Vacuum frying: An alternative to obtain high quality potato chips and fried oil

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The purpose of this work was to study the effect of different frying process (atmospheric and vacuum) on some physical and sensory properties of potato chips and to evaluate frying oil quality. In six consecutive days, sunflower oil was fried under atmospheric condition (at 180°C±5°C and vacuum frying (at 120°C, 5.37kpa absolute pressure) for 20 min each hour in a 4 hour shift. Physical properties (oil uptake and moisture content), Organoleptic tests were performed on fried potato chips and quality limits (acid value, peroxide value, polar content, polymer content and oxidized fatty acids) of the sunflower oil samples were measured. The results of this study suggest that vacuum frying at 120°C under pressure of 5.37kpa night produce potato chips with acceptable quality and improved quality of frying oil.

Key words: Vacuum frying oil uptake, sensory properties, oxidative stability.

INTRODUCTION

Frying is one of the oldest and most popular cooking methods in existence. 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). 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). 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). Snake foods play a very important role in the diet of the modern consumer. Potato chips have been a popular salty snakes for 150 years and retail sales in the many countries are about 6 billions/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 and Basuy 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 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 and Moyano et al., 2002). The drying step that follows the blanching step reduces the crispness oil absorbed on the potato chips (Pedrechi and Mayano 2005b). The application of a proper coating is a promising route to reduce oil content (Mellerma, 2002). Vacuum frying may be also an option for fried potatoes with low oil content and desired texture and flavor characteristics (Garayo and Moreira 2002).

One of the main characteristics of vacuum frying units is the de-oiling mechanism. It is used to de-oil the product before it is removed from the vacuum so the surface oil is not absorbed by the product during the depressurization process. De-oiling mechanisms are generally centrifuges, which are installed in a special vacuum dome attached to the vacuum fryer. Oil absorption mechanism in fried products is a complex process. According to Moreira et al., (1997), oil absorption is a surface phenomenon that happens as the product is removed from the fryer due to temperature difference between the product and ambient temperatures. The change in temperature causes an increase in capillary pressure in the product pores, which causes the oil to flow into the opened pore spaces. The de-oiling process becomes more important during vacuum frying because of the pressurization process. The chips do have increased oil content following vacuum frying and depressurization because of the rapid change in pressure (Vacuum to atmospheric). According to Da Silva et al., (2009), de-oiling is one of the most important unit operation steps in vacuum deep-fat frying to ensure best quality products. Most of the research found in literature is related to atmospheric deep-fat frying of foods and there are very few studies on the effect quality. For these reasons, the purpose of this research was to the effect of type of frying (atmospheric and vacuum) on the physical (moisture and oil content) and sensory properties of potato chips. And also, the evaluation of the stabilities of frying oils.

MATERIALS AND METHODS

Materials

Sunflower oil and potato tubers were purchased from local market in Al-Hasa, Saudi Arabia. The acid value and peroxide value of sunflower oil were 0.06 mg KOH per gram of oil and 0.30 active oxygen peroxides per kilogram of oil, respectively.

Sample preparation

Potatoes were peeled and then sliced using a Mandolin Slicer (Matfer model 2000, France) to a thickness gage (Mitutoyo thickness Gage, Japan), and cut into a diameter of 5.08 cm using a cylindrical metal cutter. The potato slices were rinsed with distilled water to eliminate starch material on the surface and then blotted with paper towels before each experiment. The samples were placed in aluminum foil to avoid any moisture loss before further processing.

Frying experiments

Vacuum frying experiments

The experiments were performed using a vacuum fryer available at the Food and Nutrition Science Department, Faculty of Food and Agriculture Science, King Faisal University, Saudi Arabia. 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 750rpm (63g 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 5.37kpa. The vacuum fryer system is depicted in Figure 1. The frying process consists of loading 10 potato slices (about 30g) into the basked closing the lid, and depressurizing the vessel. Once the pressure in the vessel reaches 5.37kpa at 120˚C for min each hour for 4 hour per day and six consecutive days, 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 (750rpm).

Traditional frying experiments

Frying at atmospheric pressure was performed on an electric-fried fryer (Hobart model HK3-2, Hobart Corp, Troy, Ohio, U.S.A). The frying process was repeated for six consecutive days for 20 min per hr for 4 hr per day.
Quality assurance tests for non fried and fried sunflower oil (atmospheric and vacuum)

Methods in the A. O. A. C. (2005) were used to determine acid value and peroxide value. 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 oil samples were separated by column chromatography according to the method described by Waltking and Wessels (1981). Column-packing material used was silica gel (60-120) mesh and the polar components were eluted with a solvent mixture composed of 87% light petroleum and 13% diethyl ether.

Sensory evaluation of fried potato chips

Sensory evaluation was performed on potato chips fried in sunflower oil (atmospheric at 180°C ± 5°C and vacuum at 105°C, 20 torr). The organoleptic tests of the fried potato chips were carried out every day of frying period. Prior to the sensory tests, the panelists (twenty persons) were trained to evaluate the attributes of the chips produced in this study. The sensory evaluation of fried potato chips were conducted two times and the mean score values were reported in the text. The potato chips 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 chips, placed randomly in codified plates with three-digit cogs, were served to each panelist. Panelists were placed in different places to avoid communication during the evaluation and asked to score chips for color (pale yellow, dark yellow), flavor, texture, oiliness (very low, very high), crispness (none crispy, very crispy) and overall acceptability (Carpenter et al., 2000).

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 30kpa (vacuum pressure) and 70°C until reaching constant weight (A.O.A.C., 2005).

Statistical analysis

Fried potato properties as well as differences among treatments were detected with the program SPSS software (Version 15.0 for Windows, SPSS, Inc.,
Chicago, IL) using one-way analysis of variance using Duncan's multiple range tests. Statistical significant was expressed at the \( P < 0.05 \) level.

**RESULTS AND DISCUSSION**

In vacuum frying operation, food is heated under reduced pressure in closed system that can lower the boiling point of both frying oil and water in the food. Therefore, the unbound water in the fried food can be rapidly removed when the oil temperature reaches the boiling point of water (Shyu and Hwang, 2001). Figure 2 shows the evaluation of moisture content of potato chips during atmospheric (AF) and vacuum frying (VF) of potato chips. There were significant differences ((\( P < 0.05 \)) between the fried potato chips during vacuum frying and atmospheric frying. The potato chips fried at vacuum frying gave lowest moisture contents. However, the moisture content of the potato chips fried at atmospheric frying was significantly higher than the moisture content of the vacuum frying sample.

**Oil content**

Pressure plays an important role in the uptake of oil in cases of vacuum frying. After completion of potato slices frying in a vacuum fryer, the vessel must be depressurized for removal of chips. The major oil absorption takes place during this period of pressurization causing pressure gradient between capillaries and ambient conditions, which causes oil to move from the surface of the chips to within the product (Pandey and Moreira, 2011). The experimental results (Figure 3) show the oil uptake during atmospheric and vacuum frying of potato chips. The highest oil uptake content was in potato chips during atmospheric frying, while those produced during vacuum frying had lowest oil uptake. The amount of oil uptake has generally been related to the amount of moisture lost (Dueik and Bouchon, 2011). Oil reduction may be due to the lower vapor pressure of water during vacuum frying and the lower temperatures reaching during the process, as opposed to atmospheric frying, where important structural changes, which increase oil absorption.
Sensory evaluation

The objective of this study was to evaluate the sensory properties of potato chips using two different frying methods (atmospheric and vacuum). Sensory quality characteristics evaluation for colour, flavour, texture, oiliness, crispness and overall acceptability of fried potato chips. Vacuum frying had a significant effect on colour (Table 1). Potato slices fried under vacuum had values significantly higher than the values corresponding to the slices fried under atmospheric conditions. Potato chips fried under vacuum presented a lower extent of browning and a more golden-yellow color in comparison with potato chips fried at atmospheric conditions. Texture and crispness values were significantly better for vacuum fried chips. Vacuum frying could improve the texture quality of potato chips. In general, food processors of frying products control food quality by means of appearance and taste. These characteristics can be quantified by means of measurements related to some properties of the product (Moreira et al., 1999). In this paper, sensory attributes, taste quality and overall quality, were significantly improved when vacuum frying was used instead of atmospheric frying (Table 2). The overall quality is linked to sensory perception of color, texture, taste and crispness during the mastication process of food. Color is one of the main products and could be indicative of a high quality when potato chips had a golden-yellow color influencing the perception of taste (Moreira et al., 1999). Moreover, it is known that food structure influences the mastication process and is directly related with release of volatile compounds and the perception of flavor (Taylor, 2002). All the mentioned sensory attributes are strongly physicochemical properties of the product. Hence vacuum frying can be a viable option to improve or enhance the sensory properties of potato chips processed by this technology.

Changes in some chemical properties

During frying, oil or fat 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 are 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 and Melton et al., 1994). In this study, acid value, peroxide value, polar content, polymer content and oxidized fatty acids content were employed to measure frying oil.
Acid value

During frying, fats and oils are oxidized to form hydroperoxides that can decompose further to yield the secondary oxidation products, such as alcohols, ketones, aldehydes and acids. In deep-fat frying, however, acids are also produced by hydrolysis the reaction of fat with water was to form free fatty acids (Shyu, et al., 1998). Changes in acid value of sunflower oil during two different frying methods (atmospheric and vacuum frying) are shown in Figure 4. Acid value during vacuum frying of sunflower oil samples increased slightly with frying time compared with atmospheric frying sunflower oil which increased strongly significantly (p < 0.05) with frying time.

Peroxide value

Hydroperoxides are the primary products of lipid oxidation; therefore, determination of peroxide value can be used as an oxidation index for the early stages of lipid oxidation. During vacuum frying of potato chips in sunflower oil, peroxide value increased slightly with frying period (Figure 5). While deep-fat frying of sunflower oil at 180˚C ± 5˚C for 24 hr increased strongly significantly (p < 0.05) as the frying time increased. The amount of polar components in sunflower oil (Vacuum frying) was below 25.00 %

Since the oils were at lower temperature and lower oxygen content in vacuum fryer, the formation and decomposition of hydroperoxides would be less than in deep-fat frying. In this study, sunflower oil peroxide value increased slightly with frying time and was below(45.13 meq./kg) after 24 hr of frying (vacuum) compared with deep-fat frying under atmospheric pressure, sunflower oil showed increase in peroxide value over (39.50 meq./kg oil).

Total polar content

Polar compounds in french frying oil include sterols, tocopherols, mono and diglycerides, free fatty acids and other oil-soluble components that are more polar than triglycerides (Fritsch, 1981). In this study, the content of polar in fresh oil was 0.01%. During frying, fats and oils undergo oxidation and hydrolysis to produce polar products, such as expoxides, aldehydes, ketones, alcohols, acids, mono and diglycerides. Total polar lipid components therefore increased significantly (P < 0.05) as the frying time increased. The amount of polar components in sunflower oil (Vacuum frying) was below 25.00 %
after 24 hr, While the atmospheric frying amount of polar was below 29.18 % (Figure 6) It is clear that vacuum frying can maintain better oil quality than the atmospheric frying.

Polymer content

The initial polymer content of fresh sunflower oil was 0.00% and the value increased progressively with the frying time (Figure 7). The changes in polymer content of sunflower oil during vacuum and atmospheric frying showed increase with time. Vacuum frying sunflower oil led to decrease the formation of polymers compared with deep-fat frying.

Oxidized fatty acids

The initial value of oxidized fatty acids in fresh sunflower oil was 0.00%. On frying process under the aforementioned conditions, the levels of oxidized fatty acids were gradually and significantly (P <0.05) increased throughout the frying period (Figure 8).
However, the levels of oxidized fatty acids content in this case (vacuum frying) were lower than that of oxidized fatty acids content of sunflower oil during atmospheric frying. From the results of this study, it can be concluded that vacuum frying imparted lower oxidative degradation on the frying oil than the typical frying.

From the results of this study, it can be concluded that vacuum frying decreased significantly moisture content and oil uptake of potato chips and desirable yellow golden color and texture attributes compared with those fried in the atmospheric frying. Also, vacuum frying imparted lower oxidation degradation on frying oil than the atmospheric frying.

REFERENCES


