

Comparison between traditional deep-fat frying and air-frying for production of healthy fried potato strips

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Abstract

The objectives of this work evaluate air-frying process as a new technique for frying process. The potato strips were fried in both air-frying machines (Tefal Actifry) at $180^{\circ}\text{C}\pm 5^{\circ}\text{C}$ for 40 min and traditional frying process at 180°C for 40 min, 6 min/batch. After frying process, the moisture and oil uptake were determined. Changes in some physico-chemical properties of oil extracted from fried potato strips by the two frying processes were determined. Also, organoleptic evaluation of fried potato strips by using air and traditional-frying processes were evaluated by tasters. Results indicated that the moisture content and oil uptake in fried potato strips by air frying process were significantly lower than fried potato strips by traditional frying process. Changes in some physico-chemical properties (free fatty acids, peroxide value, polar, polymer and oxidized fatty acids contents) of oil extracted from fried potato were significantly higher in traditional frying than air-frying method. Organoleptic attributes of fried potato strips by air frying surpassed on fried potato strips for traditional-frying process. Generally, the air frying processes was more suitable for frying process and produce healthy fried foods than other traditional frying method.

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Introduction

Deep-fat frying can be defined as the process of drying and cooking through contact with hot oil (Lesinka and Leszczynski, 1989; Sahin *et al.*, 1999). In deep-fat frying products, the sensory aspects should be addressed to meet consumer demand. High heat transfer rates are largely responsible for the development of the desired sensorial properties in fried products (Hubbard and Farkas, 1999). Dehydration in hot oil at temperatures between 160°C and 180°C is characterized by very high drying rate that is critical for ensuring favorable structural and textural properties of the final product (Baumann and Escher, 1995).

Frying time, food surface area, moisture content of food, types of breading or battering materials, and frying oil influence the amount of absorbed oil to foods (Moreira *et al.*, 1997). The oil contents of potato chips, corn chips, tortilla chips, doughnuts, French fries, and fried noodle (ramyon) were in the range 33% - 38%, 30% -38%, 23% - 30%, 20% - 25%, and 10% - 15% (Moreira *et al.*, 1999a), and 14% (Choe *et al.*, 1993), respectively. The absorbed oil tends to accumulate on the surface of fried food during frying in most cases (Moreira *et al.*, 1999b) and moves into the interior of foods during cooling.

In recent years, consumer's preference is to

consumer low fat and fat-free products has been the driving force of this food industry to produce lower oil content fried potatoes that still retain the desirable texture and flavor. (Pinthus *et al.* (1993) introduced the criterion UR, which expresses the ratio between the amount of oil uptake and water removed. Different means to reduce oil uptake in fried potatoes have been reported. For instance, vacuum frying may be an option for fried potatoes with low oil content and desired texture and flavor characteristics (Garayo and Moreira, 2002; Basuny *et al.*, 2012). Soaking potato strips in NaCl solution reduced oil uptake in French fries after frying (Bunger *et al.*, 2003). Pre-drying of potatoes is also a common way to reduce fat uptake in fried potatoes (Rubnov and Saguy, 1997; Krokida *et al.*, 2001; Moyano and Pedrechi, 2002) and. The blanching step previous to frying in potato chip processing improves the color and texture, and could reduce in some cases the oil uptake by gelatinization of the surface starch (Califano and Calvelo, 1987).

Frying can be considered a dehydration operation in which a simultaneous heat and mass transfer occurs giving two counter-fluxes, i.e., a water outlet from the food to the hot oil and an oil inlet by the food (Krokida *et al.*, 2000), leading to series of physical and chemical changes in the final product. Despite undergoing the large gain of oil during processing of the product, frying is a widely used domestic and

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industrial cooking technique because of its ability to generate, in the final product, a combination of texture, color, and unique flavor that makes it a more palatable and desirable food for the consumer (Mestdagh *et al.*, 2008). Among fried products, the most widely known and consumed are the ones derived from potatoes such as chips and French fries, followed by the better products and the ones of direct consumption as snacks (Clark, 2003).

Many studies showed that excessive consumption of fried products can lead to serious health risks such as cardiovascular disease, hypertension, diabetes, cancer and obesity (Saguy and Dana, 2003). These facts, together with the current trend of society to consume fat-free products, have forced the industry in general, and chips industry in particular, to focus its efforts on developing alternative methods of frying that lead to products with low oil content but with the same features of flavor, color, and texture that make them so prized by consumers. In this sense, many strategies have been proposed to reduce oil content in fried products such as low pressure (Troncoso and Oedreschi, 2009; Dueik *et al.*, 2010), microwave application (Nagadi *et al.*, 2009), different pretreatments such as blanching, freezing (Moyano and Pedreschi 2006), predrying (Debnath *et al.*, 2003). However, these alternatives do not always mimic the sensory features of conventional fried products or the cost is higher than conventional frying processes. The average world prices for sunflower seed oil were 1046.25 \$US/ton (Oils and Fats International, 2013). Hot air-frying process is a new technique to get fried products through direct contact between an external emulsion of oil droplets in hot air and the product into a frying chamber. The product is constantly in motion to promote homogeneous contact between both phases. In this way, the product is dehydrated and the typical crust of fried products gradually appears. The amount of oil used is significantly lower than in deep oil frying giving, very low fat products. Today, it is possible to find, equipment designed from this principle to obtain low-fat fried products. However, there are no references or scientific publications that describe the mechanisms and kinetics of mass transfer phenomena and volume changes taking place during hot air frying. Therefore, a better scientific understanding of this technique is necessary in order to extend its application either to fast food restaurants or industries

Accordingly, the aim of this study was to investigate the effect of air-frying process on moisture and oil contents and sensory evaluation of fried potato strips compared with traditional deep-fat frying method. Also, this study evaluated the changes

in physico-chemical properties of oil extracted from fried potato strips.

Materials and Methods

Materials

Potatoes (*Solanum tuberosum* L., Spunta variety) and sunflower oil were purchased from the local market. The initial moisture content of potato was in range of 77.25%. Peroxide and acid values of the sunflower oil were 0.75 active oxygen peroxides per kilogram of oil and 0.09 mg KOH per gram of oil, respectively.

Chemicals

All chemicals used for the present study were of analytical grade and bought from Sigma Chemical Company, (ST. Louis, US).

Preparation of potatoes strips

Potatoes were sorted, washed, hand-peeled and cut by means of a manual operated potato-cutting into strips (8 x 8 x 60 mm), the potato strips were soaked in NaCl solution and dried using tissues before frying.

Frying process

Traditional frying process

Frying was carried out in a thermostatically temperature-controlled fryer (Philips comfort, Germany) having a capacity of 2 L oil by 200 gram of potatoes, i.e., a potato-to-oil ratio of 1:20 (w/v), according to the capacity of the equipment. The potato strips were fried in sunflower oil at $180^{\circ}\text{C}\pm 5^{\circ}\text{C}$ for 40 min., 6 min/batch. All fried samples were allowed to cool at room temperature; then analyzed for its oil content by Soxhlet apparatus. All experiments were run in triplicate and the present results are the average of the obtained results.

Air frying process

Air frying equipment (Model: SERIE 001 Actifry, Tefal, France) with a nominal power: 1.400 W. Air frying experiments, 0.03 kg of oil by kilogram of potato at ratio (0.03:1) was added on potato strips for 40 min, according to the specifications of the equipment. A constant frying temperature was confirmed by means of two PT-100 temperature sensors (model: TF101K) located at the top and the bottom of each fryer. Samples were immersed in the oil in deep oil frying and on surface of foods in air frying when the initial frying temperature of 180°C was achieved.

Chemical composition of fresh and fried potatoes

Moisture, oil content, reducing sugars in fresh and fried potato strips was determined according to (A. O. A. C. 2005).

Extraction of oil

The oil of fried potato strips oil was extracted by Soxhlet Method, (AOAC, 2005). A total of 50 g dried fried potato strips sample was weighted and extracted with n-hexane in a Soxhlet apparatus at a condensation rate of 5 or 6 points per second for 4 hours with 300 ml of hexane at a temperature of 70°C. The solvent was evaporated to dryness using a rotary evaporator at 40°C.

Quality assurance tests for non fried and fried sunflower oil

Refractive index, acid value, peroxide value and iodine value were determined according to (AOAC, 2005). Petroleum ether-insoluble oxidized fatty acids and insoluble polymer contents of sunflower oil samples were determined according to the methods of Wu and Nawar (1986). Polar and non-polar components in sunflower oil samples were measured by column chromatography according to the method described by (Waltking and Wessels, 1981).

Oil stability

Oxidative stability was evaluated by the Rancimat method (Gutierrez, 1989). Stability was expressed as the oxidation induction time (h), measured with the Rancimat 679 apparatus (Metrohm Co., Herisou, Switzerland) using an oil sample of 5.00 g heated to 100°C ± 2°C with an air flow rate of 20 l/h⁻¹.

Organoleptic evaluation of fried potato chips

Sensory evaluation was performed on potato strips fried in sunflower oil by using air and traditional frying 180°C ± 5°C. Prior to the sensory tests, the panelists (twenty persons) were trained to evaluate the attributes of the strips produced in this study and become proficient. The potato strips samples were rated on a 10 point scale (1,2: bad; 3,4: poor; 5,6: fair; 7,8: good and 9,10 excellent). The potato strips from each treatment, placed randomly in codified plates with three-digit code, were served to each panelist. Judges were placed in different places to avoid communication during the evaluation and asked to score strips for taste, texture, appearance, crispiness, color, odor and overall acceptability (Carpenter *et al.*, 2000).

Statistical analysis

A one-way ANOVA followed by Duncan's

multiple range test (DMRT) were performed using SPSS 11.00 (SPSS Inc., Chicago, IL, USA) to analyze and compare the data. Results were presented as mean ± SD and P- values ≤ 0.05 were regarded as statistical significance.

Results and Discussion

Physico-chemical properties and fatty acid composition of sunflower seed oil

Table 1 presents the physico-chemical properties of fresh sunflower oil. The refractive index at 25°C and iodine value of sunflower oil were 1.4738 and 123.30, respectively. Table 1 includes the free fatty acids, peroxide value, iodine value, polar content, polymer content, oxidized fatty acids, and oxidative stability and the data were 0.09%, 0.75, 123.30, 0.08%, 0.00%, 0.00% and 7.10 h, respectively. Fatty acid composition of fresh sunflower oil indicates the presence of oleic and linoleic acids at high levels (53.90%) followed by oleic acid (30.80%). The saturated fatty acids, palmitic acid (7.70%) and stearic acid (6.50%) were present as minor constituents (< 10%). On the other hand, the major unsaturated fatty acids were linoleic acid. The C18:3, C20:0 and C22:0 were detected in trace amounts in sunflower oil. These results are in agreement with (Ali *et al.*, 2013).

Table 1. Physico-chemical properties and fatty acid composition (%) of sunflower seed oil.

Parameter	value
Refractive index at 25°C	1.4738
Acid value (mg KOH/g oil)	0.09
Peroxide value (meq. peroxides /kg oil)	0.75
Iodine number (I/100g oil)	123.30
Polar content (%)	0.08
Polymer content (%)	0.00
Oxidized fatty acids (%)	0.002
Oxidative stability (hr)	7.10
Fatty acid composition:	
C _{16:0}	7.70
C _{18:0}	6.50
C _{18:1}	30.80
C _{18:2}	53.90
C _{18:3}	0.20
C _{20:0}	0.50
C _{20:1}	0.20
C _{22:0}	0.20
Total saturated fatty acids	15.10
Total unsaturated fatty acids	84.90

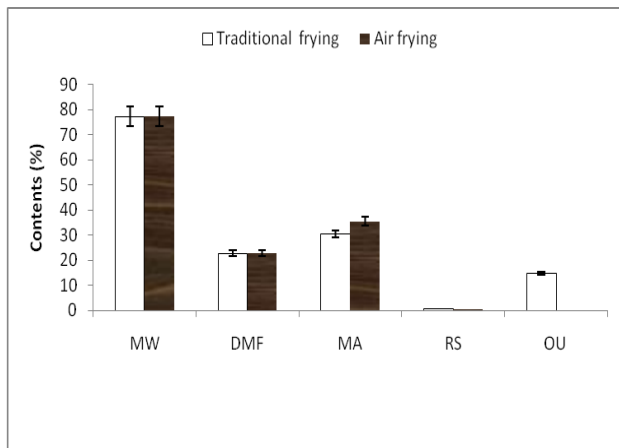


Figure 1. Chemical composition of potatoes strips before and after frying process. Where, MW= moisture before frying, DMF= dry matter before fringy, MA= moisture content after frying, DMA= dry matter after frying, RS= reducing sugar, OU= oil uptake.

The data (values \pm SE) are the mean values of three measurements for the same sample.

Chemical composition of potato strips before and after frying process

Figure 1 shows that the characteristics of potatoes before and after frying. It can be seen that potato strips contained 77.25% and 22.75% moisture and dry matter contents respectively, before frying process. After frying the, significant differences in moisture content were recorded between traditional-frying (30.51%) and air-frying process (35.25%) respectively. On the other hand, the oil content in potato strips after frying results showed that the oil uptake in traditional fried potato strips was (14.81%) which quite higher than air frying (0.0025%). From the data in same figure, the potato strips contained low reducing sugar content (0.82 mg/100 g sample) and so it is suitable potato variety to produce fried product with proper yellow color. Galoburda *et al.* (2013) reported that the water present in the raw material evaporates and is partially replaced by oil during frying process, constituting up to 40% of the finished product, and consequently influencing its properties. Boskou *et al.* (2006) mentioned that the frying is a process of immersing food in hot oil with a direct contact of air, at a high temperature of 150°C to 190°C. But air-frying is a new technique to get fried products through direct contact between an external emulsion of oil droplets in hot air and the product into a frying chamber (Andres *et al.*, 2013). From this it is clear that the traditional-frying process significantly increases (at $P \leq 0.05$) the oil uptake in potato strips more than air-frying, because the amount of oil used in air frying is very small, about 3%, but in the traditional frying oil is used as a medium fry up (1:20 w/w) potato: oil. The amount of absorbed oil in fried

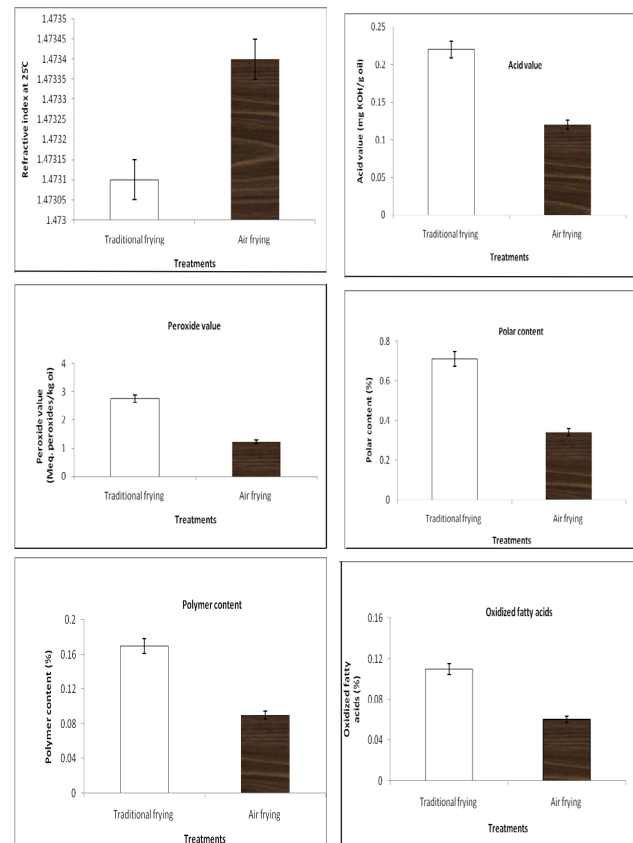


Figure 2. Changes in some physico-chemical properties (refractive index, acid value, peroxide value, polar content, polymer content, oxidized fatty acids) of oil extracted from fried potato strips.

The data (values \pm SE) are the mean values of three measurements for the same sample.

food was affected by some factors, i. e., frying time, food surface area, moisture content of food, types of breading or battering materials, and frying oil.

Changes in some physico-chemical properties of oil extracted from fried potato strips

Figure 2 presents the changes in some physico-chemical properties during traditional and air-frying processes. The refractive index at 25°C decreased from 1.4738 to 1.4731 for traditional frying and from 1.4738 to 1.4734 for air-frying respectively. The free fatty acid (FFA) content increased from 0.09% to 0.22% for traditional-frying and from 0.09% to 0.12% for air-frying. It has been suggested that production of FFA was the best indicator of fat deterioration during frying (Stevenson *et al.*, 1984).

On the other hand, the peroxide value (PV) was significantly increased from 0.75 to 2.75 meq. O₂/kg oil for traditional frying and from 0.75 to 1.22 meq. O₂/kg oil for air frying. The differences between traditional and air-frying methods in PV values may be due to quantity of oil in traditional frying was higher than the amount of oil in air-frying. During the air-frying traces of oil (3%) is used but in traditional-

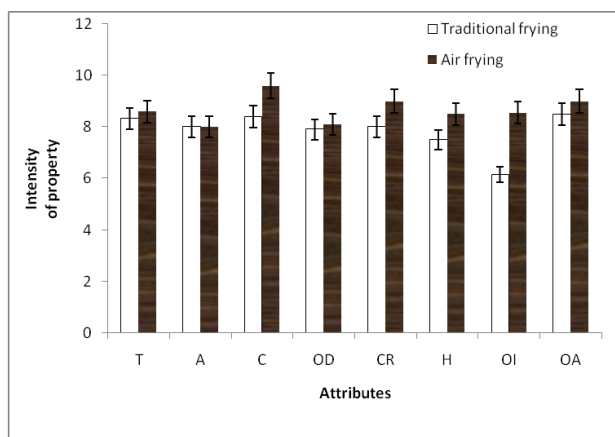


Figure 3. Sensory evaluation of fried potato strips. Where, T= taste, A= appearance, C= color, OD= odor, CR= crispness, H=hardness, OI= oiliness, and OA= overall acceptable.

The data (values \pm SE) are the mean values of three measurements for the same sample.

frying the oil used in about 2kg for frying 200 g strips every time. The free radicals formed by fatty acids react with oxygen to generate peroxides that enter into a multitude of reactions, producing numerous products, such as aldehydes, ketones, acids, esters and polymerized compounds. The extent of reaction depends on the frying temperature, aeration, type of fried or fat and the food that is being fried. The type of food being fried and its interaction with oil has been reported to contribute to the deterioration of frying oil (Stevenson *et al.*, 1984).

The changes in polar content (PC) during traditional and air-frying process are shown in Figure 2. The determination of PC in frying oil provides the most reliable measure of the extent of oxidative degradation. In this study, initial PC in fresh oil was 0.08%, but after frying the PC increased with frying time and frying temperature. PC content during frying at $180^{\circ}\text{C} \pm 5^{\circ}\text{C}$ was 0.71% for traditional frying and 0.34% for air-frying at the end of frying time, which was still below the 24% oil discard level set in many European countries (Firestone *et al.* 1991). On the other hand, the polymer content (PO) in traditional frying was 0.17% and in air-frying was 0.09%, respectively (Figure 2). In contrary, oxidized fatty acid (OFA) content was increased after frying to 0.11% for traditional frying and 0.06% for air-frying (Figure 2). Polymers formed in deep fat-frying in remarkable level since the medium is rich in oxygen. Yoon *et al.* (1988) reported that oxidized polymer compounds accelerated the oxidation of oil. Polymers accelerate further oil degradation, consequently, increased the oil viscosity (Tesng *et al.*, 1996), reduced the heat transfer, produced foam during deep-fat frying, and develop undesirable color in the food. Polymers also cause the high oil absorption to foods. Frega *et al.*

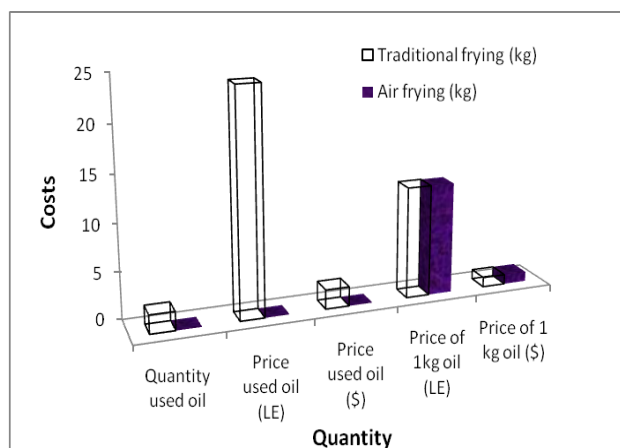


Figure 4. Costs of sunflower oil used in frying of potato strips under study.

The data (values \pm SE) are the mean values of three measurements for the same sample.

(1999) reported that free fatty acids and their oxidized compounds produced off-flavor and make the oil less acceptable for human consumption.

Sensory evaluation of fried potato strips

Sensory attributes including taste, appearance, color, odor, crispness, hardness, crispiness, oiliness, and overall acceptability of traditional and air-frying processes of fried potato strips are shown in Figure 3. Results showed that using air-frying process for fried potato strips didn't cause any significant differences on sensory attributes include taste, appearance, odor, crispiness, and overall acceptable compared to the fried potato strips using traditional frying method. On the other hand, air-fried potato strips surpassed the traditional fried potato strips in other sensory attributes (crispness, hardness and oiliness). The surpassed of air-fried potato strips in hardness and oiliness may be due to low oil uptake compared to fried potato strips by using traditional frying method.

Cost of sunflower oil used in frying of potato strips under study

The cost of oil used in both frying processes under study is presented in Figure 4. In the air-frying method, the amount of oil used for fried potato strip was 30 g/kg potato. In traditional frying method, the amount of oil is about 2 kg to fry 200 g potato strips for every batch. The price of used oil in air frying by Egyptian pound was (LE 0.0025), while, the oil price used in traditional frying (LE 24). The transfer of the price of oil used in both frying process from LE to US \$, found that the price of oil used in traditional frying around \$3.44, while, the price of oil used in air-frying around \$0.00023 Figure 4. These results illustrate the existence of clear significant differences between the prices of used oil in air-frying compared to traditional

frying. Thus, the use of air-frying technique came very low cost compared to traditional frying method (Figure 4).

Gupta (2005) reported that the availability and cost of oil are important economic factors. Even the best performing frying oil is not beneficial to the business if it is not available in sufficient quantities. The cost of oil is extremely critical for the industry. Once, air-frying method is the right method for frying foods. Most fried snack foods contain 20–40% oil. Therefore, the snack food company has to minimize the delivered cost of oil at the plant. This ends up costing money and goodwill for the snack food company in the long run.

Conclusion

The present results that the oil uptake was lower under air-frying confirming that this technique can be considered as a healthy one. Thus, this method must be practically process applied to obtain healthy fried foods.

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