Quality of Pelleted Olive Cake for Energy Generation

Tea BRLEK [1] (✉)
Neven VOĆA [2]
Tajana KRIČKA [2]
Jovanka LEVIĆ [1]
Đuro VUKMIROVIĆ [1]
Radmilo ČOLOVIĆ [1]

Summary

Olive cake is by-product of olive oil production. This material cannot be stored in original condition for a long time because it has high water content and relatively high portion of oil that causes rapid deterioration. Thus it is necessary to investigate possible methods of remediation of such by-product, where utilization for energy generation presents a useful option. Several studies have been conducted on energy generation from olive cake, however not one that includes pelleting as a pre-treatment. Therefore, the aim of this paper was to determine the chemical composition of different cultivars of olive cake, to produce pellets, and determine their basic quality parameters. The pellets obtained from olive cake had mainly satisfactory results regarding their quality in comparison to standards for fuel pellets. It should be kept in mind that these standards are manly for wood pellets, and therefore some lower criteria could be applied for olive cake and such biomass. The highest amount of residual oil and the lowest amount of protein was found in cultivar 'Buža' and produced pellets had the smallest abrasion index (8.15%). Other cultivars had lower oil and higher protein content, and abrasion index higher than 10%. For these cultivars preparation of material (conditioning and/or binder adding) prior to pelleting is necessary. Higher heating value (HHV) and lower heating value (LHV) were not significantly influenced by different chemical composition of cultivars, thus attention should be paid on their influence on pelleting process.

Key words

olive cake, chemical composition, olive cultivars, pellets

[1] University of Novi Sad, Institute of Food Technology,
Bulevar Cara Lazara 1, Novi Sad, Serbia
✉ e-mail: tea.brlek@fins.uns.ac.rs
[2] University of Zagreb, Faculty of Agriculture, Svetošimunska 25, 10000 Zagreb, Croatia

Received: August 16, 2011 | Accepted: September 19, 2011

ACKNOWLEDGEMENTS
This paper is a part of the doctoral thesis of Tea Brlek, who is enrolled in doctoral study program at the University of Zagreb, Faculty of Agriculture. It is published within the bilateral project between Faculty of Agriculture, Zagreb and Institute of Food Technology, Novi Sad: "Possibility of energy – pellets production from grape marc and olive cake" (project leaders: Neven Voća and Jovanka Lević).

Introduction

The production of olive oil has raised over the past decade, as a result of objective circumstances: incentives (state, county and local), high price of oil, positive attitudes about olive oil nutritional value, the introduction of new technology of growing olives, a sufficient number of mills, etc. In Croatia, the annual production of olive oil is 5 to 5.5 million liters, with an average yield per tree from 3.1 to 11.6 kg of olives (Statistički ljetopis, 2009). In the production of olive oil three different technologies are used: traditional pressing technologies, a two-phase decanting system, and the three-phase decanting system (Koprivnjak, 2006).

Regardless the production system, a by-product similar to a paste is produced and it is called olive cake or pomace. Such material is difficult to manipulate, it dries slowly and many difficulties arise with its disposal (Fokaides and Tsiftes, 2007).

Olive cake is a mushy mass of pulp residues and pits of the fruit, which contains a large amount of organic substances, among which is about 4% of oil, what gives olive cake a high potential for energy production (Niaounakis and Halvadakis, 2006; Roig et al, 2006). Estimated quantity of waste generated in the production of olive oil in the EU is about 6.8 million tons per year (Taralas and Kontominas, 2006). Croatia produces about 30 000 tones of olives annually, which generates about 12 000 tones of fresh olive cake (Statistički ljetopis, 2009). The main chemical constituents of olive cake are cellulose, lignin, protein, oil, polyphenols and water, but chemical composition of individual cultivars could not be found in literature. The proportion of water varies depending on the process of olive processing, and it is lower in cake obtained by pressing, than in the one obtained by decanting process (Alburquerque et al., 2004).

Given the high proportion of water and still quite a high proportion of residual oil, crude olive cake cannot be stored in its original condition for long. If exposed to the air it quickly becomes rancid. Olive cake obtained by the process of decanting deteriorates after only 4-5 days, and the one obtained by pressing, after 14-15 days. The reason is high water content. Dry olive cake, according to the literature can be stored for about 45 days, while the de-oiled and dried olive cake can be stored for about a year (Kiritsakis, 1998). Olive cake spoils quickly because the high moisture content helps the hydrolysis of triglycerides, which causes a significant increase in acidity (Kiritsakis, 1998).

Because of these characteristics olive cake is a potential threat to the environment if disposed in an uncontrolled manner. Based on European Union regulations, organic waste cannot be disposed without its previous processing. For these reasons it is necessary to further analyze this material in terms of its chemical composition, as well as to investigate possible methods of remediation of such by-products, where utilization for energy generation presents a useful option (Voća et al., 2010).

The easiest way to generate energy from olive cake is direct combustion. Depending on the plant it can be incinerated in its original state, dried or pelletized. Several studies have been conducted on energy generation from olive cake (Al-Widyan et al., 2006; Atimtay i Varol, 2009; Caputo et al., 2003; Miranda et al., 2007), however not one that includes pelleting as a pre-treatment. Pelleting of biomass provides benefits in terms of higher bulk density, and at the same time higher heating value per mass unit. It also facilitates handling and transport. Therefore, the aim of this paper was to determine the chemical composition of different cultivars of olive cake, to produce pellets from olive cake, and to determine their basic quality parameters.

Material and methods

Olive cake was obtained from olive oil producers in Istria, Croatia. Olive oil is commonly produced as a mixture of cultivars, but for this investigation four different cultivars have been produced and analyzed separately: 'Pendolino', 'Leccino', 'Buža' and 'Istarska Bjelica'. The cake was from a mill that uses three-phase decanting system; therefore their by-product is cake which contains approximately 50% of moisture. Olive cake was dried in a dryer at 40°C, until it had moisture content of approximately 7%. The material was analyzed for dry matter content (NREL/TP-510-42621), ash content (NREL/TP-510-42622), crude protein (Kjeldahl method), crude fiber (AOAC 962.10), oil (ISO 734-1:2006), C, H, N (CEN/TS 15104:2005) and S (CEN/TS 15289:2006). Dried cake was milled on a hammer mill, with 4 mm sieve openings, and the material was rehydrated to 12% moisture and pelletized at the pilot plant of the Institute of Food Technology, Novi Sad, Serbia on a flat die pellet press 14-175, AMANDUS KAHL GmbH & Co. KG (Germany), using 6 mm die opening and thickness 48 mm. After pelleting, pellets were stored for 24 hours under room conditions in order to achieve stabile moisture and temperature. The obtained pellets were analyzed: bulk density, hardness, abrasion, density (CEN/TS 15150:2005), higher heating value (HHV) (determined by adiabatic bomb calorimeter IKA C 200), lower heating value LHV (CEN/TS 14918:2005), moisture content 24 hours after pelleting (NREL/TP-510-42621) and ash content (NREL/TP-510-42622). The length of pellets was also measured (a random sample of 15), with micrometer caliper. All analyses were made in triplicate, except hardness, which was done in ten replicates.

Bulk density was measured with a bulk density tester, Tonindustrie, West und Goslar, Germany. Pellet hardness was determined with "Pellet Hardness Tester", AMANDUS KAHL GmbH & Co. KG, Germany. The average of 15 mesurments is referred to as the "Kahl hardness" (KH) of the pellet. Abrasion of pellets was determined with "Pellet Durability Tester", Bühler, Switzerland.

Statistical Analysis System (Statistica, Tulsa, Oklahoma, USA) was used for analyzing variations (analysis of variance – ANOVA) and least significant differences (LSD). The level of significance was set at $p<0.05$.

Results and discussion

Results obtained from chemical analyses of raw olive cake, are shown in Table 1, and are expressed on a dry basis. The Table presents basic chemical composition and ultimate analyses of olive cake. All the parameters are discussed in further text.

Ph values are showing a slightly acidic reaction, except cultivar 'Buža' that had a neutral reaction. Ph values were significantly different among cultivars. Alburquerque et al. (2004), as well as Baeta-Hall et al. (2005), found acidic pH values for olive cake, as well, with average value of 4.9 and 5.32, respectively.

Table 1. Chemical composition of olive cake

Dry basis (%)	Pendolino	Leccino	I. Bjelica	Buža
pH	5.13±0.02 c	6.24±0.23 b	4.47±0.02 d	7.07±0.06 a
Crude protein	6.61±0.19 a	6.68±0.10 a	6.17±0.10 b	4.39±0.10 c
Crude fiber	38.91±0.04 a	40.72±0.04 a	40.09±0.08 a	40.34±0.03 a
Oil	4.50±0.02 c	4.58±0.07 c	6.28±0.02 b	9.74±0.04 a
Ash	1.60±0.03 c	1.56±0.02 c	1.84±0.01 b	2.07±0.07 a
C	55.19±0.77 a	56.64±0.56 a	55.54±0.72 a	54.21±0.63 b
H	7.79±0.27 b	8.10±0.08 a	7.38±0.34 b	7.52±0.24 b
N	1.06±0.03 a	1.07±0.02 a	0.99±0.02 b	0.70±0.02 c
S	0.084±0.01 a	0.083±0.01 a	0.069±0.01 b	0.068±0.01 b

The results are presented as mean±SD; Different letter within the same row indicate significant differences ($p \leq 0.05$)

Table 2. Results of the analyses of olive cake pellets

Parameter	Pendolino	Leccino	I. Bjelica	Buža
Bulk density (kg/m^3)	618.33±2.89 a	601.67±2.89 b	578.33±2.89 c	601.97±2.89 b
Hardness (KH)	9.46±2.70 a	10.32±1.79 a	9.30±1.68 a	7.33±0 .92 b
Abrasion (%)	11.22±0.09 c	15.22±0.03 a	13.52±0.39 b	8.15±0.03 d
Density (g/cm^3)	1.26±0.01 a	1.26±0.01 a	1.23±0.01 b	1.23±0.00 b
Length (mm)	7.35±0.54 b	7.51±0.34 b	10.87±0.36 a	7.17±0.23 b
Moisture (%)	7.48±0.01 a	6.65±0.04 c	7.10±0.01 b	5.03±0.02 d
Ash (%)	1.88±0.02 b	1.77±0.01 c	1.85±0.01 b	1.91±0.01 a
HHV (MJ/kg)	22.91±0.13 a	22.66±0.01 a	22.92±0.13 a	22.63±0.26 a
LHV (MJ/kg)	21.22±0.18 a	20.90±0.01 a	21.3±0.16 a	20.99±0.22 a

The results are presented as mean±SD; Different letter within the same row indicate significant differences ($p \leq 0.05$)

Protein content in samples was slightly above 6.00% in 'Pendolino', 'Leccino' and 'Istarska Bjelica' samples and 4.39 was determined for 'Buža'. Significant difference was found between cultivars, except between 'Pendolino' and 'Leccino'. All the values are in accordance with literature data, where Alburquerque et al. (2004) determined protein content from 4.3 to 11.5%.

Oil content was significantly different among cultivars, except 'Pendolino' and 'Leccino', whose oil contents were alike (4.50 and 4.58, respectively). The highest content was determined for 'Buža' (9.72 %). Tekin i Dalgıç (2000) determined oil content in olive cake to have an average value of 8.2%, Alburquerque et al. (2004) have had samples with oil content between 7.7 and 19%, and Fokaides and Tsiftes (2007) determined 6.68%.

Crude fiber content of the material was around 40% for all the samples. Cellulose along with lignin is a major chemical component in olive cake (Alburquerque et al., 2004; Niaounakis and Halvadakis, 2006).

Ash content of raw olive cake, was the highest in 'Buža' samples (2.07%), with significant difference determined among cultivars, except between 'Pendolino' and 'Leccino'. Average value of ash content in olive cake, in literature, is between 2.0 and 15.1% (Baeta-Hall et al., 2005; Alburquerque et al., 2004; Miranda et al., 2007; Al-Widyan, 2006).

The ultimate analyses results (C, H, N, S) were in accordance with available literature data (Al-Widyan, 2006; Chouchene et al., 2010; Miranda et al., 2007). A significant difference was found among cultivars mainly for nitrogen. Sulphur content was low, and this is important when using olive cake for energy generation through combustion, because sulphur creates SO_2, which contributes to acid rain formation. Nitrogen is also important to consider in the same manner, due to formation of NO_x, which causes environmental pollution. Carbon and hydrogen contents are linked to heating value of the biomass.

In Table 2 physical characteristics of olive cake pellets are given with respect to the cultivar of olives. According to desired use of pellets different characteristics are important. Olive cake pellets can be used as a fuel for biomass boilers, for energy generation, and were tested primary for that purpose in this study. However, olive cake pellets can also be used as a component in feed for ruminants (Brlek, 2010).

The lowest bulk density was recorded for 'Istarska Bjelica', and it was 578.33 kg/m^3, while all other cultivars had bulk density above 600 kg/m^3, what is in accordance to Swedish Standard SS 18 71 20, which defines quality parameters for fuel pellets. Bulk density impacts transportation and storage capacities selection (Obernberger and Thek, 2004).

Significant difference was determined in hardness only for 'Buža', which had the lowest hardness (7.33 KH), and that could be assigned to the highest oil content (9.74%), which could make the pellet softer, as well as the lowest protein content that acts as pellet binder (Thomas et al., 1998). Hardness is a parameter important for the nutrition of animals, and therefore is not of great importance for fuel quality. Nevertheless it can be mentioned that pellets obtained from olive cake in this study with the lowest hardness could be used as ruminant feed (Čolović et al., 2010). For the other cultivars adding water in to the raw-material or conditioning with steam could decrease the hardness (Vukmirović et al., 2010), making the pellets more suitable for animal feed.

Abrasion of pellets, with significant differences between all cultivar, was from 8.15 to 15.22 %, which is higher than proscribed by norms for pellet fuels: < 2.3% (ÖNORM M 7135). This could be lowered also by conditioning the material or by adding binder. Conditioning raises the moisture content of the material, as well as exposing it to higher temperatures, which facilitates particle binding (Thomas at al., 1997). This parameter has to be considered in transportation and combustion systems, while higher abrasion can cause malfunctioning of the feeding system. Higher abrasion also means larger dust emissions (Obernberger and Thek, 2004).

Density of the pellets didn't show significant difference between 'Pendolino' and 'Leccino' (1.26 g/cm^3), as well as between 'Istarska Bjelica' and 'Buža' (1.23 g/cm^3). This parameter is important for combustion properties as dense materials show longer burnout time (Obernberger and Thek, 2004) and the values were in accordance with ÖNORM M 7135 and DIN plus, 51731 (>1.12 g/cm^3).

Pellets obtained from 'Istarska Bjelica' were the longest (10.87 mm) while other cultivars didn't show significant difference (approximately 7 mm). The guiding value for length of fuel pellets, proscribed by ÖNORM M 7135 is <5x diameter, in this case 30 mm (6 mm-dimater x 5).

Pellet moisture content was below 10% (ÖNORM M 7135) from 5.03 to 7.48, with significant difference for all cultivars.

Ash content of the pellets was in range from 1.77 to 1.91%, which is higher than proscribed by standards (SS 18 71 20, ÖNORM M 7135) (max 1.5 % in SS 18 71 20) for fuel pellets. It is better for pellets to have lower ash content, while it cause slag and deposit formation in the combustion furnace, and demands emptying of the ash box (Obernberger and Thek, 2004).

Higher heating values (HHV) (gross calorific value) were just above 22.6 MJ/kg (dry basis), and are within the ranges determined for olive cake as a raw-material for combustion (Al-Widyan, 2006; Chouchene et al., 2010; Miranda et al., 2007). Lower or net heating values (LHV) were from 20.90 to 21.32 MJ/kg, which agrees with standards for fuel pellets (SS 18 71 20, ÖNORM M 7135, DIN plus, 51731; ≥18 MJ/kg), as well as with previous investigations (Al-Widyan, 2006; Chouchene et al., 2010; Miranda et al., 2007). Carbon and hydrogen content contribute positively to HHV, and therefore wood fuels have slightly higher HHV values (Obernberger et al., 2006). Owning to its high energetic values, olive cake can present great renewable energy source, and could be used in olive oil mills as energy for processing.

Conclusion

The results of chemical analyses of olive cake show that variations exist among different cultivars of olive cake, therefore it would be interesting to further investigate olive cake chemical composition, mainly for oil, crude protein and crude fiber content. Also the fibre content should be further analysed, in terms of total fibre content, as well as its components (cellulose, hemicelluloses and lignin), because olive cake is mainly lingo-cellulosic material. There is also considerable amount of residual oil in olive cake, which has in this study facilitate the pelleting process, and made possible for olive cake to be pelletized without any material preparation (conditioning and/or binder adding), due to lubricating effect, which makes the process more economical.

Ultimate analyses showed low sulphur content, what meets the fuel pellet standards criteria, and this makes olive cake an environment-friendly fuel.

Since there are no available data on chemical composition of individual cultivars of olive cake, this investigation contributes in that sense.

The pellets obtained from olive cake had mainly satisfactory characteristics regarding their quality in comparison to standards for fuel pellets. It should be kept in mind that these standards are manly for wood, and wood-residue pellets, and therefore some lower criteria could be applied for olive cake and other agricultural biomass pellets. Due to their high heating values olive cake pellets present a good fuel, which is ecologically beneficial and at the same time, gives a solution to a problem of olive cake utilization.

Differences among cultivars did not impact HHV and LHV but were important for pelleting process, especially the oil content.

References

Alburquerque, J.A., Gonzalvez, J., Garcıa, D., Cegarra, J. (2004): Agrochemical characterisation of "alperujo", a solid by-product of the two-phase centrifugation method for olive oil extraction. Bioresource Technology 91, 195–200.

Al-Widyan, M.I., Tashtoush, G., Hamasha, A.M. (2006): Combustion and emissions of pulverized olive cake in tube furnace. Energy Conversion and Management 47; 1588–1596.

Atimtay, A.T., Varol, M. (2009): Investigation of co-combustion of coal and olive cake in a bubbling fluidized bed with secondary air injection. Fuel 88, 1000–1008.

Baeta-Hall, L., Saagua, M.C., Bartolomeu, M.L., Anselmo, A.M., Rosa, M.F., (2005): Biodegradation of olive oil husks in composting aerated piles. Bioresource Technology 96, 1; 69–78.

Brlek, T.; Voća, N.; Krička, T.; Bilandžija, N.; Matin, A.; Jurišić, V. (2010): Technological properties and preparation of olive cake as a feed component. In: Lević, J. (eds) Proceedings XIV Interantional Symp Feed Tech, Novi Sad, Srbija: Institute for food technology, pp 150-157.

Caputo A. C., Scacchia F., Pelagagge P. M. (2003): Disposal of by-products in olive oil industry: Waste-to-energy solutions, Applied Thermal Engineering 23, 197–214.

Chouchene, A., Jeguirim, M., Khiarib, B., Zagroubac, F., Trouvea, G. (2010): Thermal degradation of olive solid waste: Influence of particle size and oxygen concentration. Resources, Conservation and Recycling, 54; 271-277.

Čolović, R., Vukmirović, Đ., Matulaitis, R., Bliznikas, S., Uchockis, V., Juskiene, V., Lević, J. (2010),: Effect of die channel press way length on physical quality of pelleted cattle feed, Food Processing Quality & Safety, Journal of Institute for Food Technology in Novi Sad Vol. 37, Br. 1, str. 1-6.

Fokaides .A. , Tsiftes, K. (2007): Utilisation of Olive Husk in energy sector in Cyprus, Renewable Energy Sources & Energy Efficiency, 28-30, Nicosia, Cyprus.

Kiritsakis, K.A.,: Olive oil – from the tree to the table, Food & Nutrition Press, Inc., Trumbull, Connecticut , USA 1998, 75 – 85.

Koprivnjak, O. (2006): Djevičansko maslinovo ulje od masline do stola, MIH, Poreč.

Miranda, M.T., Cabanillas, A., Rojas, S. , Montero, I. , Ruiz, A. (2007): Combined combustion of various phases of olive wastes in a conventional combustor. Fuel 86; 367–372.

Niaounakis M., Halvadakis P., (2006). Olive processing waste management, Elsevier, Oxford, UK, 23 – 64.

Obernberger I, Thek G. (2004): Physical characterisation and chemical composition of densified biomass fuels with regard to their combustion behaviour. Biomass Bioenergy; 27:653–69.

Obernberger, I. Thomas Brunner, T., Bärnthaler, G. (2006): Chemical properties of solid biofuels—significance and impact. Biomass and Bioenergy 30; 973–982.

STATISTICA (Data Analysis Software System), v.8.0 (2006). StatSoft, Inc, Tulsa, Oklahoma, USA (www. statsoft.com).

Taralas G., Kontominas, M.G. (2006): Pyrolysis of solid residues commencing from the olive oil food industry for potential hydrogen production. Journal of Analytical and Applied Pyrolysis 76; 109–116.

Tekin, A.R., Dalgıç, A.C. (2000): Biogas production from olive pomace. Resources, Conservation and Recycling 30; 301–313.

Thomas, M., van Vliet, T., van der Poel, A.F.B. (1998) Physical quality of pelleted animal feed. 3. Contribution of feedstuff components. Animal Feed Science Technology 70; 59-78.

Thomas, M., van der Poel, A.F.B. (1996): Physical quality of pelleted animal feed: 1. Criteria for pellet quality. Animal Feed Science Technology 61; 89-112.

Thomas, M., van Zuilichem, D.J., van der Poel, A.F.B. (1997): Physical quality of pelleted animal feed. 2. Contribution of processes and its conditions. Animal Feed Science Technology 64; 173-192.

Roig, A., Cayuela, M.L., Sanchez-Monedero, M.A. (2006): An overview on olive mill wastes and their valorisation methods. Waste Management 26, 960–969.

Statistički ljetopis, 2009, Hrvatski državni zavod za statistiku.

Voća, N.; Krička, T.; Brlek Savić, T.; Matin, A.; Jurišić, V. (2010): Residue after wine and olive oil production as a raw material for thermal energy generation. Časopis za procesnu tehniku i energetiku u poljoprivredi – Journal on Processing and Energy in Agriculture. 14, 2; 69-7.

Vukmirović, Đ., Ivanov, D., Čolović, R., Kokić, B., Lević, J., Đuragić, O., Sredanović, S. (2010): Effect of steam conditioning on physical properties of pellets and energy consumption in pelleting process, Journal on Processing and Energy in Agriculture 14, 106-108.

Analytical methods:

AOAC International, 2002. Official method of analysis, method 962.10, crude fiber.

ISO 734-1:2006. Oil seed meals, Determination of oil content.

CEN/TS 15104:2005. Solid biofuels, Determination of total content of carbon, hydrogen and nitrogen. Instrumental methods.

CEN/TS 15289:2006. Determination of total content of sulphur and chlorine.

CEN/TS 15150:2005. Solid biofuels. Determination of particle density.

CEN/TS 14918:2005. Solid biofuels. Method for the determination of calorific value.

NREL/TP-510-42622. Determination of Ash in Biomass.

NREL/TP-510-42621. Determination of Total Solids in Biomass and Total Dissolved Solids in Liquid Process Samples.

Pellet standards:

DIN 51731. Testing of solid fuels—compressed untreated wood, requirements and testing. Berlin, Germany: Deutsches Institut für Normung; 1996.

ÖNORM M 7135. Compressed wood or compressed bark in natural state—pellets and briquettes, requirements and test specifications. Vienna, Austria: Österreichisches Normungsinstitut; 2000.

SS 187120. Biofuels and peat—fuel pellets—classification. Stockholm, Sweden: Swedish Standards Institution; 1998.

---

acs77_07