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RESEARCH ARTICLE

The Effect of Frying Time and the Addition of Rice Bran Wax to High Oleic Sunflower Oil (HOSO) on Selected Quality Parameters of Potato Starch Crackers and Frying Medium

Sylwia Onacik-Gür[1], Stanisław Ptasznik[1], Anna Żbikowska[2], Katarzyna Marciniak-Łukasiak[2]

1– Prof. Waclaw Dabrowski Institute of Biotechnology of Agricultural and Food Industry - National Research Institute; Department of Meat and Fat Technology, 4 Jubilerska St., 04-190 Warsaw

2– Warsaw University of Life Sciences, Institute of Food Science, Department of Food Technology and Evaluation Nowoursynowska 159c St., 02-787 Warsaw

Correspondence
sylwia.onacik-gur@ibprs.pl

Prof. Waclaw Dabrowski Institute of Biotechnology of Agricultural and Food Industry - National Research Institute; Department of Meat and Fat Technology, 4 Jubilerska St., 04-190 Warsaw

Abstract

Deep-fried products, due to their unique sensory properties, are very popular and are present in most cuisines of the world. However, heat treatment can reduce their nutritional value. In addition, fried products are characterized by high energy value, which has to do with the absorbed frying fat. High temperature, contact with oxygen and the presence of other ingredients from fried foods can contribute to the formation of compounds in the frying medium and in the fried product that are dangerous to human health, such as acrylamide. The study analyzed the quality of frying medium (high-oleic sunflower oil (HOSO) and HOSO with rice bran wax (1g/100ml)) and potato starch crackers. There was no statistically significant effect of wax (at 1g/100ml of HOSO) on the fat and acrylamide content of the product. Rice bran wax in the frying medium caused a reduction in the level of the browning index and the hardness of roasted potatoes. The values of the chemical parameters of the frying medium, not depending on the type, testified to their good quality after 16 hours of frying.

KEYWORDS:
deep frying, oleogels, acrylamide, fat absorption, high oleic sunflower oil

Introduction

Fried products are very popular around the world. They are valued for their texture, flavor and aroma. High temperatures (130-190°C) are used in the frying process. As a result of the high temperatures, access to oxygen and ingredients from the fried product, chemical transformations take place in the frying fat. A consequence is the formation of compounds which are hazardous to health together with the sensory and nutritional changes in the products. To ensure the quality of fried food, it is necessary to use fats with high oxidative stability. Therefore, the use of oil containing large amounts of oxidation-prone polyunsaturated fatty acids (PUFAs) is not advisable [Romano et al, 2021; Choe and Min, 2007].

Fats rich in saturated fatty acids (SFAs) have very good stability, but unfortunately, they are not recommended in the diet for nutritional reasons. Excessive consumption of SFAs leads to an increased risk of cardiovascular disease [EFSA, 2010]. Fats containing large amounts of SFAs are characterized by their solid consistency, at room temperature. The use of such frites is technologically difficult, as they require liquefaction and special dosing. One solution that is gaining increasing attention is the use of oils with high oleic acid content [Porta and Aladedunye, 2022; Onacik-Gür et al, 2014].

Oleic acid (C18:1) is built from eighteen carbon molecules and belongs to the group of n-9 monounsaturated fatty acids in the cis configuration. C18:1 is found in many oils of various plant species, but often its content does not provide sufficiently high oxidative stability. In order for an oil to have high oxidation resistance, it is important to have the content of this acid reaching above two-thirds of the total fatty acids (FA) pool and a low content of PUFAs. High oleic oils, compared to the corresponding oils from conventional plant varieties, contain several to even tens of percent more oleic acid. Such an increase in C18:1 content very significantly increases resistance to oxidation [Romano et al, 2021; Porta and Aladedunye, 2022]. According to scientific reports, the oxidation of sunflower oil from conventional varieties can occur up to twice as fast compared to HOSO. For this reason, high-oleic oils are most often used for frying [Roman et al, 2013].

Prolonged heating of the frying medium leads to its degradation. This results in the formation of health-hazardous chemical compounds that can pass into food and reduce the nutritional value of fried products [Ahmad et al., 2021]. Excessive consumption of such products can lead to cardiovascular diseases [Lin et al., 2021] and increase the risk of cancer [Ganesan and Xu, 2020].

The degree of absorption of the frying medium by the product matrix depends on many factors. Increased fat absorption can be caused by: too low a medium temperature, increased viscosity due to fat degradation, high porosity and surface area relative to weight, and low fiber and water content in the product. The absorption of fat by the product is also economically disadvantageous, as it involves the loss of frying medium. To date, most ways to reduce fat absorption by fried products are based on modifying their formulation or coating them with films such as hydrocolloids [Marciniak-Lukasiak et al, 2019; Mellema, 2003].

During frying, very complex Maillard reactions take place in the product. They occur at temperatures above 120°C. Reducing sugars and amino acids take part in them. The reaction products are responsible for shaping the desired sensory characteristics of fried products, such as taste, aroma and color. Unfortunately, some of these compounds can have negative effects on human health, such as acrylamide. This compound is recognized as being potentially carcinogenic and genotoxic [EFSA, 2015]. Fat degradation products may be involved in the formation of acrylamide. During frying, water from the products contributes to the hydrolysis of triacylglycerols and free fatty acids and glycerol are released. Glycerol can then dehydrate resulting in the formation of acrolein. This substance can also be formed by the oxidation of polyunsaturated fatty acids [Jiang et al., 2022]. Acrolein is oxidized to acrylic acid, which reacts with ammonia from the degradation of amino acids present in fried foods to form acrylamide [Szczerbina, 2005]. It has been shown that frying in fats high in unsaturated TCs can contribute to an increase in acrylamide content in the product [Ahmad et al, 2021].

To date, there has been little work on the potential use of additive waxes in frying. It has been shown that their addition increases the smoke point and can effectively reduce fat absorption in starchy snacks, from 27.14% to 19.61% [Chauhan et al., 2022]. A lighter color and less oxidative changes were also observed in the fried, oleogel-fried product, as well as less changes during storage of the products, compared to products fried in oil without the additive [Adrah et al, 2022; Guneser et al, 2021]. Such a phenomenon may be related to the fact that after the product is pulled out of the fryer, the mixture of oil and oleogelator solidifies on the surface and forms a coating, and the trapped fat in the crystal lattice is less susceptible to oxidation. The lighter color of the product may indicate fewer compounds formed as a result of a non-enzymatic browning reaction – the Maillard reaction [Verma and Yadav, 2022].

The purpose of this study was to investigate the effect of rice bran wax addition and frying time on the oxidative properties of the frying medium (high-oleic sunflower oil) and on the quality of fried potato starch crackers.

Materials and Method

1. Frying medium

The frying medium was high oleic sunflower oil (Bunge Polska Ltd.) and the oleogel obtained from it. Refined wax from rice bran (TER INGREDIENTS GMBH & CO. KG, Germany), a by-product of oil production, was used as the oleo-gelating agent. The wax was added to the oil at a rate of 1g/100ml of oil and heated until completely dissolved. The size of the additive was based on previous test results, which indicated that this amount was the critical concentration needed to produce a solid oleogel from rice bran wax.

2. Frying the crackers

The potato pellets (composition: potato starch, dehydrated potatoes, salt) obtained from Jedność (Wschowa, Poland) were fried in a fryer (Filtra PRO, Tefal), in 4 cycles, at a frequency of one per day. In each cycle, 20 grams of pellets were fried 6 times for 20 seconds at 30-minute intervals. The temperature of the frying medium was 180±5°C. The fried pellets in all cycles were from the same production batch. At the end of the frying cycle, the fryer was turned off and the frying medium cooled to room temperature of 21±2°C. The test scheme is presented below in Figure 1.

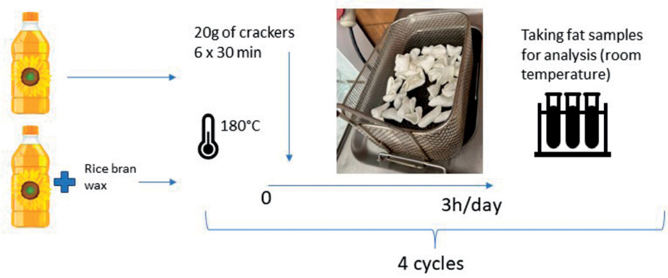


Figure 1. Diagram of the study

3. Analysis of the quality of the frying medium

After each frying cycle, a sample of the frying medium was taken for an acid and peroxide number analysis, which were determined in accordance with standards PN-EN ISO 660:2020 and PN-EN ISO 3960:2012.

4. Analysis of the quality of fried roasts

4.1. Fat absorption and fat content

Fat absorption was measured using the weight method based on the difference in weight before and after frying. Fat absorption was expressed in %.

4.2. Analysis of the color of the roasting presses

The color of the roasted products was measured with a colorimeter (CR-300, Konika Minolta) in the CIE Lab system. The color of the products was analyzed after the frying cycle. The measurement was carried out 10 times. From the obtained data of color parameters, the browning index (BI) was calculated according to the formula [Verma and Yadav, 2022].

$$BI = \frac{100\,(X - 0{,}31)}{0{,}17}$$

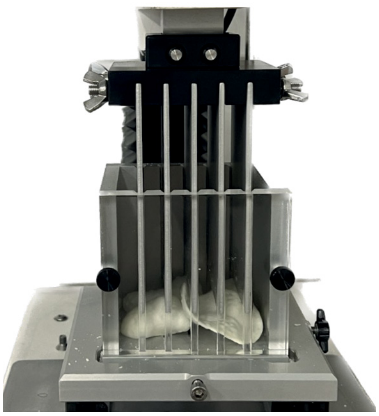
Where:

$$X = \frac{a * + 1{,}75L *}{5{,}645L * \; + a * \; - 3{,}01b *}$$

L* - the color parameter that determines brightness
a* - parameter determining the color from green to red
b* - parameter indicating the color from blue to yellow

4.3. Texture analysis

Texture testing of the crackers was carried out using a TA.XT. plus textrometer (Micro Stable Systems, UK) with a 30 kg measuring head. Using a 5-blade Kramer Chamber, the hardness of the pressings arranged in a single layer (4 pieces) was determined - Figure 2A. The travel speed of the head was 2 mm/s. The highest value of the breaking force required to destroy the specimen was determined as hardness and was expressed in N (Fig. 2B).



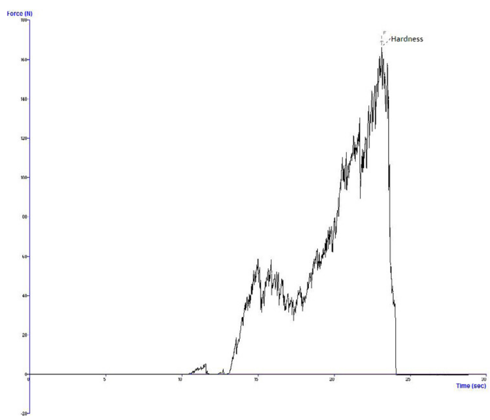


Figure 2.
A) Kramer chamber with presser bars during the test,

B) sample curve for measuring the hardness of the presser bars.

4.4. Analysis of acrylamide content

The acrylamide content of the roast was performed according to the methodology given by Roszko et al [2022]. The limit of the quantification for the method given is 10 µg/kg. The method was validated in accordance with ISO-17025.

5. Statistical analysis

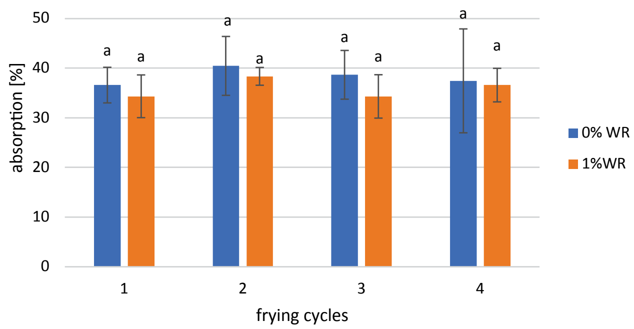
The results obtained were statistically analyzed using Statistica 13.0 software. One- and two-factor analysis of variance and Duncan's test were used to determine the statistical differences between groups ($p<0.05$).

Results and Discussion

1. Fat absorption

Fat absorption is an important factor affecting the nutritional value and taste of products. An increase in the fat content of a product increases its caloric content. Along with the absorbed fat, oxidation products present in the fryer get into the fried food and degradation products present in the fryer. The absorption of fat by products is also an economically unfavorable phenomenon, which is why in gastronomy treatments are used to reduce such absorption, i.e.: frying in a hot fryer, using higher temperatures, shortening the frying time and using fats with appropriate parameters. In contrast, in breaded products, formulation modifications are used to introduce additives that reduce absorption (e.g., cellulose derivatives), but formulation changes are not possible in all types of food.

In the study conducted, it was observed that the addition of 1% of rice bran wax did not result in a statistically significant reduction in fat absorption. However, considering the average values in each frying cycle (Figure 3) and the total fat content from all cycles, a trend was observed. Fat absorption decreased by an average of about 3.4%, and by 1.1% per product fat content (Table 1).



a - homogeneous groups determined by Ducan test,
WR - rice bran wax

Figure 3. Absorption of fat by roasting medium during individual frying cycles taking into account the addition of wax to the frying medium.

Table 1. Absorption and fat content of roasting grits fried in high-oleic sunflower oil without and with the addition of wax for all frying cycles

Wax content	Absorption [%]	Fat content [%]
0%	38,3± 6,5a	27,5± 3,3a
1%	35,9± 3,8a	26,4± 2,1a
	p-value	
Wax	0,1332	0,1552
Frying cycle	0,3423	0,3244
Wax x fry cycle	0,8849	0,8229

a - homogeneous groups determined by Ducan test

Studies by other researchers have also observed the positive effects of using oleogels in reducing fat absorption. In Indian Mathiri snacks fried in an oleogel based on soybean oil and carnauba wax at 5%, a reduction in fat content from 27.14 to 19.61% was observed, while in a study by Lim et al [2017], it was proven that frying in the same frying medium reduced fat absorption from 22.3 to 19.0% in instant noodles.

2. The parameters of the color of the roast

There was no statistically significant effect of the addition of rice bran wax to HOSO or frying time on the brightness of the roasted products (Table 2). All fried products were characterized by the proportion of the green and yellow color. The color parameter a* changed during frying, but no trend was observed. The values of the b* parameter, indicating the proportion of the yellow color, increased during successive frying cycles.

From the results obtained, the browning index (BI) was calculated, and it increased with frying time. A statistical analysis showed that wax had no significant effect on the browning of the roast, while the joint effect of factors (wax and frying time) significantly affected the value of this parameter (Table 2).

In a study by Adrah et al, [2022] observed, an increase in L* values from 33.27 for a control sample of chicken breast fried in canola oil to 47.70 for the same product subjected to frying in oleogel with the addition of 3% beeswax. Guneser et al [2021] also published similar observations, for French fries, where a 3% beeswax addition to a sunflower oil-based frying medium increased the L* parameter from 30.50 to 42.40.

3. The texture of the crackers

Texture is a very important parameter significantly affecting the sensory characteristics of a food product. Instrumental measurement gives an objective assessment of this parameter. The study shows that in each frying cycle, the roasting in oil with the participation of rice bran wax (oleogel) had a lower hardness value, which averaged from 165 to 145 N, while the values of this parameter for the roasting fried in the medium without the addition of wax ranged from 178 to 166 N. The observations were confirmed by a statistical analysis, which showed a significant effect of wax on texture (Table 2). A study by Chauhan et al [2022] also observed a reduction in the firmness of starchy snacks (Mathri) with an increase in the addition of carnauba wax in the frying medium. It can be speculated that the oleogel, forming an envelope that acts as a barrier to water, prevents starch retrogradation.

4. Acrylamide content in fried crackers

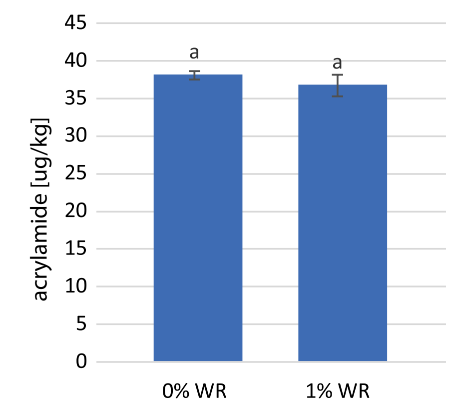
According to the Commission Regulation (EU) 2017/2158 of November 20, 2017, the level of acrylamide in potato snacks, such as roasting, should not exceed 750 μg/kg. In the analyzed HOSO-fried roasting roasted potatoes without and with the addition of wax, the average value of acrylamide was low compared to literature data and amounted to 38.1±0.6 and 36.7±1.4 μg/kg (Figure 4). In a study by Kita et al [2011], acrylamide was present in much higher amounts - 836 ppb - in potato crisps obtained by frying pellets in a mixture of palm and rapeseed fats. In contrast, the use of palm fat alone with the antioxidant TBHQ helped reduce its formation to 409 ppb.

There were no statistically significant differences between fried roasts with and without wax, indicating that this ingredient (in the amount of 1g/100ml HOSO) has no effect on the formation of acrylamide. This compound is one of the products of the non--enzymatic browning reaction - the Maillard reaction, which was confirmed by the BI values obtained in the study, which increased with frying time. In a study conducted by Verma and Yadav [2022], a significant correlation was found between acrylamide content and the browning index.

Table 2. Effect of wax addition and frying cycle (frying time) on parameters of color and hardness of the roasts

Wax content	Frying cycle	L*	a*	b*	BI	Hardness [N].
0%	1 (3h)	82.41± 1.55ab	-5,49± 0,20c	8.15± 0.69ab	5.17± 0.79ab	166± 32ab
	2 (6h)	83.14± 1.22ab	-5.73± 0.30ab	8.45± 0.68ab	5.29± 0.77ab	179± 23b
	3 (9h)	82.54± 1.44ab	-5.75± 0.30ab	8.41± 0.92ab	5.28± 1.04ab	167± 14ab
	4 (12h)	82,60± 2,39b	-5,43± 0,18c	9,47± 1,76c	7,03± 2,82c	176± 19ab
1%	1 (3h)	83,46± 1,75a	-5.77± 0.27ab	7,74± 0,98a	4,32± 1,04a	157± 18ab
	2 (6h)	83.11± 1.59ab	-5.57± 0.18bc	8.14± 0.73ab	5.04± 0.83ab	165± 27ab
	3 (9h)	83.12± 2.03ab	-5,88± 0,16a	8.99± 0.64bc	5,85± 0,73b	150± 21ab
	4 (12h)	82.29± 1.45ab	-5,88± 0,32a	9,67± 0,71c	6,82± 0,84c	145± 20a
p-value						
Wax		0,8649	**0,0011**	0,8514	0,8041	**0,0012**
Frying cycle		0,2062	0,9848	**0,0000**	**0,0170**	0,2919
Wax x fry cycle		0,2219	**0,0007**	0,2915	**0,0049**	0,5325

a, b, c - homogeneous groups determined using the Ducan test underlined and bold p-values are statistically significant



a - homogeneous groups determined by the Ducan test

Figure 4. Acrylamide content of the crackers in all frying cycles

5. Changes in the quality parameters of the frying medium

After each frying cycle, a fat sample was taken for a quality analysis, including the performance of the acid value (AV) and peroxide value (PV). An increase in AV was observed in both frying media, HOSO and oleogel. However, throughout the frying period (16 h), the level of free fatty acids remained low, given that its limit value for frying fats is 2.5 mg KOH/g fat [Regulation of the Minister of Health of September 25, 2012]. The value of this parameter for HOSO, before heating, was 0.30 mg KOH/g fat, while the highest AV of 0.48 mg KOH/g fat was observed for oleogel after 16 h of frying (Figure 5). A study by Romano et al [2021] observed an increase in free fatty acids from 0.09 to 0.15% after 16 hours of frying potatoes in high-oleic sunflower oil.

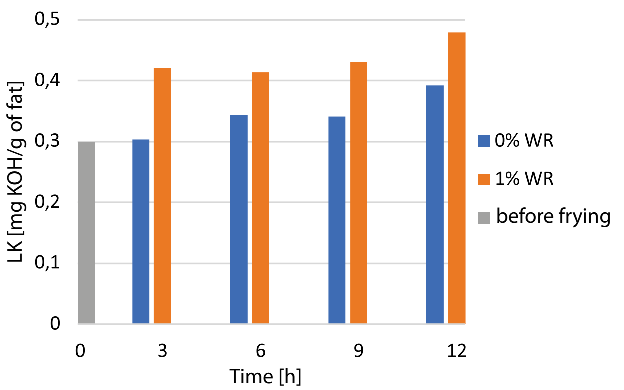


Figure 5. Changes in acid values (AV) during frying.

The PV indicates the presence of primary fat oxidation products. In the frying media analyzed, the LOO value was low (Figure 6). For high-oleic sunflower oil, the highest value of this parameter was 2.95 milliequivalent O_2/kg after 4h of frying, while for oleogel it did not exceed 1.61. In a study conducted by Romano, after 16 hours of frying potatoes, the PV of high oleic sunflower oil was 4.63 milliequivalent O_2/kg.

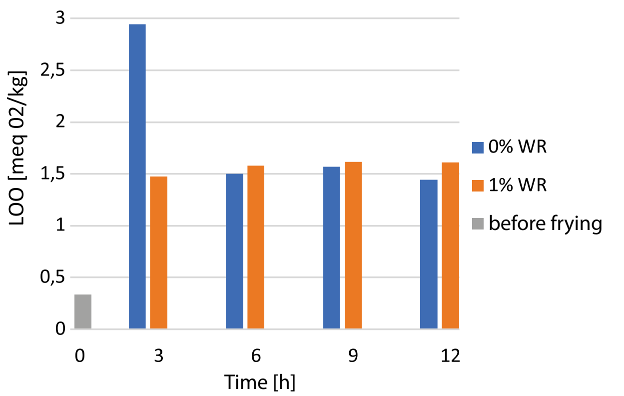


Figure 6. Changes in peroxide values (PV) during frying

Conclusions

There was no statistically significant effect of the addition of rice bran wax to high oleic sunflower oil on the absorption of the frying medium by the crackers. However, a trend toward lower fat absorption was observed, warranting further research in this area. Products fried in oleogel had a lower browning index, which may indicate that there were fewer Maillard reaction products and fat oxidation products contributing to the color change. However, the effect of rice bran wax, in the amount used, on acrylamide formation was not observed. High oleic sunflower oil and the oleogel obtained from it were characterized by very good quality parameters over the whole period. The increase in acid and peroxide value was relatively small after 16 h of heating (temperature 180° C), and their values did not exceed the limits set for frying fats.

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