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EFFECT OF ROASTING ON PROPERTIES OF WALNUTS

Agnieszka Kita[1], Adam Figiel[2]

[1]Department of Food Storage and Technology, [2]Institute of Agricultural Engineering; Wrocław University of Environmental and Life Sciences, Wrocław

Key words: roasting, walnuts, sensory and physical properties

The objective of this study was to compare properties of walnuts roasted at different technological parameters. Effects of roasting temperature (100-180°C), the roasting time (5-30 min) as well as the type of heating medium (hot air or boiled vegetable oil) on sensory and physical characteristics were determined. Experiment was conducted according to Response Surface Methodology. Nuts were analyzed for moisture content, colour, texture parameters, FFA and PV and sensory attributes.

It has been stated that properties of walnuts were dependent on temperature and time of roasting. As roasting temperature and time increased nuts moisture decreased. Nuts roasted in oil showed darker colour than the samples treated in hot air. The colour changed and was getting darker together with higher roasting temperature and longer roasting time. Nuts roasted in oil exhibited harder texture than those roasted in hot air. As roasting temperature and time increased nuts texture was more crispy and delicate, independently on type of roasting. Roasting influenced the quality of nuts oil fraction – in all analysed samples FFA content increased, however PV increased mainly in nuts roasted in oil. Samples roasted at 130-150°C for 15-20 min exhibited the best sensory properties in both methods. Nuts roasted at lower temperatures showed too hard texture, light colour and taste and flavour typical of fresh nuts. Nuts roasted at the highest temperatures and for longer time were too dark and exhibited burned taste and flavour.

INTRODUCTION

Roasting is one of the most popular methods of walnut thermal processing. It aims at the improvement of sensory properties through the change of colour, developing characteristic taste and flavour substances, as well as improving nut texture. In the course of roasting there are formed coloured Maillard compounds, resulting from the reaction between sugars and amino acids. The products of those changes are also compounds responsible for specific and slightly desirable flavour in roasted products [Saklar *et al*., 2001]. The decrease in water content effects texture alterations, which causes that, upon heating, nut texture becomes more crispy and delicate. Roasting also enables unification of raw material properties, which by their nature, are characterised by high diversity. Nuts originating from the same lot of ten differ in their shape, size, degree of maturity and moisture. Yet it is possible to obtain nuts featuring nearly the same properties if roasting parameters are appropriately assorted [Demir & Cronin, 2004]. However, thermal processing can lead to certain disadvantageous alterations in a roasted product [Bolton & Sanders, 2002]. It refers, first of all, to nut fat fraction, especially if it contains polyunsaturated fatty acids.

There can be distinguished two basic methods of nut roasting: roasting in oil and roasting in the air – so-called dry roasting. Following the first method, nuts are immersed in a vegetable oil heated to an appropriate temperature. When roasting is over, nuts undergo filtering off and oil is removed from their surface. Dry roasting involves a convection and microwave method. In the convection method nuts are heated by hot air of a proper temperature, moisture and, usually, of determined air flow speed. In a microwave method, which allows to considerably shorten the time of the process, an appropriate radiation power is asserted [Demir *et al*., 2003; Perren & Escher, 1997].

Nuts roasting is usually conducted within the range of temperatures from 100°C to 180°C and time from 5 to 60 min. Nowadays, the most commonly used industrial methods of roasting include roasting in hot air yet. Other methods are also applied depending on the way nuts are to be made use of [Özdemir & Devres, 2000].

Roasted nuts, without any additives or with spices, have become popular snacks. They constitute a valuable raw material in the industries like confectionery, bakery and others. Most often roasted are such nuts like peanuts, hazelnuts, almonds and pistachio nuts. Slightly more delicate walnut texture, as well as their irregular shape, make it more difficult to assort appropriate roasting parameters for those very attractive nuts from both sensory and health point of view [Caglarirmak, 2003]. Besides, relatively high content of polyunsaturated fatty acids, especially susceptible to oxidation alternations, requires application of mild roasting parameters (especially temperature) [Özdemir *et al*., 2001]. Therefore, this work is a trial of determining appropriate roasting parameters for walnuts roasted in oil and air.

Author's address for correspondence: Agnieszka Kita, Department of Food Storage and Technology, Faculty of Food Science, Wrocław University of Environmental and Life Sciences, Norwida 25, 50-375 Wrocław, Poland; tel.: (48 71) 320 50 38; fax: (48 71) 320 52 21; e-mail: kita@wnoz.ar.wroc.pl

MATERIALS AND METHODS

Materials. The material consisted of shelled raw walnuts bought from a local producer. Samples of walnuts halves (200 g, initial moisture content of 4.5%) were roasted in hot air (laboratory dryer, Poland) and boiled in rapeseed oil (electric fryer, Beckman, Italy). Walnuts were roasted at 100-180°C for 5-30 min. The experiment was conducted according to a central composite design.

Chemical analyses. Walnuts moisture content was determined using the gravimetric method. Fat content of walnuts was measured according to the Soxhlet's method. Fat was extracted using a Büchi B-811 Universal Extraction System (Büchi Labortechnic AG, Flawil, Switzerland). Two grams of sample were extracted for 180 min using diethyl ether as a solvent [AOAC, 1995]. Peroxide value (PV) and free fatty acids (FFA) content were determined in fat fraction of roasted walnuts according to AOAC standards [965.33, 940.28].

Texture analyses. Walnuts texture was determined using an Instron Model 5544 Universal Texture Analyser outfitted with an extensometer head of the range up to 2 kN. Single walnut halves were subjected to three point bending test and compressed between two parallel plates at the speed of 5 mm/min. Both tests lasted until the examined sample was damaged and they enabled determination of the maximum bending force Fg_{max} and the maximum compressive force Fc_{max}. Each measurement was conducted on 10 nut halves. Compressive strength examinations of walnuts were performed using a piston moving at the speed of 5 mm/min in a cylinder of 60-mm diameter and the same height [Kita & Figiel, 2006].

Colour analysis. The colour of walnuts was measured with the use of a Minolta Chroma Meter CR-200 Reflectance system. The device is a tristimulus colorimeter which measures four specific wavelengths in a visible range, specified by the Comission Internationale de l'Esclairage (CIE). Tristimulus data supply a three-dimensional value to equal perceived colour differences. The *L*, *a* and *b* values are three dimensions of a measured colour which gives specific colour value of the material. The *L* value represents light-dark spectrum with a range from 0 (black) to 100 (white). The *a* value represents green-red spectrum with the range from -60 (green) to +60 (red). The *b* value represents blue-yellow spectrum with the range from -60 (blue) to +60 (yellow). The measurements were conducted after milling walnuts to constant grind size on samples of 10 nuts from all roasting conditions [Özdemir & Devres, 2000].

The obtained results are presented as a function of frying temperature for mean frying time – 17.5 min on the basis of the obtained tri-dimensional model used in the experiment phase.

Sensory evaluation. Sensory attributes – colour, flavour, odour and texture – were assessed according to a five-grade scale (5 points – the best, 1 point – the worst). A panel of 10 panelist, ages 23-25 years (all students of the Faculty of Food Science), with sensory evaluation experience, was trained in descriptive evaluation of nuts.

Statistical analysis. The data were analysed statistically using Statistica ver. 6 programme (2001). For comparison, the results obtained were subjected to one-way analysis of variance with the application of Duncan's test ($p \leq 0.05$). To assess rank variables (sensory evaluation of nuts with the 1-5 scale), the non-parametric Kruskal-Wallis test was used. Homogenous groups were identified on the basis of the determined ranks.

RESULTS AND DISCUSSION

Moisture changes

Figure 1 presents changes in moisture content of walnuts roasted in oil and air. Regardless the method of roasting, as the temperature and roasting time increased, a decrease was recorded in walnut moisture content.

Fat uptake

In the course of roasting in oil there took place partial exchange of some mass between roasting material – nuts and a heating medium – oil. Roasting oil partly replaced evaporated water, which increased the content of fat fraction in nuts even by 5% and slightly altered their properties. The higher the roasting temperature (Figure 2), the higher fat absorption occurred.

Similar relations were recorded by other authors who compared fat absorption in different types of snacks fried at different temperatures. The higher the frying temperature, the higher the fat content to be found in the final product [Debnath *et al*., 2003; Gamble *et al*., 1987].

Since nuts were roasted in rape oil, the amount of, first of all, oleic and linolic acid in nut fat fraction increased (by 2% up

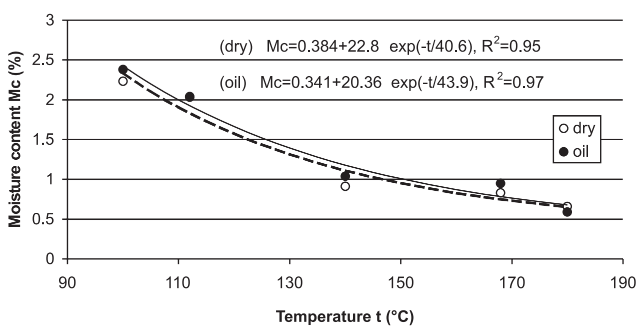

FIGURE 1. Moisture content (Mc) in walnuts roasted in oil and air.

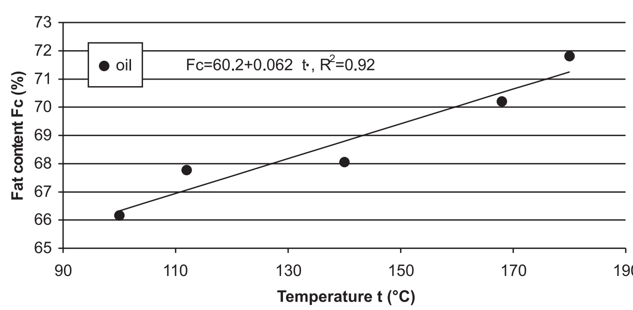

FIGURE 2. Fat content (Fc) in walnuts roasted in oil.

to 4% depending on roasting parameters, data not presented). In spite of the fact that alterations were not too big as roasting temperature increased, they could affect properties of nut fat fraction, *i.e.* free fatty acids FFA and peroxide content.

In all analysed samples FFA content increased and there were no significant differences between the roasting method (Figure 3). Although there was recorded a high content of polyunsaturated fatty acids in walnut fat fraction, roasting in the oil or in the air did not evoke considerable oxidation alterations, which was reflected by low peroxide values, not exceeding 1.5 at the temperature above 150°C (Figure 4). Yet, because of disruption of nut tissue structure in the process of roasting, one can expect oxidation alterations to take place more rapidly during nut storing than in raw nuts [Misra, 2004]. Similar results were obtained by Bolton & Sanders [2002] when roasting peanuts in two kinds of peanut oil. Roasting did not effect in the increase in peroxides content. The latter one did increase only while storing. A slight increase in peroxides content, however, was recorded by Adebiyi *et al*. [2002] in peanuts subjected to dry roasting.

Roasting considerably affected nut sensory properties and there were noticed some differences between nuts roasted in oil and in the air at the same parameters of the process (Table 1). One of the main purpose of nuts roasting is making their texture crispy and delicate. This property is highly complicated, determined by nut structure, shape, chemical composition, viscosity and other physical features. An appropriate texture depends on such factors as: raw material quality and kind, technological parameters applied during roasting of raw material, as well as changes proceeding in the course of storage (if the product is to be stored) [Saklar *et al*., 2003].

In the experiment carried out, roasting decreased nut hardness. The nuts roasted at the highest temperatures featured the most delicate and crispiest texture (Figures 5 and 6). Similar relations were stated by Saklar *et al*. [1999] when they compared hazelnuts texture roasted at different parameters according to the dry method.

When texture of nuts roasted according to the two methods was compared, it was recorded that nuts roasted in oil were characterised by a less delicate texture than those roasted in the air. Among nuts roasted in the oil, the samples featuring the lowest fat content and roasted in mildest conditions, had the hardest texture.

Similar dependencies between fat content and nut texture were recorded by other authors. For instance, when they were analysing the properties of fried snack products, *i.e.* crisps [Kita *et al*., 2007]. However, fat in nuts is contained, first of all, in storage cells – oleosomes and, in spite of a high content of this component, it affects nut structure in a different way.

The nuts roasted in the oil, although they featured higher hardness values, underwent more advanced deformation when compressed in mass, in comparison with those obtained from dry roasting (Figure 7). The cause of this phenomenon can be lower friction between the surface of nuts roasted in the oil, both between the nuts themselves as well as the nuts and a cylinder surface.

Alterations in nuts structure while roasting directly affect sensory impressions regarding nut texture. As far as sensory assessment is concerned, the highest score was assigned to the texture of the nuts roasted at lower temperatures (up to 140°C), while the method of roasting played a less important role (Table 1).

Colour measurements

Another nut property undergoing qualitative assessment was the colour. Experimentally, nut colour can be used as an effective control parameter since the content of coloured

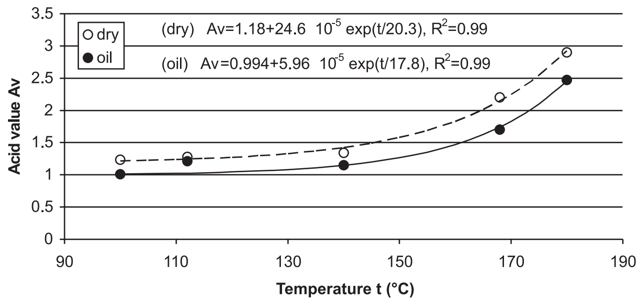

FIGURE 3. Acid value (AV) for walnuts roasted in oil and air.

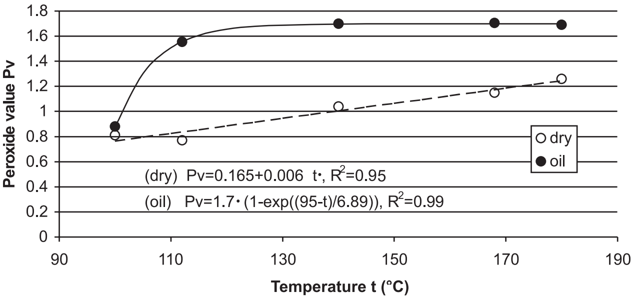

FIGURE 4. Peroxide value (PV) in walnuts roasted in oil and air.

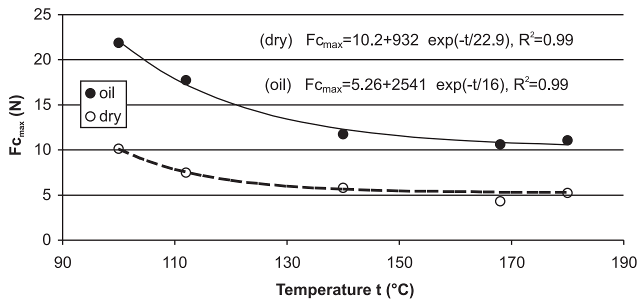

FIGURE 5. Maximum compressive force (Fc_{max}) estimated for walnuts roasted in oil and air.

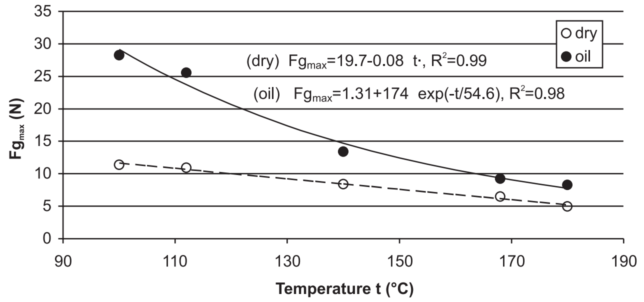

FIGURE 6. Maximum bending force (Fg_{max}) estimated for walnuts roasted in oil and air.

TABLE 1. Sensory quality of roasted walnuts at different parameters.

Roasting parameters	Colour (points 1-5)		Flavour (points 1-5)		Odour (points 1-5)		Texture (points 1-5)	
	oil	dry	oil	dry	oil	dry	oil	dry
112°C/9 min	4.25^{eA}	4.00^{eA}	4.00^{eA}	4.50^{fB}	4.50^{eB}	4.00^{fA}	4.00^{dA}	4.25^{gA}
168°C/9 min	3.75^{cA}	3.50^{cA}	4.00^{eA}	4.00^{dA}	3.75^{dA}	3.50^{dA}	4.25^{eB}	3.75^{eA}
112°C/26 min	4.75^{gA}	4.50^{fA}	4.75^{gA}	4.50^{fA}	4. 75^{fB}	4.25^{gA}	4.25^{eA}	4.50^{hA}
168°C/26 min	2.00^{bA}	2.00^{bA}	2.50^{bB}	2.00^{bA}	3.00^{bB}	1.75^{bA}	4.00^{dB}	3.50^{aA}
100°C/17.5 min	4.00^{dA}	3.75^{dA}	4.25^{fA}	4.50^{fA}	4.50^{eB}	4.00^{fA}	3.50^{bA}	4.00^{fB}
180°C/17.5 min	1.00^{aA}	1.00^{aA}	1.00^{aA}	1.50^{aB}	2.00^{aB}	1.50^{aA}	2.00^{aA}	2.00^{bA}
140°C/5 min	4.50^{fB}	4.00^{eA}	3.50^{dA}	4.25^{eA}	4.50^{eB}	3.75^{eA}	3.75^{cA}	3.50^{dA}
140°C/30 min	4.00^{dA}	3.75^{dA}	3.25^{cA}	3.50^{cA}	3.50^{cB}	2.50^{cA}	4.25^{eB}	3.00^{cA}
140°C/17.5 min*	5.00^{hB}	4.50^{fA}	4.75^{gA}	5.00^{gA}	5.00^{gB}	4.50^{hA}	4.25^{eA}	5.00^{jB}

Lower-case letters indicate significant differences in columns ($\alpha \leq 0.05$); capital letters indicate significant differences between columns ($\alpha \leq 0.05$); * mean values of 5 replications

substances increases as the reaction of browning and caramelization advances. Non-enzymatic browning depends on temperature and water activity of food. Roasted nuts colour can also be affected by nut brand and maturity, moisture content and nuts size. Therefore, roasted nuts selection exclusively on the basis of colour criterion can lead to taste insufficiencies [Sanders *et al*., 1989].

The results of colour measurements with the use of Minolta CR-200 chromameter were presented in Figures 8-10. Roasting did significantly effect colour intensity (*L*). In the nuts roasted in the oil *L* value ranged from 19 to 58, while those roasted in the air showed the values from 20 to 60. The values *a* and *b* were the lowest for nuts roasted at the highest temperatures.

The observations by Saklar *et al*. [2001] were quite alike. The team compared the colour of hazelnuts resulting from dry roasting. The *L* value decreased in the course of roasting, which resulted from non-enzymatic browning, while the values *a* and *b* increased as the temperature, speed of air flow and roasting time increased. Özdemir & Devres [2000] compared the colour of dry roasted hazelnuts at the temperature of 100-160°C in different time. They stated that as roasting time increased the colour became less intensive, while higher contribution of red colour (an increase in *a* value) in the nuts roasted at the highest temperatures could be recorded. Yet they did not observe any relation between *b* value and temperature as well as roasting time. Similar results were reported by Moss & Otten [1989] for peanuts.

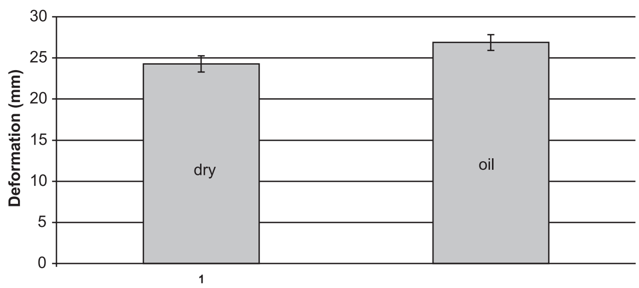

FIGURE 7. Deformation of walnuts roasted in oil and air during compression in cylinder.

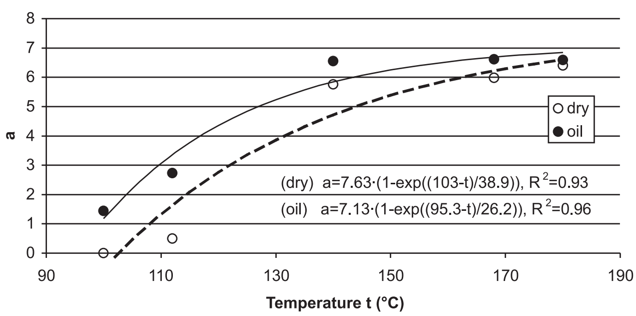

FIGURE 9. Value a for walnuts roasted in oil and air.

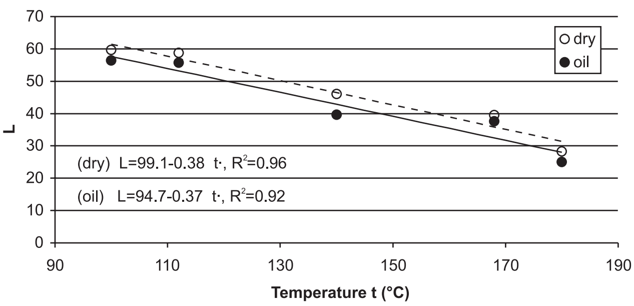

FIGURE 8. Value L for walnuts roasted in oil and air.

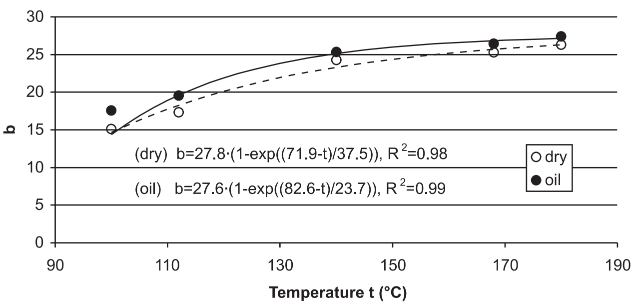

FIGURE 10. Value b for walnuts roasted in oil and air.

In the experiment conducted, nut colour became darker as the roasting temperature and time increased. The nuts roasted at the highest temperatures and the longest time, regardless the method, featured dark brown colour and they were not accepted in the view of sensory assessment (Table 1). The most appropriate colour – slightly darker than that of raw nuts, was observed in the nuts roasted at the temperatures up to 140^{o}C. The nuts roasted in the oil featured a bit darker colour as compared to the ones roasted in hot air, regardless the temperature and roasting time.

Taste and flavour

Roasting did considerably affect the taste and flavour of the nuts obtained. Better taste and flavour, in comparison to raw nuts, showed the nuts roasted at lower temperatures which were assigned the score of more than 4 points (Table 1). As the temperature and roasting time increased the nuts became more and more bitter, while their flavour could be described as strange and unpleasant.

CONCLUSIONS

Walnuts subjected to roasting within an appropriate temperature range and time feature improved texture, more attractive colour, as well as more favourable taste and flavour. Because of high fat content in nuts and more advantageous sensory properties obtained, it is advisable to roast walnuts at lower temperatures. The way of roasting – either in the oil or in the air – also plays an important role in shaping the properties of a ready product. The method of roasting should be chosen on the basis of the way nuts are to be used.

The best sensory properties exhibited the samples roasted at 130-150^{o}C for 15-20 min in both methods. Nuts roasted at lower temperatures showed too hard texture, light colour as well as taste and flavour typical of fresh nuts. Walnuts roasted at higher temperatures and for longer time were too dark and featured slightly burned taste and flavour.

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WPŁYW PRAŻENIA NA WŁAŚCIWOŚCI ORZECHÓW WŁOSKICH

Agnieszka Kita[1], Adam Figiel[2]

[1]Katedra Technologii Rolnej i Przechowalnictwa, [2]Instytut Inżynierii Rolniczej; Uniwersytet Przyrodniczy we Wrocławiu

Celem pracy było porównanie właściwości orzechów włoskich prażonych w gorącym powietrzu i w oleju oraz określenie optymalnych parametrów prażenia w zależności od rodzaju medium grzejnego.

Materiałem użytym do badań były świeże, po wstępnym podsuszeniu, łuskane orzechy włoskie w formie połówek. Orzechy poddano prażeniu w oleju oraz w gorącym powietrzu w różnych temperaturach (100-180^{o}C) i różnym czasie (5-30 min). W orzechach oznaczono wilgotność, zawartość tłuszczu, konsystencję, barwę oraz cechy organoleptyczne. W tłuszczu wyekstrahowanym z orzechów oznaczono liczbę kwasową i liczbę nadtlenkową.

Stwierdzono, że właściwości orzechów włoskich zależały od temperatury i czasu prażenia. Wraz ze wzrostem temperatury i czasu prażenia wilgotność orzechów ulegała obniżeniu. Orzechy prażone w oleju charakteryzowały się wyższą zawartością tłuszczu w porównaniu z orzechami prażonymi w gorącym powietrzu. Rodzaj i parametry prażenia wpłynęły na właściwości frakcji tłuszczowej orzechów – liczba kwasowa zwiększyła się we wszystkich analizowanych próbach, natomiast liczba nadtlenkowa tylko w orzechach prażonych w oleju. Wraz ze wzrostem temperatury i czasu prażenia pociemnieniu ulegała barwa orzechów. Niezależnie od parametrów prażenia ciemniejszą barwą charakteryzowały się orzechy prażone w oleju. Orzechy prażone w oleju charakteryzowały się bardziej twardą i mniej delikatną konsystencją w porównaniu z orzechami prażonymi w powietrzu. Wraz ze wzrostem temperatury i czasu prażenia, niezależnie od metody, konsystencja orzechów stawała się bardziej krucha i delikatna. Najlepszymi właściwościami organoleptycznymi charakteryzowały się orzechy prażone obiema metodami w temperaturze 130-150^{o}C przez 15-20 min. Orzechy prażone w niższych temperaturach były zbyt twarde, o jasnej barwie oraz smaku i zapachu typowym dla orzechów świeżych. Orzechy prażone w wyższych temperaturach i przez dłuższy czas charakteryzowały się zbyt ciemną barwą i przypalonym smakiem.