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EFFECT OF A NOVEL TECHNOLOGY (AIR AND VACUUM FRYING) ON SENSORY EVALUATION AND ACRYLAMIDE GENERATION IN FRIED POTATO CHIPS

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Abstract. The objective of this work was to sturdy the effect of different frying process as a novel technology (air and vacuum) compared with traditional frying process. The potato chips were fried in both air frying machines (Tefal Actifry) at 180°C ± 5°C for 40 min and vacuum frying at (120°C, 5.37 Kpa absolute pressure) for 40 min, 20 min/batch compared with traditional frying process at 180°C ± 5°C for 40 min, 20/ batch. After frying, the moisture content, oil uptake, acrylamide content and sensory characteristics were determined. Also, changes in some chemical properties of oil extracted from fried potato chips by different frying process were determined. Results indicated that the moisture content, oil uptake and acrylamide content in fried potato chips by (air and vacuum) frying process were significantly lower than fried potato chips by traditional frying process. Changes in some chemical properties (Acid value, peroxide value, polar, polymer and oxidized fatty acids contents) of oil extracted from fried potato were significantly higher in traditional frying process than (air and vacuum) frying process. Sensory characteristics of fried potato chips by new methods of frying (Air and vacuum) surprised on fried potato chips for traditional frying process. Air and vacuum frying can therefore be considered suitable methods of preparing potato chips for modern people who consume excessive oils and are interested in healthier and high quality products.
***Keyword**:* Vacuum frying, air frying, oil uptake, sensory properties, acrylamide content.

Introduction

In the past 40 years, the use of deep–fat frying process has increased greatly in the United States and Europe.

Deep–fat frying is a method to produce dried food where an edible fat heated above the boiling of water serves as the heat transfer medium, fat also migrates into the food, providing nutrients and flavour [FAN *et al.*, 2005 and TARMIZI and NIRANJAN, 2011, BOSTAN *et al.*, 2013, BUTNARIU and CAUNII, 2013]. These conditions lead to high heat transfer rates, rapid cooking, browning, texture, and flavor development.

Therefore, deep–fat frying is often selected as a method for creating unique flavors, colors, and textures in processed foods. However, surface darkening and many adverse reactions take place during deep–fat frying because of high temperature.

Due to the pressure lowering, the boiling points both of the fat and moisture in the foods are lowered. Vacuum frying is an alternative technique to improve the quality of dehydrated food [SONG *et al.*, 2007, BUTNARIU and GIUCHICI, 2011, RASHED and BUTNARIU, 2014, BUTNARIU *et al.*, 2012].

During vacuum frying, the sample is heated under a negative pressure that lowered the boiling points of the frying oil and water in the sample [TRONCOSO *et al.*, 2009].

Moreover, the absence of air during frying may inhibit oxidation including lipid oxidation; enzymating browning; therefore, the color and nutrients of samples can be largely preserved [TARZI *et al.*, 2011, BUTNARIU *et al.*, 2006. PUTNOKY *et al.*, 2013].

Snake foods play a very important role in the diet of the modern consumer.

Potato chips have been a popular salty snacks for 150 years and retail sales in the many countries are about 6 billion/year, representing 33% of the total sales on the market [GARAYO and MOREIRA 2002].

However, potato chips have an oil content that ranges from 35 to 45g/100g (wet basis), which is a major factor affecting consumer acceptance for oil–fried products today [DUEIK and BOUCHON 2011].

Due to consumer health concerns, fat content of potato chips is an important parameter to be controlled during processing. Various factors that affect the oil absorption during deep–fat frying are the quality of the oil in which the food is fried [RIMAC–BRNCIC et al., 2004], frying temperature, time, initial moisture content, initial interfacial tension, porosity and the crust of the food that is fried [PEDRESCHI and MOYANO 2005a, BASUNY et al., 2009].

Consumer preference for low–fat 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. Many approaches to reduce oil absorption in fried products have been reported in the literature. Rimac–Brncis and collab. [RIMAC–BRNCIS et al., 2004] reported that osmotic dehydration pretreatment can be an effective operation to produce low–fat french fries.

Predrying of potatoes is a common way to reduce fat uptake in the final fried product [MOREIRA et al., 1999, KROKIDA et al., 2001, MOYANO et al., 2002]. The drying step that follows the blanching step reduces the crispness oil absorbed on the potato chips [PEDRECHI and MAYANO 2005a].

The application of a proper coating is a promising route to reduce oil content [MELLEMA, 2003]. Vacuum frying may be also an option for fried potatoes with low oil content and desired texture and flavor characteristics [GARAYO and MOREIRA 2002] and Ruttanadech and Chungcharoen [RUTTANADECH and CHUNGCHAROEN, 2015].

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 and collab. [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, BUTNARIU, 2012]. 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].

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].

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, BAGIU et al., 2012, CAUNII et al., 2015] [BUTNARIU et al., 2013, PETRACHE et al., 2013].

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, BUTNARIU and CORADINI, 2012], 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

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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.

The objective of this work was to study ways of reducing oil uptake, acrylamide formation and sensory characteristics in potato chips.

Material and methods

Source of potatoes and oil. 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 77.50 %. Peroxide and acid values of the sunflower oil were 0.80 active oxygen peroxides per kilogram of oil and 0.07 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 potato chips: Potatoes were sorted, washed, hand–peeled and cut by means of a manual operated potato–cutting into chips (8 x 8 x 60 mm), the potato chips 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 chips were fried in sunflower oil at 180°C±5ºC for 40 min., 10 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 chips 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: TF101 K) 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.

Vacuum frying experiments: The fryer consists of a heating element. Inside the vessel, there is a basket and centrifuging system (de–oiling system) with a maximum rotational speed of 750 rpm (63 g units).

Vacuum is achieved in the vessel by a dual seal vacuum pump (Model 1402 Welch Scientific Co., Skokie, IL) with a vacuum capacity of 5.37 kpa.

The frying process consists of loading 10 potato chips (about 30 g) into the basked closing the lid, and depressurizing the vessel. Once the pressure in the vessel reaches 5.37 kpa at 120°C for 40 min., 20 min/, basket was sub–merged into the oil.

After 6 minutes of frying, the basket was raised, and the centrifuging system was applied for 405 at maximum speed (750 rpm).

Then, the vessel was pressurized and the potato chips were allowed to cool down at ambient temperature before storing them in polyethylene bags inside of desiccators for further examination.

Oil content: Oil content was determined by a simple and rapid method of total lipid extraction and purification [TARMIZI and NIRANJAN, 2010].

This method consists of an initial extraction with a mixture of 1:2:0.8 (v/v/v) in chloroform, methanol and water.

Then, this mixture was adjusted to 2:2:1.8 (v/v/v) to continue the extraction. In this way, the chloroform layer contains the purified oil. The oil content was expressed as kg oil/kg dry solid.

Moisture content: Moisture content of potato chips was measured by drying the samples in a vacuum convection oven (SHEL LAB, model) 1410–2E, USA) at 30 kpa (vacuum pressure) and 70°C until reaching constant weight [AOAC, 2005].

Extraction of oil: The oil of fried potato chips was extracted by Soxhlet Method, [AOAC. 2005].

A total of 50 g dried fried potato chips 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 extracted from potato chips: 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 [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].

Sensory evaluation of fried potato chips: Sensory evaluation was performed on potato chips 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].

Determination of acrylamide in potato samples: The acrylamide content of the potato chips was analyzed by lipid chromatography tandem–mass spectrometry (LC–MS/MS) according to Roach and collab. [ROACH *et al.*, 2003]. Samples were each spiked with 1 mL $^{13}C_3$–labeled acrylamide (200 ng/mL in 0.1 % formic acid) as the internal standard. LC–MS/MS analysis was performed using an Agilent 1100 LC system equipped with a binary pump, an autosampler, a column heater (kept at 25°C), and a degasser (Agilent Technologies., USA) interfaced to an ABI 3000 triple quadrupole mass spectrometer (Applied Biosystems., Canada).

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

Moisture and oil content: Figure 1 shows the evaluation of moisture content of potato chips during atmospheric, vacuum, and air frying process.

Deep–fat frying process (atmospheric) chips reached the desired moisture content faster than (vacuum and air frying process) chips.

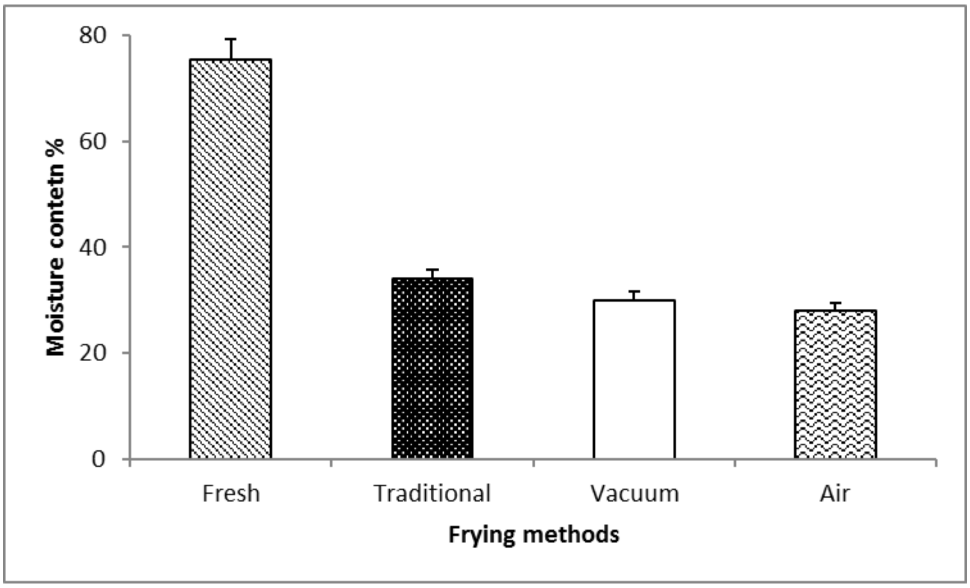

Figure 1. Effect of traditional, vacuum and air frying process on moisture content (%) of fried potato chips. The data (Values ±SE) are the mean of three measurements for the sample.

This difference can be attributed to the larger driving force for heat transfer during deep–fat frying process compared to (vacuum and air).

The experimental results (Figure 2) show the oil uptake during atmospheric, vacuum and air frying process of potato chips.

The highest oil uptake content was in potato chips during atmospheric frying process, while those produced during air frying process had lowest oil uptake.

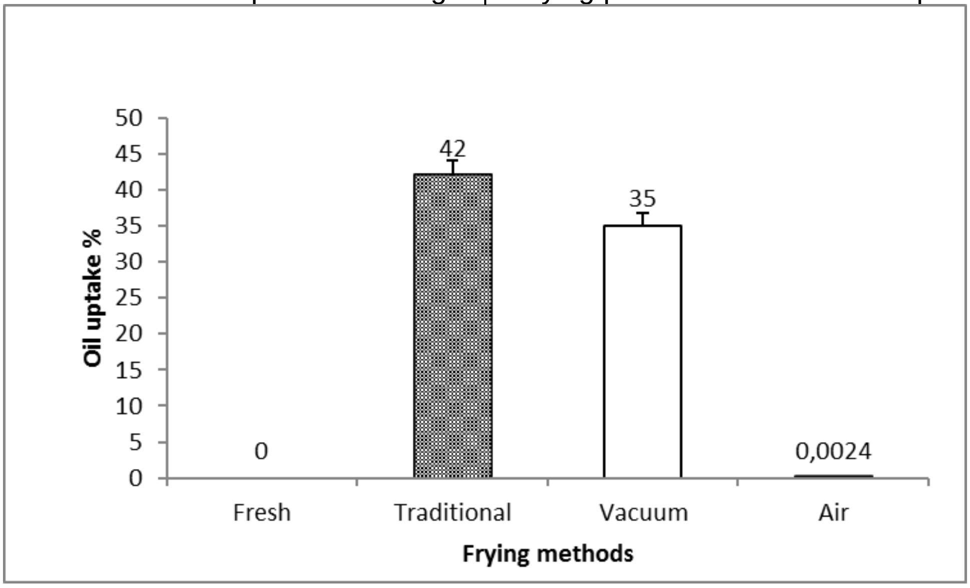

Figure 2. Effect of traditional, vacuum and air frying process on oil uptake content (%) of fried potato chips. The data (Values ±SE) are the mean of three measurements for the sample.

Galoburda and collab. [GALOBURDA *et al.*, 2013] reported that the water present in the raw material evaporates and is partially replaced by oil during frying process, and constituting up to 40 % of the finished product, and consequently influencing its properties. From this it is clear that the atmospheric frying significantly increase (P≥0.05) the oil uptake in potato chips more than air frying process, because the amount of oil used in air frying process is very small, about 3 % but the atmospheric frying process oil is used as a medium fry up (1:20 w/w) potato :oil.

Acrylamide content: Recent studies reported that acrylamide, a genotoxic carcinogen, is formed during high temperature processes, including frying. Acrylamide is formed primarily in carbohydrate rich food cooked at high temperature. Among the different food products analyzed, the highest levels of acrylamide have been found in French fries, potato chips, and other fried, deep–fat fried, or oven–cooked potato products, together with some crisp bread, biscuits, crackers and breakfast cereals [TAREK *et al.,* 2000, BUTNARIU *et al.,* 2013, PETRACHE *et al.,* 2013].

Figure 3 shows the acrylamide contents of the deep–fat frying (atmospheric), vacuum and air frying process of potato chips were 290, 100 and 78 ppm, respectively (P≥0.05).

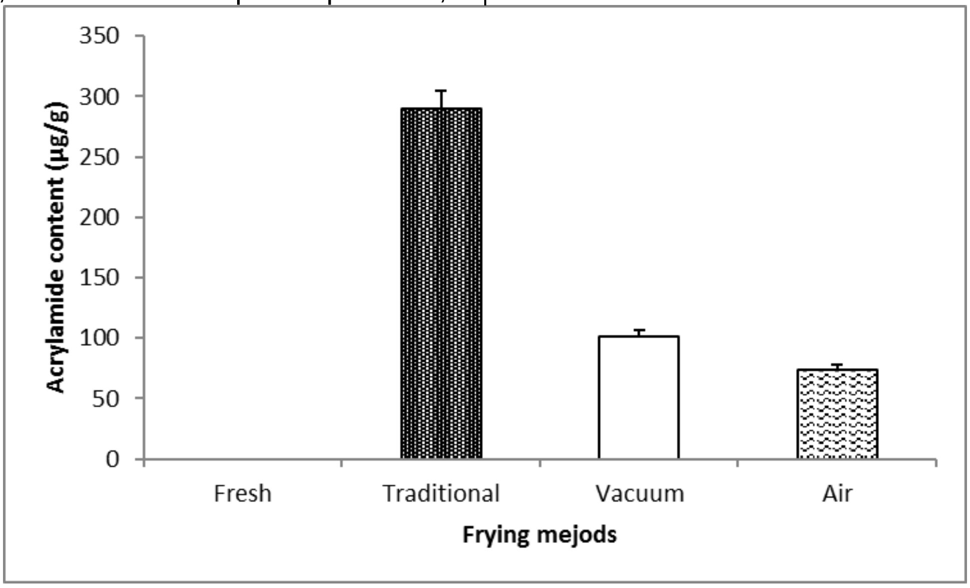

Figure 3. Effect of traditional, vacuum and air frying process on acrylamide content (µg/gm) of fried potato chips. The data (Values ±SE) are the mean of three measurements for the sample.

The chemical mechanism governing acrylamide formation during heat treatment of foods in unclear; however, the Maillard reaction has been suggested to play an important role in the formation of acrylamide. Granda and collab. [GRANDA *et al.,* 2004] reported that for fried using vacuum frying process (118°C, 8 min.) of potato chips, the acrylamide content was always lower compared whit that of chips fried with a traditional fryer (reductions 85–99 %). The lower acrylamide content in the air chips in this study may therefore result from the treatment being at a lower temperature compared with that used during deep–fat frying process.

Sensory evaluation: The objective of this study was to evaluate the sensory properties of potato chips using a new technology (air and vacuum frying process). Sensory quality characteristics evaluation for color, flavor, taste, texture, crispness and overall acceptability of fried potato chips. There were no differences (P≥0.05), however, in the hedonic scores for taste and crispness between the deep–fat frying processes (atmospheric) and other methods (air and vacuum frying process). Appearance, colour and overall acceptability were significantly higher in the deep–fat frying chips than other methods. Texture and color are the most important parameters on the definition of the quality of potato chips Figure 9.

Changes in some physico–chemical properties of oil extracted from fried potato chips: During frying process, oil is exposed to oil, water and heat. Therefore, thermal, oxidative and hydrolytic decomposition of the oil may take place. Fats and oils are oxidized to form hydroperoxides, the primary oxidation products. These peroxides as extremely unstable and decompose via fission, dehydration and formation of free radical to form a variety of chemical products, such as alcohols, aldehydes, ketones, acids, dimmers, trimmers, polymer and cyclic compounds [WHITE, 1991, MELTON *et al.,* 1994].

In this study the acid vale, peroxide value, polymer content and oxidized fatty acids content were employed to measure frying oil. The free fatty acid content increased from 0.07 % to 0.25 % for traditional frying process, from 0.07 % to 0.15 % for vacuum frying process and from 0.07 % to 0.11 % for air frying process (Figure 4).

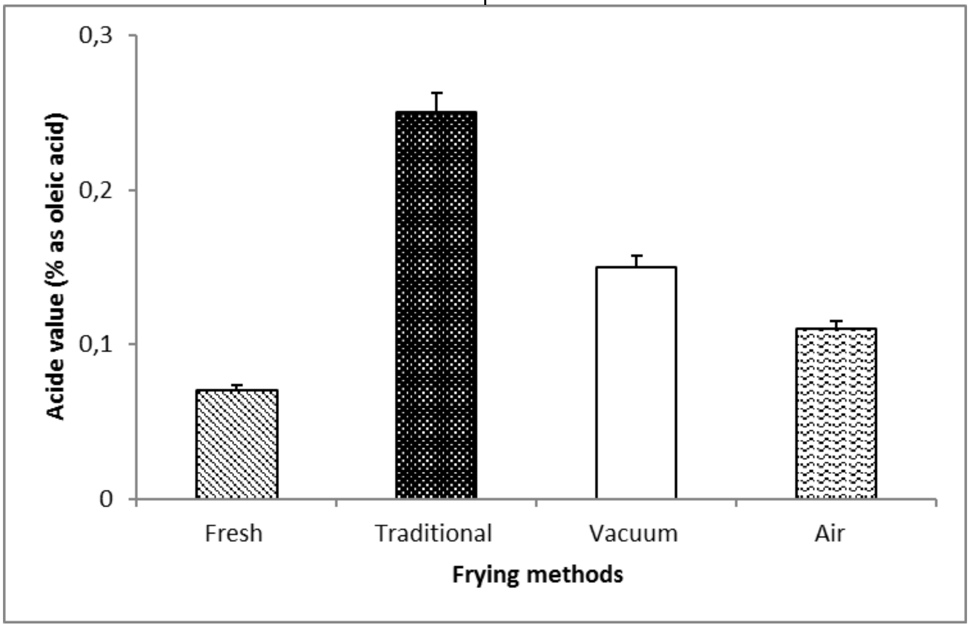

Figure 4. Changes in acid value of oil extracted from potato chips.
The data (Values ±SE) are the mean of three measurements for the sample.

It has been suggested that production of free fatty acids was the best indicate of fat deterioration during frying and the presence of free fatty acids could be used to monitor the extent of oil abused [STEVENSON *et al.*, 1994].

On the other hand, the peroxide value was significantly increased from 0.80 to 2.66 meq.O_2/kg oil for traditional frying process, from 0.80 to 1.33 meq.O_2/kg oil for vacuum frying process and from 0.80 to 0 0.98 meq.O_2/kg oil for air frying process (Figure 5).

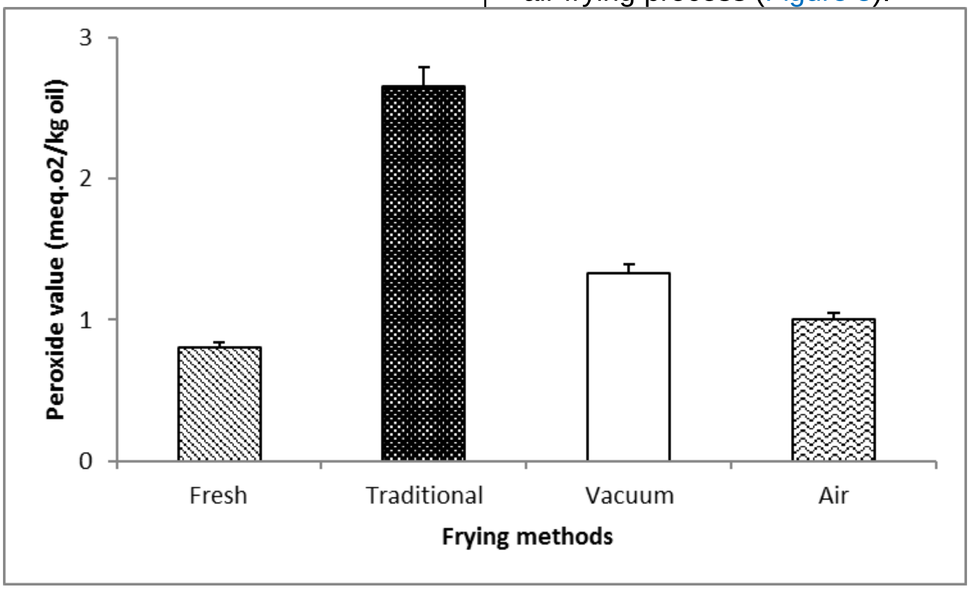

Figure 5. Changes in peroxide value of oil extracted from potato chips.
The data (Values ±SE) are the mean of three measurements for the sample.

The differences between traditional, vacuum and air frying process in peroxide values may be due to quantity of oil in traditional frying process higher than amount of quantity of oil in air frying process.

Also the absence of air during vacuum frying process may inhibit lipid oxidation compared with traditional frying process. The changes in polar content during traditional, vacuum and air frying process are shown in Figure 6.

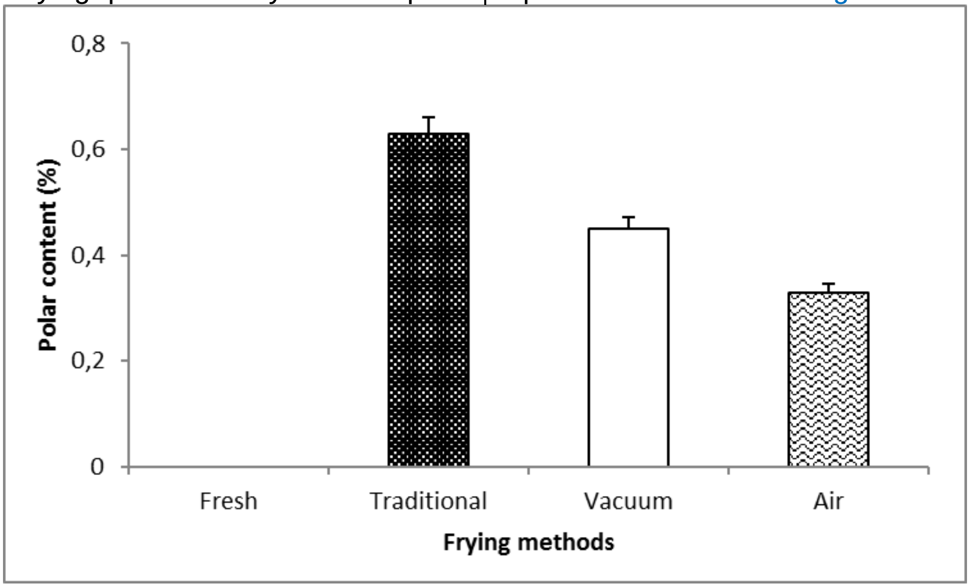

Figure 6. Changes in polar content of oil extracted from potato chips.
The data (Values ±SE) are the mean of three measurements for the sample.

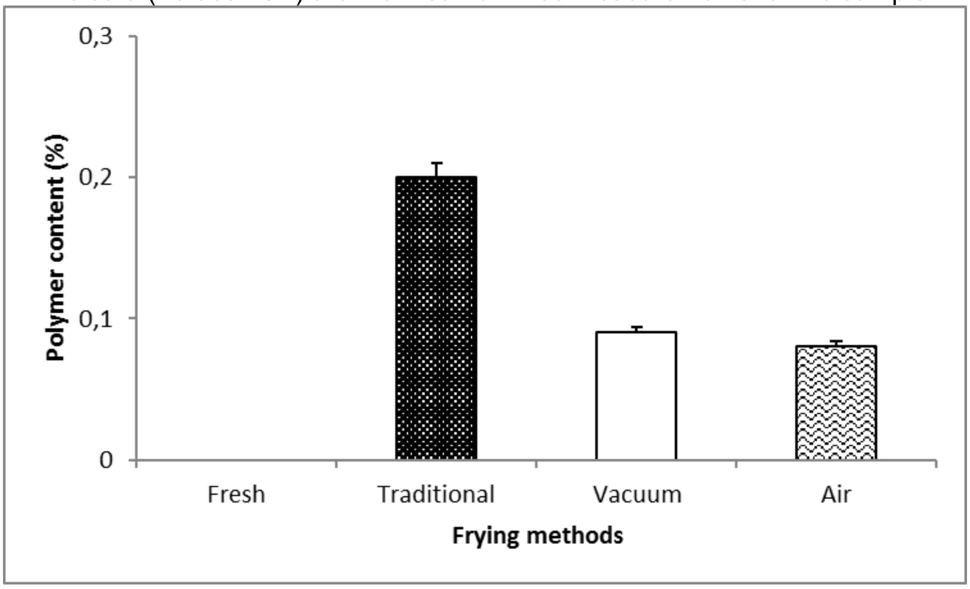

Figure 7. Changes in polymer content of oil extracted from potato chips.
The data (Values ±SE) are the mean of three measurements for the sample.

The determination of polar content in frying oil provides the most reliable measure of the extent of oxidation degradation. In this paper, initial polar content in fresh sunflower oil was 0.00 %, but after frying the polar content increased with frying time at a rate affected by frying temperature.

Polar content during frying process at 180°C± 5°C was (0.63 % for traditional frying process, 0.45 % for vacuum frying process and 0.33 % for air frying process) at the end of frying period, which was still below the 24.00 % oil discard level set in many European Countries [FIRESTONE *et al.*, 1991]. On the other hand, the polymer content in traditional frying process was 0.20 %, vacuum frying process was 0.09 % and air frying process 0.07 %, respectively (Figure 7).

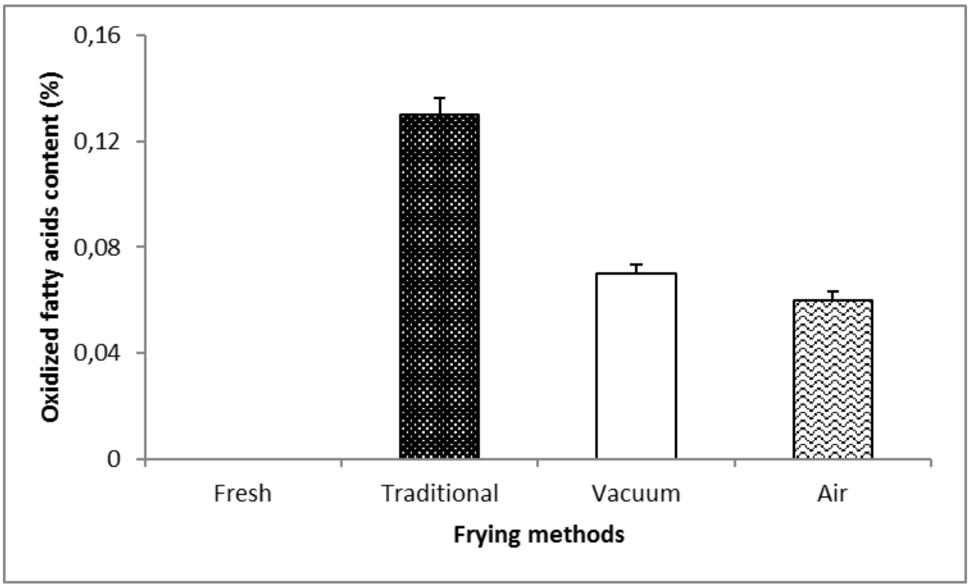

Figure 8. Changes in polymer content of oil extracted from potato chips.
The data (Values ±SE) are the mean of three measurements for the sample.

In contrary, oxidized fatty acids content was increased after frying process to 0.13 % for traditional frying process, 0.07 % for vacuum frying process and 0.06 for air frying process (Figure 8). Polymers formed in deep–fat frying in remarkable are level since the medium is rich in oxygen.

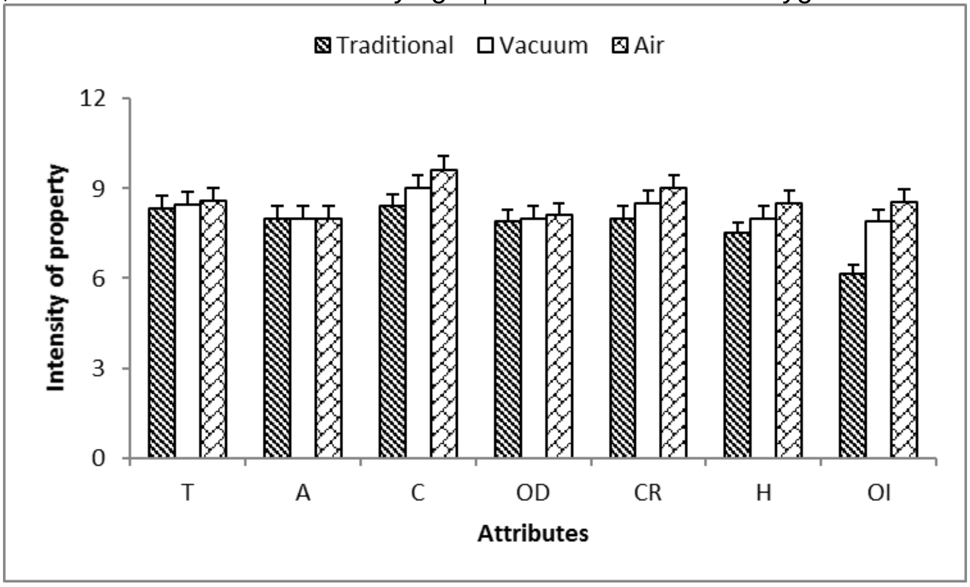

Figure 9. Sensor evaluation of fried potato chips. Were, T= Taste, A= Appearance C= Color, OD= Odor, CR= Crispness, H= Hardness, OI= oiliness and OA= Overall acceptability. The data (Values ±SE) are the mean of three measurements for the sample.

Yoon *et al.,* [YOON *et al.,* 1988] reported that oxidized polymer compounds accelerated the oxidation of oil. Polymers accelerate further degradation of the oil.

Consequently, increased the oil viscosity [TESNG *et al.,* 1996], reduced the heat transfer, produced foam during deep–fat develop undesirable color in the food. Polymers also cause the high oil absorption to foods.

Conclusions

From the results of this study, it can be concluded that vacuum and air-frying process decreased significantly moisture content and oil uptake of potato chips and desirable yellow golden color and texture attributes compared with those fried in the traditional frying.

Also, air and vacuum frying process imparted lower oxidation degradation on frying oil than the traditional frying.

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