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The effects of oils and frying temperatures on the texture and fat content of potato crisps

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Abstract

The purpose of the study was to determine the effects of oils and frying temperatures on fat content and texture of potato crisps.

The material used for the study consisted of eight kinds of vegetable oils: sunflower, rapeseed, soybean, olive, peanut, palm, partially hydrogenated rapeseed oil (modified oil I) and a mixture of hydrogenated rapeseed oil with palm oil (modified oil II). Potato crisps were fried in oils heated to 150, 170 and 190 °C. The measurements included: fat content of crisps determined by the Soxhlet method and texture of crisps measured using an Instron 5544. Fatty acid content of oils was determined by gas chromatography.

The results of the study showed that the amount of fat absorbed by the crisps, as well as their texture, depended on the kind of oil used for frying. A relationship between oleic acid content of oil and the texture of crisps fried in refined vegetable oils was found. Fat content and texture of crisps were also influenced by frying temperatures. Crisps absorbed less fat and their hardness was reduced by increasing frying temperatures.

Keywords: Texture; Fat content; Potato crisps; Frying fat; Frying temperature

1. Introduction

Potato crisps are very popular fried snacks. Their characteristic crispy texture is one of the most important quality indicators of the finished product. Developed during frying, it is mainly dependent on the quality of raw material, but also on the parameters of technological processing (Gamble, Rice, & Selman, 1987; Kita, 2002; Kita, Lisińska, Tajner-Czopek, & Rytel, 1998; Lisińska & Leszczyński, 1989). During frying, the water present in the raw material evaporates, and is partially replaced by oil, constituting up to 40% of the finished product, and consequently influencing its properties. This affects, not only the flavour and aroma of the product, but also the texture, depending on the quantity of oil absorbed during frying – from oily when the fat content is too high to harsh and less crispy when it is too low (Lisińska & Leszczyński, 1989). The quantity absorbed during frying is, to a large extent, dependent on frying temperature, which directly influences the length of the process. The effect of oil temperature on fat uptake and properties of deep-fried products has been reported (Dobarganes, Marquez-Ruiz, & Velasco, 2000; Gamble et al., 1987; Mellema, 2003; Moreira, Sun, & Chen, 1997; Saguy & Dana, 2003). In general, crisps are fried at high temperatures (175–190 °C). Temperatures above 175 °C favour the formation of acrylamides, known to be potential carcinogenic substances (Gertz & Klostermann, 2002; Grob et al., 2003). For this reason, it would be advantageous to lower the frying temperature, maintaining the quality of the product. Hence, studies of the effects of lower frying temperatures on the texture of potato crisps seem to be justifiable.

Today, the most popular oils used for crisp frying are: palm oil or its fractions, and also high-oleic sunflower, rapeseed and soybean oils. Quite popular also are hydrogenated vegetable oils (soybean, sunflower and rapeseed), characterised by enhanced thermo-oxidative stability (Kristott, 2003; Rossel, 2003). Such a wide array of oils used for crisp frying allows us to assume that the choice of the

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frying medium may influence the sensory characteristics of the fried product.

The purpose of the present investigation was to study the influence of the frying medium and temperatures on fat content and texture of potato crisps.

2. Materials and methods

2.1. Experimental material

The material taken for the study consisted of eight vegetable oils: refined sunflower, rapeseed, soybean, olive, peanut and palm oils, partially hydrogenated rapeseed oil (modified oil I), and a mixture of hydrogenated rapeseed and palm oil (modified oil II). All the oils under investigation were produced or distributed by Polish manufacturers (ZT ''Kruszwica'' S.A. and ZPT Warszawa S.A.). The oils were stored in original packaging at 4 °C in the dark until taken for frying.

A potato variety, Karlena, was used for laboratory crisp production. After washing and trimming (carborundum peeler, Sirman, Italy), the potatoes were cut into slices of 1 ± 0.1 mm thickness (slicing machine, Brown, Germany), washed in cold water, superficially dried (paper towels) and fried in a fryer (Beckers, Italy) until the moisture content was below 2%. The crisps were fried in oils heated to 150, 170 and 190 °C. After discharging of the oil and cooling, 100 g samples of crisps were packed in aluminium foil packages and taken for laboratory analysis. All experiments were performed in triplicate and the results shown in the present paper are the mean values obtained in the investigation.

2.2. Analysis

Fatty acid content of frying oils was determined by gas chromatography (AOAC). The fatty acid methyl esters were prepared with BF_3 in methanol as the methylating agent. Determination of fatty acid composition was achieved by gas chromatography (GC), using a capillary column RTX-2330, 105 m length, diameter 0.25 mm ID and film thickness 0.20 μm. Detector (FID) temperature was 260 °C. Injection temperature was 260 °C. Column temperature was 160 °C/30 min/−3 °C/min – 180 °C/17 min/−5 °C/minimun – 210 °C/45 min and the carrier gas was helium.

Fat content of potato crisps was determined using the Soxhlet procedure (AOAC). Fat was extracted using a Büchi B-811 Universal extraction system (Büchi Labortechnic AG, Flawil, Switzerland). A 2 g sample was extracted for 180 min using diethyl ether as a solvent.

The texture of potato crisps was determined using an Instron 5544 connected to a computer, equipped with a ''share blade'', rectangular attachment for cutting (70 mm × 3 mm). The velocity of the head with the attachment was 250 mm/min with a 100 kg load cell. The measurements were taken for determining maximum shear force (Fg_{max}) necessary to cut one slice of potato crisp. Each measurement was conducted on 30 potato crisps.

2.3. Statistical evaluation

One-way analysis of variance was used for comparison of the results obtained with fat content and texture of potato crisps. Homogeneous groups were determined using Duncan's test ($p \leqslant 0.05$). Correlation coefficients (ANOVA) were determined in order to find a relationship between the type of oil and frying temperature versus fat content and texture of crisps. Differences at $p \leqslant 0.05$ were considered significant. The data were analysed using a Statistica 6.0 programme.

3. Results and discussion

The frying oils under investigation were of good quality and no significant differences in chemical parameters were found (Table 1). The vegetable oils used for crisps frying varied in fatty acids content. The predominant components in refined vegetable oils were unsaturated fatty acids, e.g., oleic acid (from 27.8% in soybean to 74.7% in olive oil). Besides, modified oils, especially modified oil I, were high in oleic acid (71.1%). The presence of *trans* isomers of fatty acids was found in modified oils: 9.49% (I) and 22.0% (II) as well as in palm oil (1.04%).

Potato crisps were fried in the oils heated to 150, 170 and 190 °C. The quantity of fat absorbed varied, depending on the type of oil and frying temperature (Table 2) and it decreased with increasing frying temperature, irrespective

Table 1
Characteristics of oils used for potato crisps frying

Kind of oil	C_{18} is fatty acids (%)				*trans*-Isomers (%)	IV	PV (meqO_2 kg^{-1})	FFA (% oleic acid)
	18:0	18:1	18:2	18:3				
Sunflower oil	3.60[c]	30.2[b]	58.2[h]	0.70[b]	–	123[f]	1.61[a]	0.02[a]
Soybean oil	4.64[d]	27.8[a]	49.7[g]	6.38[d]	–	119[f]	2.83[c]	0.05[a]
Peanut oil	4.30[d]	58.0[e]	19.8[f]	0.19[a]	–	93[d]	2.03[b]	0.10[a]
Rapeseed oil	1.92[a]	62.3[e]	17.7[e]	9.04[e]	–	105[e]	2.08[b]	0.06[a]
Olive oil	3.18[bc]	74.7[f]	8.50[c]	0.70[b]	–	82[c]	2.63[c]	0.42[b]
Palm oil	4.83[d]	39.8[c]	9.21[d]	0.24[a]	1.04[a]	55[a]	1.43[a]	0.05[a]
Modified oil I	2.67[b]	73.8[f]	3.40[a]	0.30[a]	9.49[b]	76[b]	1.17[a]	0.04[a]
Modified oil II	7.55[e]	43.8[d]	5.84[b]	2.10[c]	22.0[c]	73[b]	1.92[b]	0.06[a]

Table 2
Fat content of potato crisps, depending on frying temperatures and kind of oil

Kind of oil	Frying temperatures		
	150 °C	170 °C	190 °C
Sunflower oil	42.42^{dC}	41.14^{dB}	34.00^{aA}
Soybean oil	43.30^{eC}	39.49^{cB}	35.53^{bA}
Peanut oil	41.67^{cB}	39.53^{cB}	35.61^{bA}
Rapeseed oil	37.98^{aB}	36.40^{aA}	36.04^{bA}
Olive oil	46.64^{fB}	38.28^{bA}	38.02^{dA}
Palm oil	42.32^{dC}	38.13^{bB}	37.04^{cA}
Modified oil I	42.64^{dC}	41.23^{dB}	38.98^{eA}
Modified oil II	39.68^{bC}	38.11^{bB}	34.06^{aA}

Lower-case letters indicate significant differences in columns ($p \leqslant 0.05$).
Capital letters indicate significant differences between columns ($p \leqslant 0.05$).

Table 3
Texture (N) of potato crisps, depending on frying temperatures and kind of oil

Kind of oil	Frying temperatures		
	150 °C	170 °C	190 °C
Sunflower oil	17.50^{aA}	22.08^{bA}	20.80^{cdA}
Soybean oil	25.90^{abA}	22.25^{bA}	21.10^{cdA}
Peanut oil	23.24^{abB}	14.36^{aA}	13.36^{aA}
Rapeseed oil	21.11^{aB}	13.48^{aA}	17.71^{bcAB}
Olive oil	30.26^{bC}	21.48^{bB}	15.43^{baA}
Palm oil	21.70^{aA}	21.05^{bA}	18.25^{bcA}
Modified oil I	22.90^{abA}	19.57^{bA}	16.21^{abA}
Modified oil II	23.33^{abA}	21.43^{bA}	22.54^{dA}

Lower-case letters indicate significant differences in columns ($p \leqslant 0.05$).
Capital letters indicate significant differences between columns ($p \leqslant 0.05$).

of the frying oil. However, no significant differences in fat absorbed by crisps fried in rapeseed and olive oils at 170 and 190 °C were found. The crisps fried in rapeseed oil absorbed the smallest amount of fat (36.8%), irrespective of frying temperature, whereas the crisps fried in olive oil and modified oil II absorbed the highest quantity of fat (41%). Annapure, Singdal, and Kulkarni (1998) compared fat content of crisps fried in different vegetable oils and found the highest fat absorption with peanut oil (35.9%), and the lowest with cottonseed oil (30.6%).

Frying temperature was the most important factor affecting the quantity of fat adsorbed by potato crisps. Significant differences in fat content of potato crisps fried in rapeseed and olive oils were observed between the lowest frying temperature (150 °C) and two others (170 and 190 °C). Fat content of crisps fried in peanut oil decreased with the highest frying temperature (190 °C). Potato crisps fried in the other vegetable oils varied in fat content at all frying temperatures under investigation. With every increase in frying temperature by 20 °C, fat absorption was reduced by 3%, on average, with all the oils under investigation. Baumann and Escher (1995) show a kinetic model of fat absorbed by potato slices during frying, in which the increasing temperature of frying increased water evaporation rate, which at the same time reduced the length of frying and the quantity of fat absorbed. The relationship observed between fat content of potato crisps and frying temperature was in disagreement with that observed by other authors (Gamble et al., 1987) who found that an increase in oil temperature increased the quantity of oil absorbed by potato chips. Garayo and Moreira (2002), who fried crisps under low pressure conditions, also observed higher fat contents of crisps fried at higher temperatures. On the other hand, Guillaumin (1988) found that frying temperatures between 150 and 180 °C had no significant impact on the quantity of fat absorbed by food products.

A characteristic crispy texture of crisps is developed during frying. Table 3 shows the results of measurements of crisp texture, expressed in $Fg_{\max}$ (max. force necessary to break a slice of crisp). Frying temperatures had no significant influence on the texture of potato crisps fried in sunflower, soybean, palm and the two modified oils. Crisps fried in rapeseed and peanut oils exhibited more hard and less crispy textures when they were fried at 150 °C. Most variable texture, depending on frying temperature, was in crisps fried in olive oil – hardest at lower frying temperature (30.26 N) and crispy at highest (15.43 N). Except for olive oil there were no significant differences between textures of crisps fried at 190 and 170 °C. That means that a decrease in frying temperature below 175 °C does not influence the texture of potato crisps. This observation is important with regard to acrylamide formation in potato crisps. It is possible to reduce acrylamide content of this kind of potato product with no consequences on its quality, by decreasing frying temperature.

The other aspect of texture investigations was the influence of type of frying oil. At every frying temperature, between eight analysed frying oils, more crispy and less hard textures were exhibited in crisps fried in rapeseed oil (Table 3). The greatest influence of frying oil on the texture of potato crisps was observed at highest frying temperature (190 °C). However when potato crisps were fried at 170 °C, more delicate and crispy textures were shown in crisps fried in rapeseed and peanut oils (below 15 N) than in other used oils (Fig. 1).

Rani and Chauchan (1995) compared the textures of crisps fried in hydrogenated vegetable oil and two refined oils and found that those fried in refined soybean and peanut oils were harder than those fried in hydrogenated oil or other oils.

Fig. 2 shows that the texture of potato crisps fried in refined vegetable oils depends on the content of oleic acid in the oil used for frying. When the content of oleic acid in frying medium is between 30% and 75%, irrespective of frying temperature, less hard and more crispy textures of potato crisps was obtained when oleic acid content was about 60%. Equations of regression describing those relationships are showed in Table 4.

In our previous experiment, when textures of French fries were analysed, we found some correlations between fatty acid content of frying media and the texture of products obtained (Kita, Lisińska, & Powolny, 2005). The hardness of French fries increased with increasing saturated fatty acids and *trans* isomer fatty acid contents. In this

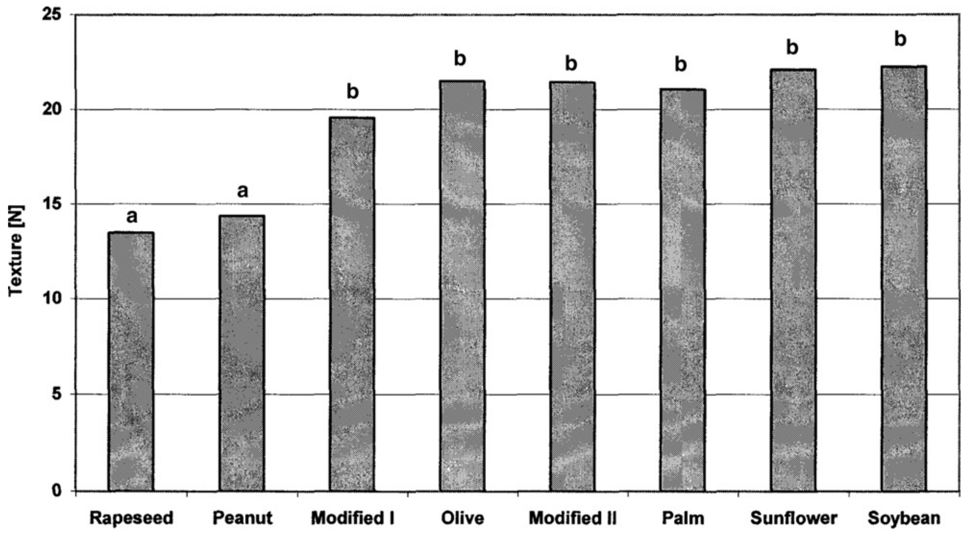

Fig. 1. Texture of potato crisps fried in eight kinds of oils at 170 °C. (a,b) Different letters indicate statistically significant differences ($p \leqslant 0.05$).

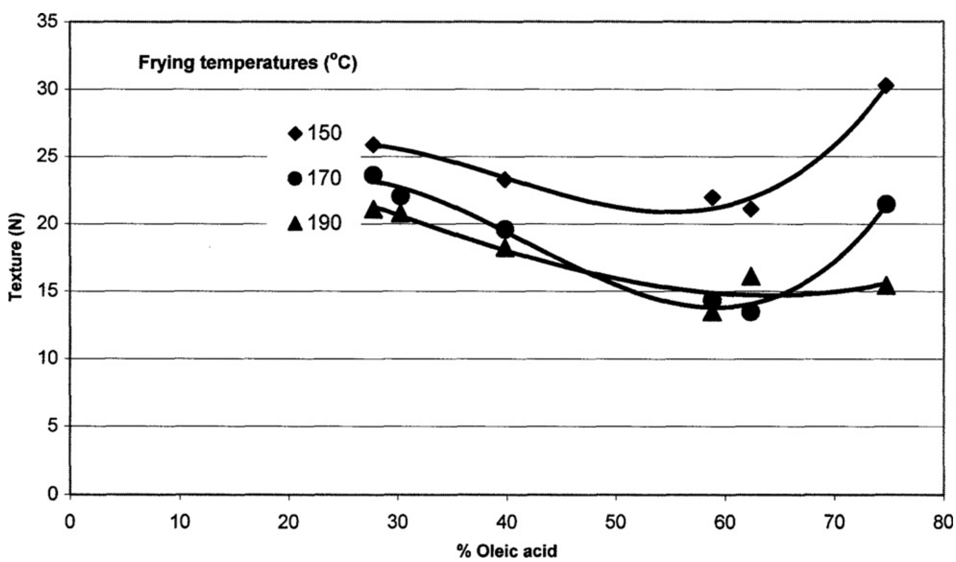

Fig. 2. Texture of potato crisps, depending on oleic acid content of frying oil (only refined oils).

Table 4
Equations of regression describing the relation between the texture of potato crisps and oleic acid content of frying medium (refined vegetable oils)

Model	*a*	*b*	*c*	*d*	Coefficient of determination r^2	Standard error	Frying temperature
$Y = a + bx + cx^2 + dx^3$	10.26	1.49	−0.04	0.0004	0.97	0.85	150 °C
	1.85	2.03	−0.06	0.0005	0.98	0.67	170 °C
	28.59	−0.19	−0.01	6E − 0.5	0.9	1.29	190 °C

experiment, when frying oils were more varied in fatty acid composition, it was possible to devise models describing a relationship between oleic acid content and texture of potato crisps in relation to frying temperatures. However, they were only for non-modified refined vegetable oils.

The correlation coefficients confirm the relationship between the parameters discussed (Table 4). Both the oils used for frying and frying temperatures markedly affected fat con-

Table 5
Correlation coefficients (*r*) between parameters examined

Parameters	Correlation coefficent (*r*)	
	Texture (N)	Fat content of crisps (%)
Kind of oil	0.76[a]	0.73[a]
Frying temperatures	−0.58[a]	0.80[a]
Fat content	0.45[a]	*x*

[a] Significant correlation coefficients.

tent and texture of potato crisps. The quantity of fat absorbed by the crisps was also correlated with their texture (Table 5).

The fat content and texture of crisps could be controlled by the selection of oil for frying. A decrease in frying temperature to 170 °C increased fat absorption, but did not have a significant impact on the texture of a finished product. Rapeseed oil proved to be the best, among the oils under investigation, for potato crisp frying at lower temperatures. Potato crisps fried in that oil, at 170 and 150 °C, absorbed less fat than to those fried in other oils.

4. Conclusions

The results obtained in the present study show that fat content and texture of potato crisps are influenced by the type of oil used for frying. There is a relationship between oleic acid content of the frying oil and the texture of crisps fried in refined vegetable oils. Frying temperature significantly influences the quantity of fat adsorbed by crisps; the lower the temperature, the higher is the fat content of the product. A frying temperature below 170 °C markedly reduces the hardness of potato crisps. A decrease in frying temperature of rapeseed oil to 170 °C has no influence on the texture of potato crisps.

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