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Oak acorn, polyphenols and antioxidant activity in functional food

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Abstract

In this paper, are presented the results of physical and chemical investigations of differently treated samples of oak acorn. The aim of this investigation is to estimate the influence of thermal treatment on physical and nutritive characteristics of investigated samples. Oak acorn, *Quercus robur*, (belonging to *Fagaceae* family) was investigated in native and thermally treated forms. By subsequent extraction of dry toasted oak acorn (*Quercus semen tostum*) the aqueous extract was obtained which is then dried in a spout-fluid bed. The content of total polyphenols, then polyphenols unadsorbed on hide powder and tannins was determined by spectrophotometric methods with phosphor-wolfram acid according to Ph. Yug. V. Galic acid was determined by HPLC. The total antioxidant activity (TAA) of the aqueous extract compared to the control samples of pigs fat and synthetic antioxidant butylated hydroxyanisole BHA was estimated by Schall–Oven test at 60 ± 1 °C in dark, and oxidative changes were determined by measuring the Peroxide value (PV). For determination of macro- and microelements the method of AAS was used.

By detecting the changes of PV it is established that aqueous extract was influencing the stability of pigs fat, that is, showing the antioxidant activity. The activity was increasing with increasing concentration in tested samples. The obtained results regarding the total polyphenols content, the content of galic acid, nitrogen compounds, macro and microelements show that acorn, after treatment, was retaining and in some cases improving its functional properties.

Keywords: Acorn; *Quercus robur*; Total polyphenols; Tannins; Functional foods; Thermal treatment; Spout-fluid bed; HPLC

1. Introduction

Acorn have been a part of the local diet for some time, furnishing up to 25% of the food consumed by the porer classes of Italy and Spain (Hill, 1937). They are consumed in the form of bread cake and as a coffee substitute (Fernald & Kinsey, 1943). The use of acorn in the human diet has been reported since the end of the 19th century in Serbia (Pelagić, 1893), with recommendations about its application and beneficial action. The preparation of drinks based on thermally treated acorn (dry roasting) was especially recommended for children. There are data in the current literature on the antioxidative action of some acorn components (Lee, Jeang, & Man-Jinoh, 1992; Chiou, 1989). Antioxidant activity is a fundamental property important for life. Many biological functions, such as antimutagenity, anticarcinogenity and antiaging among others, originate from this property (Cook & Samman, 1996). The important group of pharmacologically active and therapeutically useful secondary metabolites of herbals consist of glycosides. Basically, these are sugar complexes (glycones) with some other organic non-sugar compounds (aglycones). The connections of these two parts is enabled by

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ether-glycoside bond. As aglyconic component of glycosides the molecules of flavonoides appear which represents the largest group of herbal polyphenols (Kovačević, 2000). This group of polyphenols contains most certainly tannins which are very abundant in the herbal world (Gorunović & Lukić, 2001). Recent investigations connected to antioxidant activity and polyphenols for a number of herbals that are used in fighting cancer, show that polyphenols, that is flavonoids, tannins and phenolic acids are carriers of these properties (Wei & Shiow, 2001; Ming et al., 2002; Sakakibara, Honda, Nakagowa, Ashida, & Kanazawa, 2003; Cai, Sun, & Corke, 2003; Yizhong, Qiong, Mei, & Harold, 2004; Ferrari, 2000; Goun et al., 2002).

Acorn has a high moisture content and for long term storage the moisture content must be reduced to below 10–15 mass.%. Acorn may be used as an additive to dough, for the preparation of bread. When roasted and chopped (*Quercus semen tostum* or *Glandes Quercus tostea*) it is administered as an astringent and antidiarrhoeal (Gorunović & Lukić, 2001). Besides biologically nutritious components, acorn also possesses biologically active substances that enable the utilization of acorn in the preparation of functional foods (Lee et al., 1992; Chiou, 1989; Rakić, 2000; Cantos et al., 2003; Rakić, Maletić, Perunović, & Svrzić, 2004). Phenolic compounds from the oak wood were investigated (Fernandez de Simon, Cadahia, Conde, & Garcia-Vallejo, 1999; Cadahia, Munoz, Fernandez de Simon, & Garcia-Vallejo, 2001) and bark (Andrenšek et al., 2004).

The term functional food was first presented in Japan in 1980s. The Institute of Medicine's Food and Nutrition Board defined this term as "any food or food ingredient that might provide a health benefit beyond the traditional nutrients it contains" (Claire & Hesler, 1998; Ferrari, 2000; Ferrari & Torres, 2003). The worldwide nutritional health products (NHPs)market, which includes organic food, nutraceuticals, functional food and dietary supplements, has become an extremely fast growing market. Consumers' confidence and attitudes towards herbal supplements are generally on the rise, indicating an important growth demand (Molyneaux, 2002) Some previous results on acorn indicated that the ethanolic extracts of thermally treated acorn have increased protective properties in regard to lipids compared with native samples (Rakić et al., 2004).

2. Materials and methods

2.1. Materials

The representative sample used in this investigation was the *Quercus robur* acorn, which belongs to the *Fagaceae* family. The fruit was collected in October 2003. Healthy, ripe nuts that had fallen to the ground, without mechanical or other damage, were collected by the Ada Ciganlija lake in Belgrade. Regarding the high moisture content (more than 30 mass.%), the samples were first dried in an oven at 50 °C for 12 h to prevent spoilage during storage. All reagents and chemicals used in the experimental work were of analytical grade. BHA, galic acid, and hide powder are from Sigma Aldrich Co. (USA). Sodium wolframate, potassium iodide, sodiumthiosulfate and phosphoric acid are from Lachema, (Czech Republic), and starch (pro analysi) from Merck-Alkaloid (Former Yugoslav Republic of Macedonia).

2.2. Thermal treatment

The thermal treatment consisted of "dry roasting" of the samples, previously crushed in a mortar, at 200 °C for 15 min. The aqueous acorn extract was obtained after thermal treatment and milling in a Buehler MLU202 laboratory mill (Switzerland) in a 2 l glass round bottomed vessel equipped with a reflux condenser for 30 min after the sample started boiling. Distilled water was used as the solvent.

2.3. Physical and chemical characteristics

The acorn samples were characterized physically by determining the number of nuts in 1 kg, the mass of 1000 nuts and the ratio of the shell and the nut. The chemical analysis consisted of determining the moisture content (at 105 °C to constant mass) and the protein content according to Kjeldahl by applying a semi-micro procedure using a "Tecator-Kjeltec System 1002" apparatus. The ash content was determined by heating at 800 °C to constant mass (Kaluđerski & Filipović, 1998).

2.3.1. Determination of total polyphenols, polyphenols unadsorbed on hide powder and tannins

This determination was performed by the spectrophotometric method with phosphorus tungstic acid according to Yugoslav Pharmacopoeia (Ph. Yug. 5., Vols. 1–3, 2001) at apparatus JENWAY B6105 UV/Vis at wave length 715 nm. The results were calculated with regard to the dry matter.

All the extraction and dilution procedures were performed with light protection. Stock solution was prepared from 0.75 g of milled sample mixed with 150 ml of water, treated at the water bath for 30 min, then cooled and water added up to 250 ml of solution followed by filtration. Total polyphenols were determined from 5 ml aliquot of stock solution diluted to 25 ml. An aliquot of 5 ml of formerly prepared solution is mixed with 1 ml phosphorus tungstic acid and 50 ml (150 g/l) of sodium carbonate solution. The adsorption was read after 2 min at 715 nm (A_1) using water for compensation. Polyphenols unadsorbed on hide powder

was determined from 10 ml of stock solution with addition of 0.1 g hide powder vigorously mixed for 60 min, and filtrated. From this filtrate aliquot of 5 ml is diluted to 25 ml with water, and further procedure for adsorption reading is the same as described with determination of total polyphenols (A_2). Standard pyrogallol solution was prepared from 50 mg pyrogallol in water diluted up to 100 ml. An aliquot of 5 ml of this solution is diluted with water and made up to 100 ml. 5 ml of thus prepared solution is mixed with 1 ml of phosphorus tungstic acid and 50 ml (150 g/l) of sodium carbonate solution. The adsorption was read after 2 min, and not after more than 15 min after pyrogallol dissolution, at 715 nm (A_3).

The tannin content is determined according to the following relation:

$$\%\ \text{tannin} = \frac{13.12(A_1 - A_2)}{A_3 \cdot m},$$

where m is sample mass in grams.

2.3.2. Identification of galic acid

This identification was performed by HPLC at apparatus Agilent 1100 with UV detector (DAD). The samples were previously dissolved in mobile phase and then filtrated through membrane filter with an aperture size of 0.45 μm. Reversed phase HPLC was performed with an isocratic elution (1.0 ml/min flow rate) using Phosphate buffer: Acetonitrile (95:5) solution as eluent. The pH of the solution was adjusted to 4.5 by using concentrated H_3PO_4 Zorbax Eclipse XDB-C8 column having dimensions 150×4.6 mm SbAq 250×4 mm with particle size 5 μm. Quantification was performed by external calibration with galic acid standard at $\lambda = 272$ nm. The analyses were performed at room temperature. The results were calculated with regard to the dry matter.

2.3.3. The preparation of the model sample and determination of antioxidant activity

The aqueous extract (the extraction procedure is explained earlier) from thermally treated acorn and synthetic antioxidant (BHA) in amounts of 0.02% were added to pigs fat that did not contain additives. The antioxidant activity and the concentration influence of 0.02% and 0.04% of aqueous extract compared to control sample, were investigated. All tests were performed on duplicate samples of pigs fat. Fat (20 g) was measured in open glass goblets (50 ml) and thermostated at 60 °C in dark for 10 days. Schall–Oven test was performed at 60 ± 1 °C in dark, and oxidative changes were detected by measuring of the peroxide value (PV) according to standard JUS ISSO 3960 from 2001. Investigation included also BHA concentration of 0.01% and the control without additives. Fat was sampled on a daily basis as well as measuring of the PV.

2.4. Determination of the macro-and microelements

Various methods were used to determine the macro- and microelements. The plant samples were dried and milled to a powder. Preparatory chemical analysis was performed by the method of "dry burning" at 500–550 °C (Jones & Case, 1990), after which the samples were transferred to an acidic solution (HCl) and filtered (2×5 ml of HCl was evaporated, washed with another 5 ml of HCl and quantitatively transferred into 50 ml flask). Phosphorus was determined from this solution (with concentration 2.50 g/100 ml) colorimetrically by the vanadate-molybdate method. Potassium was determined from the same solution by a flame photometer. The AAS method using a Varian 1200 AA atomic absorption spectrometer was applied to determine Ca, Mg, Zn, Mn, Fe and Cu from the same solution (Jakovljević & Blagojević, 1998). The results were calculated with regard to the dry matter.

2.5. Drying of the extract suspension in a spout-fluid bed dryer with a draft tube

The liquid extract was dried in a dryer with a spout-fluid bed with a draft tube, Fig. 1. The drying process in the spout-fluid bed with the draft tube is performed in such a manner that the bed of inert particles is established with hot air, to attain the corresponding temperature regime. Suspension is introduced into the bed through the twin fluid nozzle at the top of the annulus. Due to intensive circulation of the bed particles, in the annulus downward and through the draft tube upward, the suspension is dispersed, and a thin film coat of the liquid forms on the surface of the particles. During the residence in the bed, the film dries, and is carried into the spout, where the contact with the hot air is intensified. During the residence in the draft tube the film is completely dried, and the scum of dry material is formed on the particles surface. In the zone above the spout, due to fluid-particle, particle–particle drag forces and inertion forces from the impact with the deflector, positioned above the draft tube in the fountain zone, the scum is detached from the particles and carried away in the air stream to the collector. The particles are retained in the bed for repetitive wetting.

For the formation of the bed, air at room temperature was used, with a characteristics: air density $\rho_f = 1.204$ kg/m^3, specific heat $C_{pf} = 1.00$ kJ/kg °C, air viscosity $\mu_f = 1.78 \times 10^{-5}$ Pa s, air humidity $x = 0.011$–0.013 kg H_2O/kg air. Polyethylene particles were used as the column packing (particle diameter $d_p = 3.2$ mm, particle density $\rho_p = 940$ kg/m^3, velocity at minimum fluidization $U_{mF} = 0.78$ m/s, terminal velocity $U_t = 8.7$ m/s, bed porosity $\varepsilon = 0.35$, particle sphericity $\phi = 0.87$).

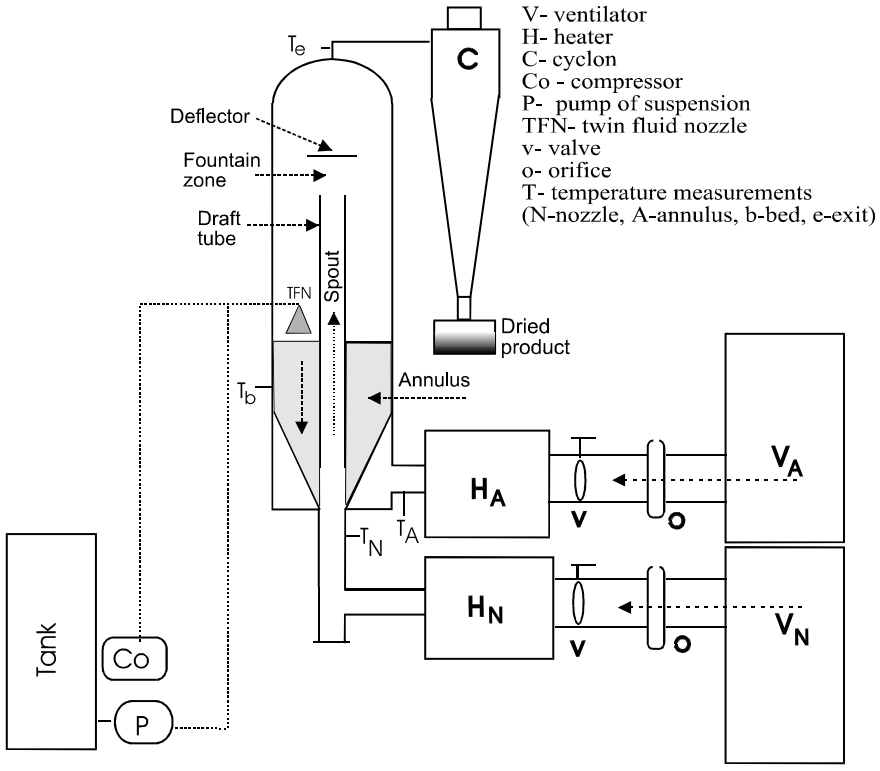

Fig. 1. Spout-fluid bed dryer with a draft tube.

The central part of the experimental unit dryer was a column of 250 mm diameter and 1.5 m height, which had a perforated conical bottom at an angle of 45°. A tube of 65 mm diameter and 600 mm length was positioned in the column axis 5 cm from the bottom of the column. The spout-fluid bed was formatted by air introduced into the column through two separated inlet streams, nozzle stream (N) and annular stream (A), Fig. 1.

The nozzle, internal diameter of 50 mm, was positioned axially at the bottom of the column, while the annular inlet zone was set on the bottom of the column, below the perforated cone.

Air was introduced to the column by 2.2 kW ventilators, V_N and V_A, for the nozzle and annular inlet stream, respectively.

The airflow rate was measured by standard orifices, (o), and regulated by valve (v), positioned on the tubes just in front of the heat exchangers.

Heating of air was done by an electrical exchangers of 11 kW, (H_N and H_A) for each stream, respectively.

During the drying process, the extract suspension was pumped by a membrane pump (P) to the twin-fluid nozzle (TFW) where it was dispersed by compressed air (Co), at the top of the annulus. After a drying of suspension in the bed, dried powder is separated in a high efficient cyclone (C).The drying parameters were the following: mass air flow on the nozzle flow 100 kg/h at 140 °C, mass air flow on the annular flow 150 kg/h at 120 °C, while the bed temperature was maintained at 70 °C.

2.6. Data and statistical analysis

The obtained experimental data were processed using mathematical-statistical methods (SAS Institute Inc., JMP^R, 1995). The relative dependence between investigated traits were defined. The obtained coefficients were tested (correlation and determination) by *t*-test for the risk level of 5% and 1%.

3. Results and discussion

The investigations encompassed the following samples: native *Quercus robur* acorn, thermally treated (dry roasting) samples, and samples obtained in a spout-fluid bed. The basic physical characteristics of the investigated samples are presented in Table 1.

Sample 1 is dried acorn nut, roughly crushed in a mortar and milled in a laboratory mill, in powder form, light brown colored. Sample 2 is acorn nut thermally treated at 200 °C for 15 min and then milled in a laboratory mill, in powder form, dark brown colored. Sample 3 is a dry powder obtained by drying the aqueous extract, obtained from thermally treated acorn nut, in a spouted bed.

The physical characteristics of the starting material are important for several reasons, foremost the nut

Table 1
Characteristics of the analyzed samples

	Treatment	Appearance
Sample 1	Dried and milled nut	Light brown powder
Sample 2	Thermaly treated nut at 200 °C–20 min	Dark brown powder
Sample 3	Dried of suspension of water acorn extract	Brown powder

collecting procedure, including the mechanical separation of the shell from the nut, drying and crushing or milling. The basic physical properties of the collected acorn nuts are presented in Table 2.

The samples were subjected to critical temperature conditions that led to more severe hydrolytic reactions, the degradation of existing, and the formation of new, compounds is within a broader research program of studying the changes in chemical composition of acorn subjected to thermal treatment (dry roasting), hydrothermal treatment (preparation of aqueous extract), as well as drying of solution (fluidized dryer). The changes in the content of the nitrogen-containing and tannin fractions were of particular interest. The results of the changes in the chemical composition during the described procedures of *Quercus robur* acorn treatment are presented in Table 3.

The moisture content of the investigated samples was found to lie in the acceptable limits. To ensure safer and longer storage, the acorn samples were dried immediately upon collection and the moisture content lowered to 7.89%, sample 1. This values lies within the limits that enable safe storage. The thermally treated acorn samples, sample 2, had acceptable values within the limits for safe storage, under the applied experimental conditions. It is significant that the dry aqueous extract, sample 3, was not too hydrophilic and that the moisture content was 3.7% lower than the limiting values required for its stability.

The value of the total ash for sample 1, was in agreement with previous results (Chiou, 1989; Rakić, 2000), while there was a slight increase in the value in the case of sample 2, which might be explained by the loss of organic matter in favor of mineral matter during thermal treatment. Sample 3 showed a high mineral content

Table 3
Chemical characteristics of oak acorn *Quercus robur*

Sample	Moisture (%)	Ash (%)	Protein (%)	Dry extract (%)
Sample 1	7.89	2.0773	4.18	29.41
Sample 2	1.96	3.3390	4.51	18.21
Sample 3	3.72	8.4169	14.06	–

compared with other samples. Generally, it may be concluded that the applied procedures considerably affected the ash content, which indicated the need for further detailed investigations related to determinations of micro- and macroelements. The total protein content, expressed as the total nitrogen content, was also determined. The mean value of the total protein content, calculated with regard to the dry matter, was somewhat lower for sample 1 in comparison to previous results (Rakić, 2000). This might be explained by the difference in location, year of harvest and environmental conditions. There was a slight increase in the value for sample 2 which was the consequence of the treatment favoring the total proteins and their stability during this process. Sample 3 had a quite high protein content as compared with the total product mass, which was a positive aspect of the process because it enabled not only the maintenance, but also the production of a product with a higher content of these very important food components. The results regarding protein and mineral content for sample 1 are accordant to the results from Saffarzadeh and collaborators who analysed the acorns from Mediterranean climate region (Saffarzadeh, Vincze, & Csapo, 1999). On the basis of three parallel determinations it is confirmed that the native seed *Qercus robur semen* is giving 29.41% while thermally treated seed *Quercus robur semen tostum* 18.21% of aqueous extract.

Tannins are complex, polyphenolic, non-nitrogen-containing, non-toxic compounds with a harsh flavour. In Table 4. are presented the results of polyphenols content in investigated samples of oak acorn *Quercus robur.*

The correlation coefficient between total polyphenols and galic acid content is statistically important at a level of 98.1% and has a value of $R = 0.99$ with determination coefficient of $R^2 = 0.9801$. The correlation coefficient between polyphenols unadsorbed on hide powder and galic acid content is not statistically important with the value $R = 0.33$, and determination coefficient $R^2 = 0.1089$. The

Table 2
Physical characteristics of oak acorn, *Quercus robur*

Run	1	2	3	4	5
Lenght (cm)	3.59	3.61	3.6	3.62	3.6
Width (cm)	2.12	2.08	2.1	2.07	2.06
Number of bead in 1 kg	138.44	139.10	138.94	139.21	138.89
Mass of 1000 bead (kg)	7.22	7.19	7.19	7.18	7.19
Crust (%)	14.47	13.95	14.31	14.51	14.42
Nub (%)	85.53	86.05	85.69	85.49	85.58
Shape	Peaked cylindrical	Peaked cylindrical	Peaked oval	Peaked oval	peaked oval

Table 4
The content of polyphenolic compounds in oak acorn *Quercus robur*

Polyphenols content (%)				
Sample	Total	Unabsorbed on hide powder	Tannins	Galic acid
Sample 1	12.33	3.26	9.06	0.142
Sample 2	11.76	4.0	7.76	0.108
Sample 3	14.93	4.02	10.9	0.270

total tannins and galic acid are in correlation at level 97%, and with determination coefficient $R^2 = 0.9216$. In relation to starting material 1 the increase of the total polyphenols content for sample 3 is significantly larger for 21% while the increase of galic acid content for the same sample is even larger and has the value 91%. The authors who formerly investigated the correlation between total polyphenols and galic acid content in oak acorn from other species of acorn have also found a positive correlation (Lee et al., 1992).

The results indicate that acorn is a raw material rich in polyphenols and tannins. Thermal treatment leads to a decrease in the tannin concentration, while extract drying yields a somewhat higher content compared to the starting sample, due to concentration effects and the short drying time.

Potassium deficiency in the human body causes weakening of the musculature and may also lead to paralysis (Savićević, Đorđević, Kocijančić, Milošević, & Milošević, 1983). Table 5 shows the contents of Ca, Mg, P and K in the investigated acorn samples and the products obtained by "dry roasting" and by drying the extract in a spout-fluid bed.

The difference in the P content of native and thermally treated acorn is insignificant on a dry weight basis. The thermal treatment did not influence significantly the potassium concentration, but increased the Ca concentration from 0.1% to 0.62%, while the changes for Mg are from 0.04 to 0.05%. The water extraction of thermally treated oak acorn and solution drying are increases Mg, K and P concentrations which is important for this procedure of obtaining the final product. Ca is partially extracted by this procedure.

The role of oligoelements or trace elements in the human body is biocatalytical, so they have also been called inorganic vitamins. Fe is a constitutive part of hemoglobin and myoglobin, while so-called functional Fe is found deposited in the liver, spleen and bone marrow (Ferrari & Torres, 2003). The role of Cu is indispensible in the synthesis of hemoglobin and for the utilization of Fe by hematogenic organs. It is considered that Cu has a catalytic role in the bonding of Fe to globin and a significant role in the formation of erythrocytes (Leung, 1998; Gutteridge, 1995). Obtaining contents of Fe, Cu, Zn and Mn by analyzing samples 1, 2 and 3 are presented in Table 6.

The concentration of Fe in native and thermally treated samples is relatively high. Dry roasting considerably increased the concentration compared to the raw sample, which was not the case for the final product obtained upon extract drying in which the concentration decreased to almost half the value. The thermal treatment of acorn did not relevantly affect the Cu content in the case of samples 1 and 2, while the Cu content in the final product increased in the extract drying procedure. Similar results were obtained by other authors who investigated macro- and microelements from oak acorn (Saffarzadeh et al., 1999).

For the purpose of obtaining a more complete view of the chemical characteristics of oak acorn, we did the comparison with some most commonly used cereals in human food. These data are presented in Table 7.

Oak acorn *Quercus robur* has a lower protein content compared to cereals and is richer in Ca and K, and poorer in other investigated elements, while the Fe content is approximately the same as in sorghum and wheat.

Table 5
Content of Ca, Mg, P and K in native and in products obtained by "dry roasting" and by drying the extract in a spout-fluid bed

Macroelements (%)				
Sample	Ca	Mg	K	P
Sample 1	0.10	0.04	0.83	0.10
Sample 2	0.62	0.05	0.88	0.09
Sample 3	0.37	0.13	3.29	0.40

Table 6
The content of microelements in oak acorn *Quercus robur*

Microelements (mg/kg)				
Sample	Fe	Cu	Zn	Mn
Sample 1	41.00	5.50	6.50	3.00
Sample 2	68.50	6.00	7.50	3.50
Sample 3	22.50	12.50	25.00	7.00

Table 7
Chemical characteristics of oak acorn *Quercus robur* and some of the cereals

Feedstuffs						
Components	Acorn	Sorghum	Barley	Wheat	Ryse	Oat
Dry matter (%)	92.10	87.00	89.00	89.00	88.00	89.00
Crude prot. (%)	4.18	8.80	11.00	11.50	12.1	11.45
Ca (%)	0.1	0.04	0.03	0.05	0.06	0.06
P (%)	0.1	0.30	0.36	0.31	0.32	0.27
Mg (%)	0.04	0.15	0.14	0.10	0.12	0.16
K (%)	0.83	0.35	0.48	0.42	0.46	0.45
Fe (mg/kg)	41.00	45.00	78.00	40.00	60.00	85.00
Cu (mg/kg)	5.50	10.00	10.00	7.00	7.00	8.00
Mn (mg/kg)	3.00	15.00	18.00	24.00	58.00	43.00
Zn (mg/kg)	6.5	15.00	30.00	28.00	31.00	38.00

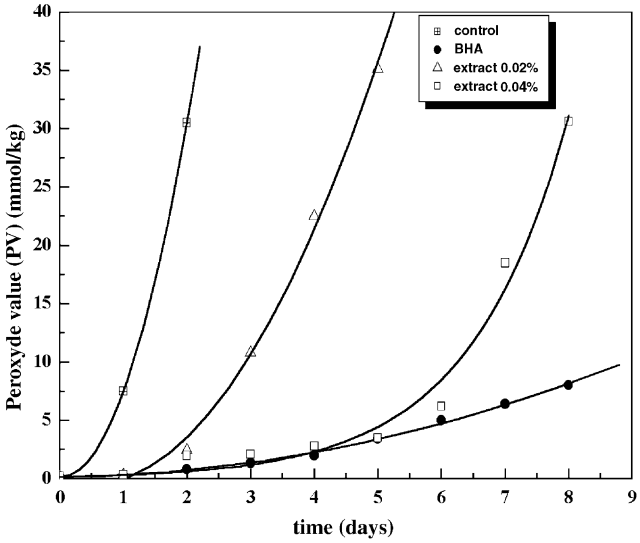

Fig. 2. Antioxidant activity of aqueous extract of oak acorn *Quercus robur* and BHA.

In Fig. 2 presents the influence of aqueous extract having concentration 0.02% and 0.04% of oak acorn, together with the synthetic antioxidant BHA at 0.02% concentration on PV value increment while keeping in dark at 60 °C, compared to control sample.

Peroxyde value (PV) at the beginning of the experiment was 0.21 mmol/kg. After the first day, the difference between samples appeared, when the control sample oxidates very quick and its PV is 7.5 mmol/kg and after the second day the value is increased up to 30.5 mmol/kg. The fat, containing the acorn aqueous extract was not different in PV from the PV of fat with BHA. At the second day, PV for the sample 2 was 2.47 while the value for BHA was 0.81. After 4 days the sample 2 oxidated very quickly when the PV value was increased to 22.5 while for the BHA it was 2.0. On the fifth day, the PV value for the sample 2 was over 30 and for BHA was 3.41. On the basis of the former it can be concluded that oak acorn aqueous extract showed antioxidant activity on pigs fat compared to the control sample and that the activity of BHA was more pronounced. The influence of concentration at antioxidant activity of oak acorn aqueous extract is evident. PV value for the 0.02% concentration was 35.1 mmol/kg on the fifth day while for the 0.04% was 3.53 mmol/kg and after 8 days its value increased to over 30 mmol/kg.

4. Conclusion

Oak acorn *Quercus robur semen* is characterized by its variety of nutritional, energetic and functional-protecting materials. Dry aqueous extract of thermally treated oak acorn seeds contains: 14.93% of polyphenols, 0.270% of galic acid, 14.06% of proteins, 8.4169% of crude ash, 0.37% of Ca, 0.13% of Mg, 3.29% of K, 0.4% of P, 41.00 mg/kg of Fe, 5.5 mg/kg of Cu, 25.00 mg/kg of Zn and 7.00 mg/kg of Mn. Antioxidant activity of the oak acorn aqueous extract, obtained by drying of solution in spout-fluid bed was evident compared to control sample of pigs fat. Antioxidant activity of acorn extract is influenced by its concentration. This antioxidant activity originates from the substances that are soluble in water. The significant statistical correlation between total polyphenolics and galic acid content was found at level 98.1% and has the value R = 0.99, with determination coefficient $R^2 = 0.9801$. The statistical correlation between polyphenolics not adsorbed at skin powder and galic acid is not significant ($R = 0.33$ and $R^2 = 0.1089$). The fruits of oak *Quercus robur* are shown as convenient nutritional components with antioxidant effects. The chemical composition of native and thermally treated oak acorn are pointing to acceptability of this material. The obtained results for dry oak acorn aqueous extract gave justifications for further investigations on its applicability as a functional food.

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