product. The adsorbed oil is part of the fried product and its distribution differs during frying and after frying. The total amount of oil in any fried product influences product quality and nutritional composition of the food products.

Mechanism of oil uptake

The mechanism of oil uptake during frying depends on the evaporation of water from the product surface. This is explained by the fact that as moisture evaporates from the outer surface, crust formation occurs. Surface dehydration creates voids from which the fat enters the immediate crust layer of the product. During frying, the temperature inside the product increases and moisture within the product is converted to steam which creates a positive pressure gradient within the food product. Some of the steam escapes through cracks, defects, open capillaries, channels in the cellular structure and membranes of the product while the rest remains trapped within the products of small surface area. The high internal steam pressure prevents the penetration of oil into the product while complete surface dehydration provides surfaces for the adsorption of oil. Therefore, oil penetration is limited to the immediate crust layer of non-reformed products (Gamble *et al.*, 1987, Mellema, 2003, Dana & Saguy, 2006). Ufheil & Escher (1996) and Dana & Saguy (2006) reported that the total amount of oil in any fried product is a result of the balance between the oil adsorbed on the product surface and that which drains off when the product is removed from the frying oil. Therefore, the product microstructure plays a crucial role in oil uptake.

Distribution of oil in fried products

As previously mentioned, frying oil is restricted to the surface of the product during frying because of the high inner vapour pressure which prevents oil penetration. When the food product is removed from the hot oil, cooling results in condensation of vapour in the pores and this subsequently decreases the internal pressure. So, the oil that adhered to the food surface is sucked in during cooling due to the resultant vacuum effect (Gamble *et al.,* 1987, Moreira *et al.,* 1997, Mellema, 2003, Dana & Saguy, 2006, Duran *et al.,* 2007, Tran *et al.,* 2007, Pedreschi & Zuniga, 2009, Moreno *et al.,* 2010, Pedreschi, 2012). Yagua & Moreira (2011) reported that oil absorption in vacuum fried potato chips occurred during the pressurization period when the pressure of the system is raised till normal atmospheric pressure.

Ufheil & Escher (1996) observed that when potato slices were fried in non-dyed oil and dyed oil, the results showed that oil remains in the surface and is only taken up at the end of the frying period. This was shown when the non-dyed oil was replaced by dyed oil during the few seconds of frying in dyed oil. Moreira *et al.* (1997) observed that during frying of tortilla chips, more oil was retained on the surface than that which was absorbed into the chips. During cooling, more oil (64%) is absorbed into the chips compared to oil (36%) retained in the chip's surface. Aguilera & Gloria-Hernandez (2000) reported that when par-fried frozen potatoes were first fried in colza oil (CO) and immediately transferred to coconut fat (CF) at the same temperature, 82% of CO was replaced by CF in just 2 secs of frying in CO. In addition to that, when potatoes fried in CO were cooled and then transferred to hot CF, more CO was retained by the potatoes. Therefore, surface oil is easily washed off during frying while cooling caused absorption of oil such that it is not easily washed off during the second frying. Duran *et al.* (2007) reported that 38% of the total oil content was absorbed by potato chips during frying and 62% remained in the chip's surface. During cooling, 65% of the total oil content was absorbed while 35% remained in the surface.

Oil content of fried products

The final oil content of fried food products varies depending on a variety of factors among which include; nature of food material, pre-frying conditions, frying conditions and post frying conditions. Gamble & Rice (1988) and Shaker (2014) mentioned frying time, surface area of food substances, solid content and moisture content of food products, types of breading or battering materials and frying oil as some of the factors that affect the final oil content of fried food products.

The effect of oil temperature on final oil content of fried products was studied and contradicting results were obtained. Gamble *et al.* (1987) reported that final oil content was not directly related to the frying temperature. Contrary to such results, Krokida *et al.* (2000) observed that the final oil content of French fries increased with increase in frying temperature. Garayo & Moreira (2002) and Yagua & Moreira (2011) reported that the oil content of potato chips fried under vacuum increased with increase in frying temperature. In another study, Duran *et al.* (2007) and Pedreschi *et al.* (2007b) noted that oil content decreased with increase in oil temperatures.

The duration of frying also affects the final oil content of fried products. Gamble *et al.* (1987) observed that oil content increased with the square root of the frying time. Ansarifar *et al.* (2012) noted that the final oil content of crust models increased with frying time.

Product size is another factor that affects the final oil content of fried products. Gamble & Rice (1988) noted that increase in potato slice thickness resulted in decreased oil content. Similar results were observed by Krokida *et al.* (2000) and Basuny *et al.* (2009) who noted that thinner potato strips retained more oil after frying than thicker strips. Contrary to the aforementioned results, Tajner-Czopek *et al.* (2008) noted that French fries of sizes 10 x 10mm absorbed more oil than those of 8 × 8mm when fried for 5 and 4 mins, respectively.

A comparative study by Ufheil & Escher (1996) noted that potato chips produced under laboratory conditions contained higher oil content than those produced on a conventional industrial line. Bradshaw & Ramsey (2009) stated that the oil content of domestically fried chips (40-50%) was higher than industrially fried chips (36%). Shaker (2014) compared deep fat fried potato chips and those that were air fried and found that deep fried potato chips contained significantly more oil than air fried potato chips.

The composition of food materials affects the product's final oil content. Ufheil & Escher (1996) and Basuny *et al.* (2009) observed that potato chips from tubers of high density or high dry mass content contained lower oil content while tubers of low density (low dry mass content) yielded chips of high oil content. Moreira *et al.* (1997) noted that tortilla chip made from fine flour contained more oil than those made from coarse flour.

Covering of food surfaces with edible coatings and films was found to affect the final oil content of fried food products. Garcia *et al.* (2002) noted that coating French fries with MC and HPMC retained less oil compared to uncoated samples. In the same study, it was observed that different edible coatings reduced the oil content by different values. French fries coated with MC retained less oil than those coated with HPMC. Rimac-Brncic *et al.* (2004) noted that coating of potato strips with CMC from different sources generally reduced the oil absorption and the final oil content varied for coatings from different sources. Freitas *et al.* (2009) also observed that coating of preformed cassava products with whey protein, pectin and soy protein isolated reduced the final oil content. Similar results were obtained by Asarifar *et al.* (2012) with crust models coated with chitosan and egg white. Hua *et al.* (2015) also observed that coating potato chips with sunflower head pectin and MC reduced the final oil content. Contrary to the aforementioned results, Duran *et al.* (2007) observed that HPMC coatings were not effective in reducing oil absorption in potato chips.

Bajaj & Singhal (2007) observed that increasing the concentrations of gellan gum coating in sev (a traditional Indian snack food) significantly reduced the final oil content. Hua *et al.* (2015) found that increasing the concentration of pectin and MC coating did not significantly affect the oil content of fried chips.

A study by Bajaj & Singhal (2007) showed that combining different edible coating materials with gellan gum did not significantly reduce the product's final oil content. Hua *et al. (*2015) noticed that when potato chips coated with sunflower head pectin were dried prior to frying, the final oil content was slightly higher than non-dried coated chips.

The initial moisture content of the food materials was also observed to significantly affect the final oil content of food products. Moreira *et al.* (1997) noted that tortilla chips with more moisture retained more oil than those that had lower initial moisture content. Drying treatments before frying were observed to affect the final oil content of fried products. Debnath *et al.* (2003) noted that extruded chickpea ribbons when dried for 40 mins, the final oil content reduced by 54%. Pedreschi *et al.* (2007b) noted that dehydration by soaking of blanched potato slices in sodium chloride reduced the oil absorption by almost 10%. Tran *et al.* (2007) observed that pre-drying and dipping of potato slices in a sugar solution resulted in much lower oil content than pre-drying alone. Duran *et al.* (2007) found out that dehydrating chips with NaCl was more effective at reducing the final oil content than coating with HPMC. When Tajner-Czopek *et al.* (2008) compared the effect of pre-drying methods on the final oil content of potato strips, the results showed that potato strips pre-dried using the vacuum microwave method absorbed less oil than strips pre-dried using the convective hot air method.

Rimac-Brncic *et al.* (2004) studied the effect of different blanching treatments of French fries on the oil content of potato strips and observed that blanching in calcium chloride reduced the final oil content by 27-28%, while blanching in citric acid reduced oil content by 13-15%. Pedreschi & Moyano (2005) observed that blanched potato chips contained more oil than non-blanched chips. Bingol *et al.* (2012) noted that infra-red dry blanched French fries contained less oil than un-blanched samples.

Mehta *et al.* (2011) studied the effect of maturity of potato tubers on the final oil content and noted that the oil content of tubers decreased with maturity though the differences were non- significant.

Kita *et al.* (2007) studied the effect of oil type on the final oil content of fried potato crisps and observed that frying crisps in different oils yielded different values of oil content, rapeseed oil (36.8%), olive oil and modified oil (41%).

Moreira *et al.* (1997) studied the effect of oil quality on final oil content of fried tortilla chips and found out that oil quality did not affect the final oil content of the chips. Tortilla chips fried in fresh oil and degraded oil had almost similar amount of total final oil.

Garayo & Moreira (2002) reported that the final oil content of potato chips was not affected by frying under different vacuum pressures, while Pedreschi (2012) reported that vacuum frying produces chips of lower oil content.

Colour of fried products

Colour development occurs when sufficient moisture has been lost from the food surface during frying (Pedreschi *et al.*, 2007b). It relies on a non-enzymatic browning (Maillard) reaction between reducing sugars and amino acids. The colour of any fried food material is affected by the reducing sugar content, frying temperature and frying time.

Higher frying temperatures resulted in darker potato chips (Pedreschi *et al*, 2007b). Meanwhile Marquez & Anon (1986) and Romani *et al.* (2009) found that lightness values decreased while redness and yellowness increased with frying temperature and time elongation. Ansarifar *et al.* (2012) observed that crust models coated with egg white and chitosan had lightness and yellowness values decrease while yellowness values decreased with frying time.

Lyman & Mackey (1961) observed that conditioned potato tubers gave lighter coloured chips while chips from unconditioned tubers were dark coloured. Since colour development is due to a reaction between reducing sugars and amino acids, the total reducing sugar content of food materials affects colour of fried foods (Rodriguez-Saona & Wrolstad, 1997). The reducing sugar content of potato tubers increases under cold storage conditions (Marquez a & Anon, 1986). Conditioning at room temperature and blanching have been noted to minimize the amount of reducing sugars in potatoes (Hesham, 2005). Furthermore, Mehta *et al.* (2011) stated that the prescribed limit for reducing sugar content in French fries is 0.2% fresh weight basis.

The specific gravity of potato tubers also contributes to the colour quality of fried products. Lyman & Mackey (1961) noted that potato tubers of high specific gravity produced lighter coloured chips compared to tubers of low specific gravity.

Frying conditions have also been found to affect the colour of fried food products. Garayo & Moreira (2002) found that vacuum fried potatoes were significantly lighter and had higher redness and yellowness values than potato chips fried under atmospheric conditions.

Pre-frying conditions like coating of food products with edible coating materials have been observed to give different colour results. Garcia *et al.* (2002) noted that coating with MC and HPMC had no significant effect on colour of potato strips while coated dough disks showed a significant difference in lightness and redness. In another study, Hua *et al.* (2015) noted that coating potato chips with sunflower head pectin had no effect on lightness but slightly increased redness values while coating with MC resulted in lower lightness values and higher yellowness values. Other pre-frying treatments like pre-drying with either vacuum microwave method or conventional hot air method yielded higher values of yellowness, greenness and lightness in French fries (Tajner-Czopec *et al.*, 2008)

The size of food materials was found to affect the colour quality of food products. Tajner-Czopek *et al.* (2008) noted that potato strips of smaller size (8mm x 8mm) showed better colour attributes than those of larger size (10mm x 10mm).

Texture of fried foods

The texture of any fried food materials depends on a variety of factors. The final moisture content of fried food materials was related to the texture of fried foods. A higher maximum force was required to break potato chips of lower moisture content. Therefore, the crispness of potato products corresponds with moisture content (Gamble & Rice, 1988, Pedreschi & Moyano, 2005). Tajner-Czopek *et al.* (2008) also showed that potato strips of higher dry matter content required higher cutting force compared to those of lower dry matter content. Debnath *et al.* (2003) observed that an extruded chick pea snack with lower moisture required higher breaking strength than those with higher moisture content. Therefore, it can be concluded that food materials with less moisture are harder than those with more moisture.

Pre-frying treatments like cutting, blanching and pre-drying were observed to alter the texture of potato. Lisinska & Golubowska (2005) found that blanched potatoes required a force of 31 Newtons while blanched and pre-dried potato required 24.8 Newtons to break. So, blanching and pre-drying resulted in increased softness in potatoes. Pedreschi & Moyano (2005) noted that blanching reduced the hardness of raw potato slices but it did not significantly affect the final texture of fried potato slices. Pedreschi *et al.* (2007b) reported that potato chips that were blanched and then soaked in NaCl were crispier than chips which were blanched only.

Basuny *et al.* (2009) compared the texture of different potato varieties and found that the texture of potato chips primarily depended on the chemical composition of potato tubers.

Numerous researchers have studied the effects of various frying conditions on the texture of fried foods. Garayo & Moreira (2002) and Pedreschi & Moyano (2005) observed that the hardness of potato chips increased with oil temperatures and frying time. The frying temperature did not significantly affect the texture of the chips (Garayo & Moreira, 2002, Pedreschi & Moyano, 2005, Kita *et al.,* 2007). Choe & Min (2007) stated that over fried food has greasy texture due to excess oil absorption. Kilincceker (2011) observed that penetrometer values of chicken nuggets decreased with increase in frying time while Ansarifar *et al.* (2012) noted that the hardness of crust models increased with frying time. It was also noted that frying under vacuum resulted in softer potato chips than frying under atmospheric condition (Garayo & Moreira, 2002).

Garcia *et al.* (2002) studied the effect of coating potato strips with MC and HPMC and noted that these coatings did not significantly alter the texture of fried potato strips. Similar results were obtained by Bajaj & Singhal (2007) when gellan gum either added alone or in combination with CMC or sodium alginate or soy protein isolate to extruded chickpea snack ‘sev’. Ansarifar *et al.* (2012) observed a decrease in hardness when dextrin and dried egg were added to batter mixes used for coating crust models. Also, crust models coated with chitosan showed greater hardness.

Kita *et al.* (2007) found that the composition of the frying media affected the texture of French fries. Frying oils with more saturated fatty acids and trans-isomer fatty acids gave French fries with harder texture. Mehta *et al.* (2011) studied the effect of potato tuber maturity on the texture of French fries. The results showed that the texture of French fries improved towards maturity and varieties with higher dry matter content yielded firmer fries.

Moisture content of fried foods

The moisture content of fried food materials varies throughout the frying process depending on a variety of factors which include; - nature of food material, pre-frying treatments and frying conditions. When food is immersed in hot oil, intense bubbling occurs on food surfaces due to evaporation of unbound water. Bubbling decreased as frying continued (Gamble *et al.,* 1987). Garayo & Moreira (2002) and Tran *et al.* (2007) classified moisture loss during frying into three stages; - The first stage is the initial heat up period in which the product surface temperature rises rapidly to boiling point of water. Secondly, the constant rate period where moisture loss continues provided the food surfaces contain moisture. Finally, the falling rate period which occurs when product surface is dry and moisture loss is due to diffusion of moisture from inside the product. Basuny *et al.* (2009) noted that potato varieties with high moisture content had higher moisture losses. The reduction in moisture content during frying resulted in increased solid matter content (Rimac-Brncic *et al.,* 2004, Lisinska & Golubowska, 2005). In another study, Lisinska & Golubowska (2005) reported that moisture loss during frying resulted in shrinkage of surface cells of French fries.

Food materials of various sizes give different final moisture content results. According to Gamble & Rice (1988) and Krokida *et al.* (2000), the large potato products retained more moisture than thin potato products. Moreover, Gamble & Rice (1988) studied the effect of frying time on the final moisture content of potato slices and observed that longer frying times resulted in sufficient moisture loss. Similar results with French fries were obtained by Krokida *et al.* (2000).

The final moisture content of fried products was found to be closely related to the oil content. Gamble *et al.* (1987) noted that potato slices with higher moisture had lower oil content. Identical results were obtained by Debnath *et al.* (2003), who dealt with an extruded and fried chickpea snack. Garayo & Moreira (2002) explained that the high oil content is due to more free space created by the evaporation of more moisture.

Krokida *et al.* (2000) noted that final moisture content of fried products is affected by the frying temperature. Higher frying temperatures resulted in lower final moisture content of fried products since moisture evaporation is faster at higher frying temperatures.

The effect of edible coatings on the final moisture content of fried product was studied. Garcia *et al.* (2002) found that coating of potato strips with MC and HPMC resulted in higher moisture retention compared to uncoated strips. The MC coated strips retained more moisture than HPMC coated strips. Freitas *et al.* (2009) also observed that fried cassava products retained more moisture when they were coated with pectin, whey protein and soy protein isolate. Pectin coatings retained more moisture compared to other coating used. Kilincceker (2011) noted that fried chicken nuggets coated with zein and soy protein isolate had more moisture than non-coated nuggets. Hua *et al.* (2015) found that increasing the concentration of MC and sunflower head pectin (SFHP) did not significantly affect the moisture content of fried potato chips. Chips coated with SFHP had significantly more moisture than those coated with MC.

Pre-frying treatments that lower the moisture content of food products were observed to give fried products of lower moisture content. Debnath *et al.* (2003) observed that a fried chickpea snack that had previously been pre-dried contained less moisture than that which had not been pre-dried. Tran *et al.* (2007) noted that fried potato slices previously dipped in sugar solution had lower moisture than non-dipped slices. The method of frying used was observed to affect the moisture content of fried products. Shaker (2014) compared the moisture content of air fried and conventionally fried potato strips and the results showed that air fried strips contained 35.25% moisture while conventionally fried strips contained 30.51% moisture.

Bradshaw & Ramsay (2009) stated that the moisture content of frozen par fried French fries should be less than 70% to prevent limpness and separation of the interior and crust.

Health Aspects of Fried Foods

Fried products contain high amounts of oil which in turn results in high total energy intake. Frequent consumption of fried food resulted in weight gain which leads to overweight/obesity. Consumption of products fried in olive oil was observed to pose a lower risk to overweight compared to other types of oil (Sayon-Orea *et al.*, 2013). Sartorelli *et al.* (2014) reported that consumption of fried foods resulted in weight gain in pregnant women.

Numerous studies have reported about the presence of acrylamide, a carcinogenic compound in laboratory animals has been confirmed as present in fried food products. Acrylamide is formed as a result of the Maillard reaction (between reducing sugars and asparagine) and the same reaction is also responsible for the desirable colour and flavour of fried foods. Several techniques like selection of potato varieties with low reducing sugars, use of proper storage temperatures and conditioning minimize the accumulation of reducing sugars, proper blanching to leach out precursors of acrylamide, enzymatic hydrolysis of asparagine, coatings treatments with alginic acid and pectin, controlling frying conditions lower the levels of acrylamide in the final product (Pedreschi, 2012, Vinci *et al.*, 2012)

Shelf-life of fried products

The shelf-life of fried products varies depending on the condition of oil used for frying and the storage conditions. The storage period of fried potatoes decreased when the number of frying in any given oil increased. Potato chips fried in palm olein showed a significantly longer shelf-life compared to those fried in soy bean oil. Furthermore, blended oils with more palm olein yielded chips with a slightly longer shelf life. Storage of fried potato chips at lower temperatures prolonged their shelf-life (Che Man *et al*, 1999)

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محددات جودة أصابع البطاطس المحمرة :العوامل المؤثرة عليها
استعراض مرجعي

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نظراً لاستهلاك الملايين حول العالم لأصابع البطاطس المحمرة، فلقد تنامى الاهتمام بها و هو ما انعكس إيجابا على تطوير صناعة و تسويق هذه المنتجات. هناك عمليات تصنيعية عديدة تطبق لإنتاج أصابع بطاطس محمرة تتميز بالجودة العالية و لقد توفر قدر كبير من المعلومات خلال العقود القليلة الماضية حول التأثيرات الصحية للأغذية المحمرة عامة و هو ما أدى إلى زيادة اهتمام المستهلك بمحتوى الزيت في هذه المنتجات.

يلقى هذا الاستعراض المرجعي الضوء على العمليات التصنيعية و كذا الظروف التي يجب أن تؤخذ في الاعتبار و تأثيراتها على محددات الجودة لناتج الأصابع المحمرة النهائي. وتتضمن مثل هذه العمليات و الظروف كلاً من: ظروف تخزين درنات البطاطس الطازجة، السلق ، التجفيف قبيل التحمير و التحمير العميق.

و يركز هذا الاستعراض المرجعي أيضاً على عدة عوامل من شأنها التأثير على محتوى الزيت في المنتجات المحمرة و كذا محددات الجودة لهذه المنتجات مثل اللون و القوام، و من أهم العوامل في هذا السياق تغطية أصابع البطاطس قبيل تحميرها بمواد قابلة للأكل، طبيعة الزيت المستخدم في التحمير، درجة حرارة و زمن التحمير.