Characterization of Oil Uptake and Fatty Acid Composition of Pre-treated Potato Slices Fried in Sunflower and Olive Oils

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Abstract: In this study, the oil uptake and fatty acid composition of fried potato slices were determined. Some pre-treatments such as blanching, freezing, and blanching-freezing were applied to potato slices before frying while the untreated samples were used as a control. The frying process was carried out in sunflower and olive oils. The percentage oil uptake in slices varied from 4.26% to 10.35% when fried in sunflower oil. In the case of the control samples slices fried in olive oil contained high monounsaturated fatty acid (oleic acid) content (5.45%), and lesser oil uptake was observed that those processed in sunflower oil, which is rich in polyunsaturated fatty acid (linoleic acid is 5.99%) (p < 0.05). The oil uptake was also compared in the case of potato slices fried in two different oils after pre-treatments. The maximum oil uptake was observed in the case of blanched-frozen potatoes, whereas minimum oil uptake was observed in frozen only slices for both oils. The fatty acid contents in oils extracted from fried potato slices showed that the predominant fatty acids were palmitic, stearic, oleic, and linoleic acids. The best results were observed in frozen potato slices fried in both sunflower and olive oils.

Key words: frying, sunflower oil, olive oil, fried potatoes, oil uptake, fatty acid composition

1 Introduction

Frying is an ancient food processing technique performed at high temperatures (mostly between 160°C –180°C)¹. Oils have significant roles in the production of fried products, as they area medium of heat transfer between food and fryer, affecting the texture and flavor of food². Several chemical reactions (hydrolysis, oxidation, and polymerization) may occur in frying oils due to the effects of high temperature, oxygen, unsaturated fatty acids, water, and metal³. Consumption of fried food has gradually increased due to the convenience and speed of the frying technique, in addition to the palatable sensorial properties (flavor, taste, color, and crispness) of fried products⁴. The degradation products that accumulate in frying oil (particularly volatile and non-volatile components) reduce the quality of the oil and fried food. Accordingly, the quality and the amount of oil absorbed into the product may have important effects on the nutritional characteristics and shelf-life of the fried products⁵.

The presence of saturated and unsaturated fatty acids may also affect the deterioration of frying oils⁶. Generally, oils containing high amounts of polyunsaturated fatty acids (such as sunflower, soybean, corn, peanut, and rapeseed oils) are considered good for use in routine cooking. However, those low in linoleic acid and high in oleic acid such as olive, almond, and canola oils are more stable for use in the frying process⁷. Frying is also associated with the evaporation of moisture, due to heat and fat uptake⁸. Several studies have been carried out for reducing the absorption of oil into the product being fried⁹–¹⁰. Ramadan et al.¹¹ compared and correlated the results of physicochemical parameters and antiradical performance of some oil blends during deep frying. Ramadan¹² reported that the proportion of 7-keto derivatives decreased during frying while the proportion of 7-β-hydroxy derivatives increased. The effect of using LPP-NPsE as an antioxidant on the oxidative stability of sunflower oil and reducing of acrylamide induction in potato chips during deep frying was evaluated by Mekawi et al.¹³. It is desirable for fried foods to contain as little oil as possible. Therefore, different pre-treatments...
are being studied in order to minimize oil uptake by food. The objectives of this study included the comparison of the fatty acid composition of potato slices fried in olive and sunflower oils and the effects of some pre-treatments (blanching, freezing, and both blanching and freezing) on potato slices before frying.

2 Materials and Methods

2.1 Materials

Potatoes, sunflower oil, and olive oil as the raw materials were purchased from a local market in Konya and Mersin, Turkey. Sunflower oil is produced in Zade Oil Factory in Aydin under the brand name of Tariş. Both oils are new crop products. Potato tubers were stored at 8°C and 95% relative humidity. The chemicals used were of analytical grade and purchased from Sigma-Aldrich Corporation, USA.

2.2 Methods

2.2.1 Pre-treatments

Potatoes were manually peeled and cut to slices (1.0 × 1.0 × 5.0 cm), and kept in water for 5 minutes to remove the surface starch. In the present study, we followed the methodology implemented by Bouchon et al. and Pedreschi et al. Slices were dried using paper towels, divided into four groups, and different pre-treatments were applied to them before frying:

I. Control: Potato slices without blanching and freezing processes were used as the control
II. Blanching: Samples were blanched on hot plate for 5 min and blotted with paper towel
III. Blanching-Freezing: Blanched samples were frozen in deep-freezer
IV. Frozen: Untreated potato slices were frozen

2.2.2 Frying process

Sunflower and olive oils were used for frying 4 different groups of potato slices. Frying experiments were carried out using an electric fryer (Moulinex, France) equipped with a thermostat. At each frying temperature, slices were fried for four different time intervals until they reached a final moisture content of 1.8 g/100 g wet solid. The frying times required to achieve this moisture content under various experimental conditions were previously determined. The oils (2 L in each trial and used once only) were preheated at 180°C (preset using an infrared thermometer (Testo 845)). Slices per sampling time were deep-fried in hot oil contained in an 2 L capacity electrical fryer. A sample of 200 g slices was placed in the fryer. Frying was carried out at 180°C for 3 min, followed by cooling of the slices at room temperature (25°C) before subsequent analyses. The frying temperature was kept nearly constant (± 1°C) by a controller system. After each frying trial, a 50 mL oil sample was filtered through a Whatman #1 filter (Maidstone, UK), transferred to a glass bottle, and stored at 4°C until analyses.

2.2.3 Sample oil uptake

Fried potato slices were crushed with a porcelain mortar and pestle. The determination of the total oil contents of the fried samples was based on the AOAC method, which involved the extraction of total fat from samples with petroleum benzene for 5 h in a Soxhlet apparatus. This was followed by evaporation of the solvent at 50°C and reducing pressure with a rotary vacuum evaporator.

2.2.4 Fatty acid composition

An oil sample of approximately 250 mg was extracted from fried potato slices, and was esterified following the ISO-5509 method. The analysis of fatty acid composition was carried out in a gas chromatography (GC) system (Shimadzu GC-2010). The GC system was equipped with a flame-ionization detector (FID) and Tecnocroma TR-CN100 capillary column (60 m × 0.25 mm, film thickness: 0.20 µm). The injection block and detector temperatures were set at 260°C. Nitrogen was used as a mobile phase, and its flow rate was at 1.51 mL/min. The split and total flow rate were set at 1.40 mL/min and 80 mL/min, respectively. The temperature of the column was kept at 120°C for 5 min, and was increased to 240°C at the rate of 4°C/min. It was then maintained at the final temperature for 25 min. The temperature program was increased in increment of 1.5°C/min from 155°C to 220°C, 10 min isotherm, injector 250°C, and detector 250°C. The carrier gas was 36 cm/s hydrogen, the split ratio was 1:50, and the detector gases were at 30 mL/min hydrogen, 300 mL/min air, and 30 mL/min nitrogen. The sample injection was manual and set at less than 1 µL.

2.3 Statistical analysis

The experiments were based on a complete randomized split plot block design, and the analysis of variance (ANOVA) was performed on the obtained data from triplicate analytical values using JMP version 9.0 (SAS Inst. Inc., Cary, N.C., USA). The results of the study were analyzed for mean ± standard deviation (MSTAT C) and statistical significance using analysis of variance.

3 Results and Discussion

The data for fat absorption in fried potato slices is presented in Table 1 and Figs. 1 and 2. The percentage oil uptake in slices varied from 4.26% to 10.35% when fried in sunflower oil (Fig. 1), and from 5.11% to 13.045 when fried in olive oil (Fig. 2) (p < 0.05). In the case of the control samples slices fried in olive oil contained high monounsaturated fatty acid (oleic acid) content (5.45%),
Oil Uptake of Pre-treated Potato Slices Fried in Sunflower and Olive Oils

Table 1 Oil uptake of fried potato slices (%).

<table>
<thead>
<tr>
<th>Potato Slices</th>
<th>Oil Uptake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fried in sunflower oil</td>
<td>5.99 ± 0.38*d</td>
</tr>
<tr>
<td>Fried in olive oil</td>
<td>5.45 ± 0.63d</td>
</tr>
<tr>
<td>Blanched and fried insunflower oil</td>
<td>5.86 ± 0.59d</td>
</tr>
<tr>
<td>Blanched and fried in olive oil</td>
<td>5.43 ± 0.87d</td>
</tr>
<tr>
<td>Frozen and fried insunflower oil</td>
<td>4.26 ± 0.48c</td>
</tr>
<tr>
<td>Frozen and fried in olive oil</td>
<td>5.11 ± 0.76d</td>
</tr>
<tr>
<td>Blanched, frozen and fried in sunflower oil</td>
<td>10.35 ± 0.38b</td>
</tr>
<tr>
<td>Blanched, frozen and fried in olive oil</td>
<td>13.04 ± 0.89a**</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation (n=3)

**Values within each row followed by different letters are significantly different (\( p < 0.05 \))

Fig. 1 Effect of pre-treatments on oil uptake of potato slices fried in sunflower oil. S-F: potato slices fried in sunflower oil; B-S-F: potato slices blanched, fried in sunflower oil; F-S-F: potato slices frozen, fried in sunflower oil; B-F-S-F: potato slices blanched, frozen, and fried in sunflower oil.

Fig. 2 Effects of pre-treatments on oil uptake of potato slices fried in olive oil. O-F: potato slices fried in olive oil; B-O-F: potato slices blanched, fried in olive oil; F-O-F: potato slices frozen, fried in olive oil; B-F-O-F: potato slices blanched, frozen, and fried in olive oil.

Fig. 3 Effect of pre-treatments on oil uptake in fried potato slices. S-F: potato slices fried in sunflower oil; O-F: potato slices fried in olive oil; B-S-F: potato slices blanched, fried in sunflower oil; B-O-F: potato slices blanched, fried in olive oil; F-S-F: potato slices frozen, fried in sunflower oil; F-O-F: potato slices frozen, fried in olive oil; B-F-S-F: potato slices blanched, frozen, and fried in sunflower oil; B-F-O-F: potato slices blanched, frozen, and fried in olive oil.

and lesser oil uptake was observed than those processed in sunflower oil, which is rich in polyunsaturated fatty acid (linoleic acid is 5.99%). The original food microstructure is responsible for the oil absorption and fracturability during frying. Additionally, the porous structure of the food, formed due to frying, also influences oil absorption. The oil uptake was also compared in the case of potato slices fried in two different oils after pre-treatments. The maximum oil uptake was observed in the case of blanched-frozen potatoes, whereas minimum oil uptake was observed in frozen only slices for both oils. Oil uptake in control (untreated) and blanched only slices remained similar for per oils (Fig. 3). The best results were observed in frozen potato slices fried in both sunflower and olive oils. Control slices and slices that only underwent blanching showed
less oil absorption when fried in olive oil. Frozen and blanched-frozen slices fried in sunflower oil also showed lower oil absorption. Odenigbo et al. studied different potato cultivars and determined that the mean oil uptake was 4.80–9.61%. According to Sandhu et al., the fat contents of fried potatoes were 66.20% at 175°C and 78.90% at 190°C, hence showing a marked increase with frying temperature. Pedreschi and Moyano studied oil uptake in blanched and unblanched potato slices after frying, and reported that oil absorption was reduced at higher temperatures in unblanched slices. Similar observations were reported by Kita and Lisinska and Kita et al. Contrary to the current study, Pedreschi and Moyano also determined that blanched potatoes showed more oil absorption after frying. Similarly, Alvarez et al. reported that the high temperature and frying time of blanched potato strips showed increased oil absorption. However, Califano and Calvelo and Aguilar et al. reported that oil uptake was decreased when frying was done after blanching potato fries. They attributed this effect to heat-induced starch gelatinization at the sample surface. According to Troncoso and Pedreschi, blanched potato chips absorbed less oil (0.65 g oil/g) than unblanched ones (0.66 g oil/g) after atmospheric frying at 180°C, and investigation of oil uptake results were done according to an empirical model. Their results show conformance with the present study reported here. It was also ascertained that applying blanching treatment to potato slices, together with soaking in NaCl solution before frying, resulted in decreased oil uptake.

The analytical results showing changes in the fatty acid

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>S-F</th>
<th>B-S-F</th>
<th>F-S-F</th>
<th>B-F-S-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myristic</td>
<td>0.07 ± 0.01b</td>
<td>0.07 ± 0.01b</td>
<td>0.08 ± 0.03a</td>
<td>0.07 ± 0.01b</td>
</tr>
<tr>
<td>Palmitic</td>
<td>6.11 ± 0.47bb</td>
<td>6.24 ± 0.61a</td>
<td>6.21 ± 0.55a</td>
<td>6.08 ± 0.72c</td>
</tr>
<tr>
<td>Stearic</td>
<td>3.21 ± 0.15a</td>
<td>3.24 ± 0.21a</td>
<td>3.13 ± 0.78bb</td>
<td>3.14 ± 0.17</td>
</tr>
<tr>
<td>Oleic</td>
<td>35.04 ± 1.27b</td>
<td>35.13 ± 1.18a</td>
<td>35.05 ± 0.97b</td>
<td>35.04 ± 1.06b</td>
</tr>
<tr>
<td>Linoleic</td>
<td>52.69 ± 1.23c</td>
<td>52.55 ± 1.57d</td>
<td>52.70 ± 1.42b</td>
<td>52.77 ± 1.34a</td>
</tr>
<tr>
<td>Arachidic</td>
<td>0.24 ± 0.03c</td>
<td>0.26 ± 0.01a</td>
<td>0.25 ± 0.07b</td>
<td>0.25 ± 0.03b</td>
</tr>
<tr>
<td>Linolenic</td>
<td>0.33 ± 0.07a</td>
<td>0.31 ± 0.03b</td>
<td>0.30 ± 0.01c</td>
<td>0.29 ± 0.03da</td>
</tr>
<tr>
<td>Behenic</td>
<td>0.69 ± 0.09c</td>
<td>0.71 ± 0.07</td>
<td>0.67 ± 0.03d</td>
<td>0.70 ± 0.09b</td>
</tr>
</tbody>
</table>

S-F: potato slices fried in sunflower oil
B-S-F: potato slices blanched, fried in sunflower oil
F-S-F: potato slices frozen, fried in sunflower oil
B-F-S-F: potato slices blanched, frozen, and fried in sunflower oil

*Mean ± standard deviation (n=3)

** Values within each row followed by different letters are significantly different (p < 0.05)
composition of differently pre-treated potato slices, fried either in sunflower or olive oil, are shown in Tables 2 and 3, respectively. The fatty acid contents in oils extracted from fried potato slices showed that the predominant fatty acids were palmitic, stearic, oleic, and linoleic acids. Other fatty acids such as myristic, arachidic, linolenic, behenic, and arachidonic acids were found in smaller quantities. The most common fatty acid was linoleic acid when slices were fried in sunflower oil (Fig. 4). Oleic acid was dominant in samples fried in olive oil (Fig. 5). Pre-treatments did not show marked effects on the fatty acid composition of fried slices. According to Manzano et al. [30], the fatty acid profiles of potato crisps were affected by frying oils. They fried two different varieties of potato crisps and used a mixture of sunflower and olive oils. They observed that oleic, linoleic, palmitic, and stearic acids were the most common fatty acids in crisps. It was also observed that lauric, myristic, palmitoleic, linolenic, arachidic, and behenic acids were found in trace levels. Romano et al. [31] studied the thermal stability of high oleic sunflower oil (HOSO), sunflower oil (SO), and mixed oil (MIX) during deep-frying. It was observed that the most dominant fatty acids were 5.53% palmitic, 3.10% stearic, 31.62% oleic, and 58.49% linoleic acids in the case of SO. In HOSO, the results found 3.61% palmitic, 77.58% oleic, 2.70% stearic, 13.42% linoleic, and 0.34% linoleic acids (p < 0.05). Sharoba and Ramadan [32] reported that sunflower and canola oils, with high polyunsaturated fatty acid contents, were less stable than palm oil. They also observed that the fatty acid compositions of these oils did not differ from each other after frying.

4 Conclusion

It may be inferred that pre-treatments showed significant effects on the total oil uptake in slices, and blanching and freezing pre-treatments alone resulted in a decrease in oil uptake after frying. However, the combination of these two pre-treatments showed an increase in oil uptake. There was also variation in the fatty acid content of potato slices fried after different pre-treatments, in addition to expected differences due to oil used. In the case of the control samples slices fried in olive oil contained high monounsaturated fatty acid (oleic acid) content, and lesser oil uptake was observed than those processed in sunflower oil, which is rich in polyunsaturated fatty acid. The fatty acid contents in oils extracted from fried potato slices showed that the predominant fatty acids were palmitic, stearic, oleic, and linoleic acids. The best results were observed in frozen potato slices fried in both sunflower and olive oils.

Acknowledgements

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