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THE INFLUENCE OF CUTTING THICKNESS, SHAPE AND MOISTURE CONTENT ON OIL ABSORPTION DURING POTATO FRYING

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Abstract: Potato chips and French fries are products which are often used in the human diet. The aim of this study was to investigate the influence of cutting thickness, shape and moisture content on palm olein uptake, as well as the quality of the palm olein during the production of fried potatoes. Blanching operation was conducted in water for 3 minutes at a temperature of 85°C, while the frying process was conducted in palm olein for 3 minutes at a temperature of 165°C. The peroxide value and free fatty acid content (% oleic acid) were determined by standard analytical methods. The oil content in samples was determined by the standard Soxhlet extraction (the reference method). The results showed that the potato chips had approximately four times more oil uptake compared to potato sticks. The oil content was significantly lower in blanched potato slices (by 43.3%) but significantly higher in blanched potato sticks (by 53.5%) compared to unblanched samples. The analyzed quality parameters of palm olein were within the allowable value range. Based on the results obtained in this study, it can be concluded that the thickness, surface area and moisture content of the potato had a significant effect on oil uptake.

Key words: fried potato, palm olein, surface area, peroxide value, free fatty acids content.

Introduction

The potato (*Solanum tuberosum*) is a tuberous vegetable that is the most commonly used in human nutrition. The reasons for its widespread use are that the potato has a favourable economic factor, and it is available throughout the year (Popović-Djordjević et al., 2018). In terms of nutrition value, this vegetable is a

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rich source of starch, amino acids, micro and macro elements, as well as numerous antioxidant compounds such as vitamins and polyphenols (Xu et al., 2009; Popović-Djordjević et al., 2020). There are several ways to prepare potatoes for a meal: cooking, stewing, baking and frying. However, frying is the most common method of processing potatoes in the human diet because it provides a tasty product with a crunchy texture. Before frying, potatoes can be cut into different thicknesses and shapes. Potato chips are usually cut into slices of 1–2 mm, while the French fries are cut into sticks 1 cm thick. The research has shown that slice thickness and total surface area of slices affected the absorbed oil content in the product (Gamble and Rice, 1988; Lioumbas and Karapantsios, 2012). The oil most commonly used for industrial frying is palm oil in combination with its liquid fraction, palm olein (Pande et al., 2012; Paunović et al., 2020). In relation to palm oil, palm olein has a higher oleic than palmitic acid content (Lin, 2011; Pande et al., 2012). Compared to other oils, palm oil has proven to be the most suitable due to its higher content of saturated fatty acids, as well as tocopherols, tocotrienols, carotenoids and chlorophyll, and therefore, it is oxidatively more stable (Edem, 2002; Pande et al., 2012; Mba et al., 2015). During the frying process, saturated fatty acids are more stable than unsaturated fatty acids and thus reduce the possibility of the formation of numerous compounds resulting from chemical reactions such as hydrolysis, oxidation, isomerization and polymerization (Choe and Min, 2007). From the aspect of health, this is very important because a significant amount of oil could be absorbed during frying potatoes (Moyano and Pedreschi, 2006). Increased oil uptake during the prolonged frying process is probably related to higher oil viscosity caused by polymerization reactions (Dana and Saguy, 2006). Therefore, the fried potatoes contain higher oil content and thus the fatty acid degradation products, which certainly affect the sensory properties and the health of consumers. In addition, the moisture content significantly affects oil absorption (Gamble and Rice, 1988; Pedreschi et al., 2008). Blanching is a technological operation that is used before vegetable freezing. This procedure achieves the inactivation of enzymes that would contribute to degradation changes in the frozen product during the storage period. Also, blanching achieves the expulsion of gases from plant tissue, partial reduction of microorganisms, as well as shortening the frying period of time. However, blanching increases the moisture content, and the aim of this study was to determine to which extent this moisture content affected the oil absorption during frying. In addition, this study aimed to investigate the influence of potato cutting thickness and shape on the absorption of palm olein, which was a medium for heat transfer by convection, as well as the quality of absorbed oil after a certain frying time.

Material and Methods

The material for this experiment was purchased at a retail store in Belgrade, Serbia. Potatoes were produced in Serbia. Palm olein originated from Malaysia.

Sample preparation. Two kilograms of potatoes were cut into thin slices 2 mm thick (potato chips) and sticks 1 cm thick (French fries) using a manual potato slicer. Potatoes were blanched for 3 minutes at a temperature of 85°C (500 g of each sample) and then fried in an open deep fryer (2 L of palm olein was poured) at a temperature of 165°C for 3 minutes. The frying process was repeated for potato chips and French fries, which were not blanched, under the same conditions.

All post-frying and fresh oil samples were compared by standard analytical methods for determining peroxide value (PV) and free fatty acid content expressed as % oleic acid (FFA; % ol. acid). The oil content was determined by the Soxhlet extraction method in all post-frying potato samples. There were seven potato samples: fresh potato (A), blanched potato slices (B), blanched potato sticks (C), fried potato slices (D), fried potato sticks (E), fried blanched potato slices (F) and fried blanched potato sticks (G). Also, there were five oil samples: palm olein sample before frying (1), palm olein sample taken after the fried potato slices (2), fried potato sticks (3), fried blanched potato slices (4) and fried blanched potato sticks (5).

The total dry matter content (DM) was determined by the standard gravimetric method [AOAC, 2005].

The peroxide value (PV) [SRPS EN ISO 660:2015], expressed in mmol/kg, was determined by the reaction of oil (dissolved in acetic acid and isooctane) with a solution of potassium iodide. The liberated iodine was then titrated with a standard volumetric sodium thiosulfate solution.

The free fatty acid content (FFA) [SRPS EN ISO 660:2015; ISO 660:2009], expressed as a percentage of oleic acid (% ol. acid) in 100 g of sample, was determined by the titration of a solution of oil dissolved in ethanol:ether (1:1) with an ethanolic solution of potassium hydroxide.

The oil content [SRPS EN ISO 659:2011] was determined by the standard Soxhlet method of extraction (the reference method).

Statistical analysis was performed using statistical software STATISTICA 12. The results are shown as the arithmetic mean of three replicates ± standard deviation, and the differences between samples were determined by the Duncan test. Results were considered at the significance level $\alpha = 0.05$. A correlation analysis was carried out using the same program.

Results and discussion

The results obtained in this study are given in Tables 1 and 2.

The results of absorbed oil content indicated a significant difference between the samples. The amount of absorbed oil in fried potato depends on several factors. The surface area of the potato in contact with oil, moisture content and frying conditions (time and temperature) are among the most important ones (Razali and Badri, 1995). In this study, the sample with the highest absorbed oil content was potato chips (Table 1). Compared to potato sticks, potato slices (potato chips) had a larger surface area in contact with oil, resulting in the potato chips having approximately four times more oil uptake. During frying, large voids in the food were created due to water evaporation which was replaced by oil, which explains the high content of absorbed oil in the fried product (Dana and Saguy, 2006). Gamble and Rice (1988) and Lioumbas and Karapantsios (2012) described similar mechanisms during potato frying. All these mechanisms explained that the cutting thickness certainly had an effect on the oil uptake in food. If the food was thinly sliced, there was more intense water evaporation which was replaced by oil. The surface area also influenced the oil absorption of blanched potato samples (Table 1). The amount of absorbed oil in fried blanched potato slices was significantly higher in relation to fried blanched potato sticks for the stated reasons.

Table 1. The dry matter and absorbed oil content in potato samples.

Potato sample	DM (%)	Oil content (palm olein) (%)
A	20.69	-
B	18.65	-
C	17.45	-
D	86.66	$39.85^{a} \pm 1.06$
E	38.46	$8.95^{d} \pm 0.82$
F	88.01	$22.60^{b} \pm 1.30$
G	36.73	$13.74^{c} \pm 0.61$

Values are presented as means±SD (n=3); Different letters indicate a significant difference between the samples at the significance level $\alpha = 0.05$.

On the other hand, moisture content also affected the amount of absorbed oil. Blanching increased the moisture content of the samples by approximately 2% (Table 1). The content of absorbed oil in fried blanched potato samples changed significantly in relation to unblanched samples fried under the same conditions. Namely, the content of absorbed oil in fried blanched potato slices decreased by 43.3% in relation to unblanched potato slices (Table 1). In the study conducted by Rimac-Brnčić et al. (2004), obtained results have shown that the different pre-frying treatments significantly decreased the oil absorption, even by over 50%. The

best result was obtained using a 0.5% solution of calcium chloride in the blanching process. Unlike the results obtained in Rimac-Brnčić et al. (2004) and our study, Pedreschi and Moyano (2005) have published that the blanching of potato slices before frying significantly increased the absorbed oil content. These authors pointed out that only the increase in frying temperature had the effect of reducing oil uptake. In the study of Al-Khusaibi and Niranjan (2012), the results have shown that the combination of blanching with high-pressure pretreatment may be used to reduce frying time but not oil uptake. The absorbed oil content was significantly higher (by 53.5%) in blanched potato sticks compared to the unblanched sample (Table 1). These results were consistent with the findings of Pedreschi and Moyano (2005) and Al-Khusaibi and Niranjan (2012). According to Bingol et al. (2012), the oil uptake in French fries could be significantly reduced using infrared dry-blanched as a pretreatment technique instead of commonly blanching. Bunger et al. (2003) observed a significant decrease in oil uptake by soaking potato strips in 3% NaCl solution for 50 minutes prior to frying.

In this study, palm olein was analyzed before and after frying to determine peroxide value and free fatty acid content as its quality parameters. The results showed that the peroxide value and free fatty acid content of all oil samples taken after frying were significantly higher compared to initial values in palm olein before frying, as expected (Table 2). These parameters increased immediately in a very short period of frying time (Gunnepana and Nawaratne, 2015; Paunović et al., 2020). On the other hand, peroxide values and free fatty acid content in all oil samples taken after the frying process did not indicate a significant difference between samples (Table 2). This can be explained by the fact that the frying period was too short (3 minutes) for numerous chemical reactions. However, during the prolonged frying process, as well as multiple frying, the peroxide value and fatty acid content could be significantly increased (Ebba et al., 2012; Gunnepana and Nawaratne, 2015; Paunović et al., 2020). As the frying time is prolonged, chemical reactions of hydrolysis, oxidation, isomerization and polymerization become more intense, and these oils have an unpleasant taste and aroma, and additionally become unsafe to the consumer health (Ebba et al., 2012; Kaleem et al., 2015).

Table 2. The peroxide value and free fatty acid content in oil samples.

Oil sample	PV (mmol/kg)	FFA (% ol. acid)
1	$2.00^{b} \pm 0.20$	$0.56^{b} \pm 0.12$
2	$3.20^{a} \pm 0.20$	$0.85^{a} \pm 0.12$
3	$2.80^{a} \pm 0.20$	$0.85^{a} \pm 0.12$
4	$3.20^{a} \pm 0.20$	$0.56^{b} \pm 0.12$
5	$2.80^{a} \pm 0.20$	$0.85^{a} \pm 0.12$

Values are presented as means±SD (n=3); Different letters indicate a significant difference between the samples at the significance level $\alpha = 0.05$.

Based on the results, it can be concluded that the oil uptake undoubtedly depends on the thickness and surface area of the potato. If the surface area in contact with oil is larger, the oil absorption in the product will be increased. The moisture content also affected oil uptake. The oil content was significantly lower in blanched potato slices but significantly higher in blanched potato sticks compared to unblanched samples. Since the frying period was short, the analyzed quality parameters of palm oil were within the allowable value range.

Conclusion

Frying is the most common method of processing potatoes in the human diet, and products are potato chips and French fries. Based on the results obtained in this study, it can be concluded that the thickness and surface area of the potato had a significant effect on oil uptake. Compared to potato sticks, potato chips had a larger surface area in contact with oil, resulting in the potato chips having approximately four times more oil uptake. Moisture content also affected oil uptake. The oil content was significantly lower in blanched potato slices (by 43.3%) but significantly higher in blanched potato sticks (by 53.5%) compared to unblanched samples. Since the frying period was short, the analyzed quality parameters of palm oil were within the allowable value range.

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UTICAJ DEBLJINE LISTOVA, OBLIKA I SADRŽAJA VLAGE KROMPIRA NA APSORPCIJU ULJA TOKOM PRŽENJA

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R e z i m e

Čips i pomfrit su proizvodi koji se često koriste u ljudskoj ishrani. Cilj ovog rada bio je da se istraži uticaj debljine listova, oblika i sadržaja vlage na apsorpciju palmoleina, kao i kvalitet palmoleina tokom proizvodnje prženog krompira. Operacija blanširanja izvedena je kuvanjem u vodi u trajanju od 3 minuta na temperaturi od 85°C, dok je prženje u palmoleinu izvršeno u trajanju od 3 minuta na temperaturi od 165°C. Vrednosti peroksidnog broja i sadržaja slobodnih masnih kiselina (% oleinske kiseline) utvrđeni su standardnim analitičkim metodama. Sadržaj ulja u uzorcima određen je ekstrakcijom po Soxkhlet-u (referentna metoda). Rezultati su pokazali da je čips apsorbovao oko četiri puta višu količinu ulja u odnosu na pomfrit. Sadržaj ulja bio je značajno niži u listovima krompira koji su prethodno blanširani (za 43,3%), ali značajno viši u štapićima krompira koji su blanširani (za 53,5%), u poređenju sa neblanširanim uzorcima. Analizirani parametri kvaliteta palmoleina bili su u granicama dozvoljenih vrednosti. Na osnovu rezultata dobijenih u ovom istraživanju, može se zaključiti da su debljina listova, površina i sadržaj vlage krompira značajno uticali na apsorpciju ulja.

Ključne reči: prženi krompir, palmolein, površina, peroksidni broj, sadržaj slobodnih masnih kiselina.

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