iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5013

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Olive Cake as a Fuel: A Comparison with Lignite

Gulay Yakar[1], Burcin Deda Altan[2]
[1,2]Department of Mechanical Engineering, Faculty of Engineering, Pamukkale University, Kinikli 20070 Denizli, Turkey

***Abstract*: Olive cake as a solid waste is a fuel which is high in organic content and energy value, low in ash, sulphur dioxide emission and environmentally friend. In the analyses, both olive cakes processed from the seeds of black and yellow olives from south west region of Turkey, Aydın and lignite of Soma Eli and lignite of 0.18 Tuncbilek types of coal. Measurements show that yellow seed olive cake has the least ash content as low as 0.43 %. Although lower heating value of lignite is greater than that of olive cakes, it seems to be high enough in sulphur and ash contents. In addition, the ash content of another olive cake, mixed powder olive cake, has been determined as high as 2.13%.**
***Keywords:* Biomass, olive cake, coal, fuel characterization, energy**

I. INTRODUCTION

Energy demand is greatly affected by change in the world population and use of technological goods. Increasing trends of these factors require more and more energy despite fact that limited amount of fossil fuels will extinct in a near future. For this reason, human being need to consider other types of energy sources, especially the renewable one. One of the renewable energy sources is the biomass energy, which is most commonly used in the developed and developing countries.

Biomass is considered as an important source of energy which is believed to be inexhaustible source and ready for use especially in rural areas. It should be noted that availability of biomass energy supports socio-economic developments in rural areas. Furthermore biomass emissions are low enough compared to coal. Thus use of biomass energy leads lower amount of greenhouse gases and less consumption of fossil fuels.

Olive cake (OC) is one of the remarkable biomass energy source. OC is an industrial waste from olive oil production. It is an important type of biomass available in Mediterranean countries. The efficient and proper use of olive cake in energy production enables the production of clean energy and the reusability of this matter, which is the waste of olive oil facilities [1].

The use of OC as a fuel offers big advantages in terms of energy, environment and economy. These advantages are as follows: OC has a low amount of ash. The waste can be used completely to protect the ecologic balance. Furthermore, the emissions are lower than the fossil fuels. Moreover, OC with a high potential for production can be used as high-calorie energy source with low cost when burnt on its own or with coal.

There are a lot of studies in literature about the use of olive cakes with such advantages as a fuel; De Las Obras Loscertales et al [2] experimentally investigated the effect of combustion temperature and flue gas recycle composition on pollutant emissions and on the sulphating process, in order to optimize the SO_2 retention in circulating fluidized beds (CFBC). They found that SO_2 recycle produced an increase in the sulphur retention as a consequence of the higher SO_2 concentration existing in the bed. Varol et al. [3] studied co-combustion of Bursa-Orhaneli lignite and woodchips mixtures containing 10%, 30% and 50% by wt. of woodchips in a circulating fluidized bed combustor in order to investigate the effect of excess air ratio (λ) on the flue gas emissions. Results of their study showed that increasing excess air had a cooling effect on the combustor, but at the same time it also provided smoother temperature profile along the combustor. Abu-Qudais and Okasha [4] experimentally studied direct combustion of a diesel and olive cake (OC) slurry in vertical, cylindrical, water-cooled combustor. They obtained the heat transfer distribution for the water jacket, flame stability and combustion efficiency over wide ranges of air: fuel ratios, and at different percentages of OC in the diesel fuel. Al-Widyan et al. [5] examined the burning OC in pulverized form in a vertical tube furnace with equivalence ratios from 0.8 to 1.4. The results of their study showed that the concentration of CO was below 1.6%, while the NO_x emission was within 550 ppm and the SO_x maximum was 30 ppm. Alkhamis and Kablan [6] were tested to produce carbonaceous matter from combinations of the three materials mentioned above. They ensured that the minimum temperature to achieve complete carbonization was 500°C for a minimum heating time of 1.5h. Topal et al [7] used a circulating fluidized bed of 125 mm diameter and 1800 mm height to find the combustion characteristics of olive cake (OC) produced in Turkey. They observed that the minimum emissions were at λ=1.35. Van Dyk et al. [8] determined whether the most relevant characteristics of coal were representative of the typical coal from the South African Highveld region. In addition, they needed a detailed understanding of the coal and coal ash in order to explain slag formation and mineral transformations. They observed that the mineral grains showed a wide range of types that ranged from pure coal to pure minerals. Atimtay and Varol [9] used a bubbling fluidized bed of 102 mm inside diameter and 900 mm height to burn olive cake and coal mixtures. They investigated combustion performances and emission characteristics of olive cake and coal mixtures. They found that the highest combustion efficiency of 99.8 % was obtained with an excess air ratio of 1.7, secondary air flow rate of 40 L/min for combustion of 25 wt% olive cake and 75 wt% coal mixture. Akpulat et al. [10] experimentally examined flue gas emissions and combustion efficiencies during combustion and co-combustion of olive cake and coal in a bubbling fluidized bed. Results of their study showed that coal combustion occurs at lower parts of the combustion column, whereas olive cake combustion takes place more in the freeboard region. Varol and Atimtay [11] investigated combustion performances and emission characteristics of olive cake and coal in a bubbling fluidized bed. They fixed the optimum operating conditions with respect to NO_x and SO_2 emissions as 1.2 for λ and 50 L/min for secondary air flow rate for the combustion of olive cake. Hiltunen et al. [12] reviewed in the light of experience the main differences in fuel and ash properties and how the fuels from coal, peat, rice husk, rape seed and sunflower seed can be fired in CFB boilers.

Miranda et al. [13] applied techniques of thermal analysis to compare the behaviour of different wastes coming from olive oil mills. Toraman and et al. [14] used a circulating fluidized bed (CFB) of 125 mm diameter and 1800 mm height to investigate the combustion characteristics of sewage sludge (SS) produced in Turkey.

They burned separately sludge+olive cake and sludge+lignite coal mixtures. Results of their study showed that the combustion mainly takes place in the upper regions of the main column where the temperature reaches 900°C SS+coal burn in the CFB with an efficiency of 95.14 % to 96.18%. Abu Qudais [15] studied the hydrodynamics and combustion processes in a bench – scale fluidized- bed combustor with OC as a fuel. They investigated the effects of static-bed (0.1 and 0.15 mm) height, sand- particle size, air-flow velocity, and OC feeding ratio. Atimtay and Topal [16] investigated the combustion characteristics of olive cake (OC)+coal mixture. They carried out the combustion experiments with various excess air ratios. Results of their study suggest that OC is good fuel that can be mixed with lignite coal for cleaner energy production in small- scale industries by using CFB. Arnesto et al. [17] aimed to assess the feasibility of co-firing coal and a very specific biomass waste from the olive oil industry. They selected two different Spanish coals for their study: a lignite and an anthracite.

Their pilot plant tests showed that the combustion of foot cake/lignite or anthracite mixtures in bubbling fluidised bed is one way to utilise this biomass residue in energy generation.

In this study, the black seed OC, yellow seed OC and mixed powder OC (sifted) were burned and their fuel characteristics have been determined. The results of the moisture, ash, sulphur, volatile matter and calorific values obtained from the OC were compared with those of two kinds of coal, the lignite from Manisa and its surround (Soma Eli) and lignite in Kütahya and its surround (0.18 Tuncbilek).

II. MATERIAL AND METHODS

A. Sample Preparation

Dried samples of OC obtained from Aydın city which is located in the southwest of Turkey were used as samples. Dried OC, at first, sifted and then it was separated into two parts, powder and seed. The black seed OC, yellow seed OC, mixed powder OC, lignite of Soma Eli and lignite of 0.18 Tuncbilek types of coal were prepared for the analysis.

B. Analysis

In the cement plant in Denizli, moisture, ash, volatile matter, sulphur contents and calorific values of the types of coal and OC were measured in IKA-C- 4000 bomb Calorimeter with manual ignition system on adiabatic principle, temperature sensors and calibration certificates.

Drying process of OCs was achieved in two steps. In the first step, OCs were exposed to sunlight then they were ovendried. The oven was started about 30 min before the drying process to reach steady state conditions. Drying process was carried out at 100°C. The samples with a weight of about 1.5 g put into the reaction container. The bomb was filled with oxygen under nearly 30 atm. pressure.

C. Validity of this study

In Table 1, the results of the analysis of the OCs of this study are compared with those of the previous ones. As shown in Table 1, a very good agreement was observed for mixed powder OC in comparison with Refs. [6], [11] and [16].

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

TABLE 1
THE COMPARISON OF THE ANALYSIS RESULTS OF THE MIXED POWDER OC WITH THE ANALYSIS RESULTS OF THE LITERATURE STUDIES.

	Ash (wt%)	Moisture (wt%)	Volatile Matter (wt%)	Sulphur (wt%)
Present Study	2.13	10.34	70.07	0.10
[6]	2.56	7.31	80.19	0.10
[11]	6.32	13.49	72.00	0.11
[16]	9.01	6.53	68.82	0.12

III.RESULTS AND DISCUSSION

The contents of calorific value, ash, sulphur and flying material were obtained from the analyses. In Figure 1, contents of moisture obtained from the combustion of the OC and coal samples were shown. As observed from the figure, black seed OC has the lowest content of moisture. The obtained content of mixed powder OC, 10 %, is low in comparison with the maximum content available in the literature, at about 15 %, [18]. From experiments, one can easily observe that OCs of black and yellow seeds have the lowest content which is at about 5 %. Therefore, it appears to be all three kinds of OCs are suitable in terms of moisture content for heating in comparison with lignite whose contents are between 18-20 %. As is well known, low enough moisture content is an important factor in efficient combustion and so a critical parameter for low air pollutant emissions.

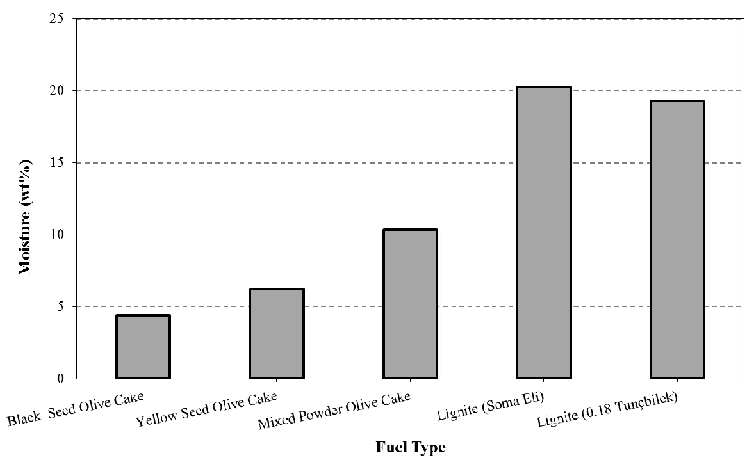

Fig. 1 Moisture contents of different fuel types

Figure 2 shows the amounts of volatile matter by weight. High CO emissions are caused by the fact that volatile matters of the OCs and types of coal used as a fuel have high contents and that these volatile matters are mixed with the stack gas before the combustion is completed. As seen in Figure 2, the lowest volatile matter amount is with lignite of 0.18 Tuncbilek, while the highest one is with yellow seed OC.

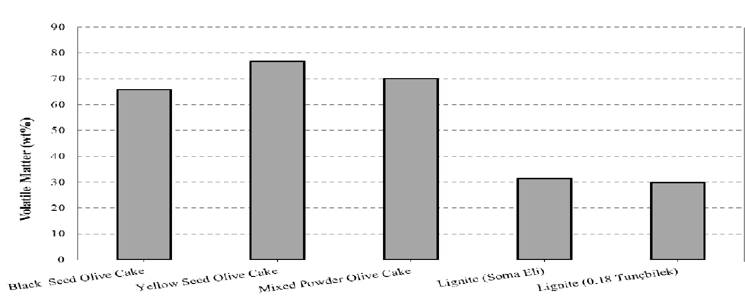

Fig. 2 The volatile matter contents of different fuel types

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Figure 3 shows the contents of ash resulting from the combustion of OC and coals analysed. Ash is the unburned element in the fuel. The highest content of ash after the combustion of the coal types and OC analysed is with the black seed OC and the lowest content is with the yellow seed OC. In the study, a 5% difference was obtained between lignite of 0.18 Tuncbilek and black seed OC with a high content of ash. For high quality combustion in the OCs, the content of ash is to be lower than 4% [18]. Accordingly, the best combustion in terms of ash content occurred in yellow seed OC with 0.43% as seen in Figure 3. In addition, the ash content of mixed powder OC was determined as 2.13%. In this case, quality combustion took place in the mixed powder OC, too. The higher the amount of ash after the combustion, the higher the amount of ash in the atmosphere, and then this powder emission leads to air pollution. Therefore, yellow seed and mixed powder OCs appear to be clean fuels in environmental terms when compared with the types of coal and black seed OC analysed.

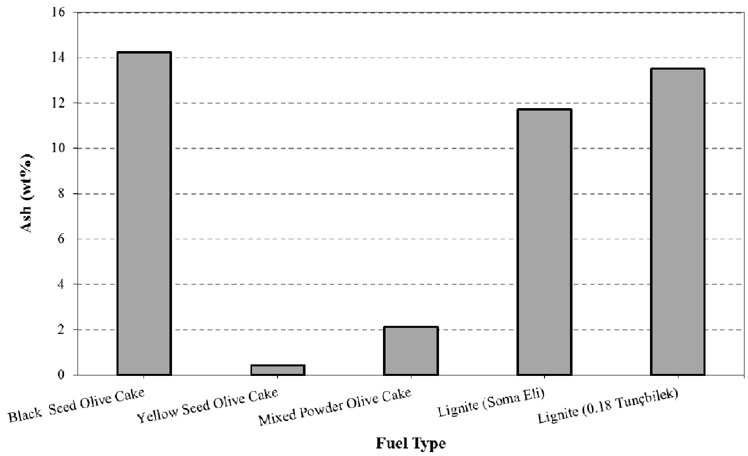

Fig. 3 Ash contents of different fuel types

The contents of sulphur of the OCs and types of coal analysed are shown in Figure 4.

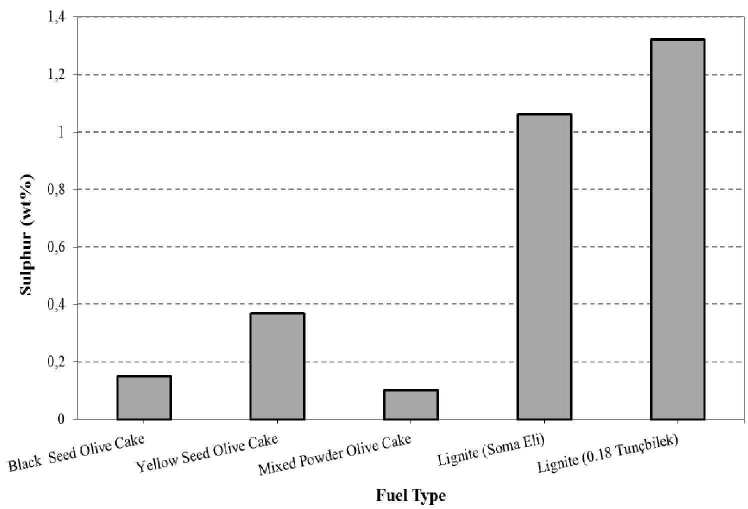

Fig. 4 Sulphur contents of different fuel types

As seen in Figure 4, the sulphur contents of the types of coal analysed are about 80% higher than the types of OC. For the coal to be a good fuel, the content of sulphur is not to be higher than 0.9% [18]. However, the contents of sulphur of lignite of Soma Eli and lignite of 0.18 Tuncbilek coals were determined as 1.06% and 1.32%, respectively. For this reason the types of coal analysed are higher than they ought to be in terms of the sulphur content.
The sulphur contents of the OCs used as fuel are usually as low as 0.15%. Therefore, they are used as environmental-friendly fuels. The sulphur contents of the black, yellow seed OC and mixed powder OC analysed in this study were determined as 0.15%, 0.37%

and 0.10%, respectively. In this case, black seed OC and mixed powder OC can be defined as environmental-friendly fuels in terms of the sulphur content.

Figure 5 shows the lower heating values of the OCs and types of coal analysed. The highest lower heating value belongs to lignite of 0.18 Tunçbilek, while the yellow seed OC has the lowest lower heating value. As the lower heating values of these three types of OC analysed are between 4000 and 4500 kcal/kg [18], it can be concluded that the results of this study are very close to the quality of lignite in terms of the lower heating value.

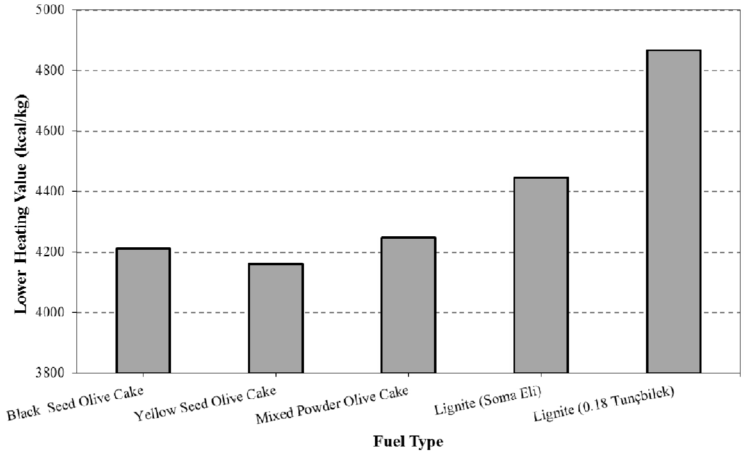

Fig. 5 The lower heating values of different fuel types

IV. CONCLUSIONS

In this study, a comparison was made between the analysis results of the black seed OC, yellow seed OC and mixed powder OC of Aydın and lignite of Soma Eli and lignite of 0.18 Tuncbilek coals. According to these comparisons, the moisture contents of the OCs analysed were below 15%, so it was determined that these OCs are suitable as fuel in terms of the moisture contents. According to the analysis results obtained, three types of OC are higher than lignite of Soma Eli and lignite of 0.18 Tuncbilek in terms of the content of volatile matter. However, this disadvantage can be eliminated with the use of a proper technology (pre-heating/gasification; mechanical supply) in the combustion processes. Considering the comparisons in terms of ash content, it is necessary that ash content should not be higher than 4% for quality combustion, so the best combustion was observed to be with yellow seed OC with a 0.43% value. Also, it was determined that mixed powder OC has a low content of ash, which is 2.13%. Accordingly, it was concluded that yellow seed and mixed powder OCs are cleaner fuels than coal in terms of environment. It was determined through the analysis results that these three types of OC have lower contents of sulphur than coal. This result shows that they are very good and clean as a fuel in environmental terms. The comparison based on heating value revealed that these three types of OC are close to lignite as a fuel. According to these findings, the heating values of OCs are close to that of lignite, while their sulphur emission is lower than that of lignite, in terms of the fuel features. Additionally, the prices of OCs are much lower than those of coal, a fact which shows that it will contribute a lot to the economy of the country if used as a fuel.

V. ACKNOWLEDGMENT

The authors would like to express their appreciation to the Denizli Cement Plant, Turkey, for this study.

REFERENCES

[1] Kurtuluş, E., Günerhan, H., "Prinanın Bir Yakıt Olarak Kullanımı ve Eldesi", II. Yenilenebilir Enerji Kaynakları Sempozyumu, İzmir, 15-18 Ekim 2003.
[2] M. DE Las Obras- Loscertales, A. Rufas, L. F. De Diego, F. Garcia- Labiano, P. Gayan, A. Abad and J. Adanez, "Effects of Temperature and Flue gas recycle on the SO2 and NOx Emissions in an Oxy-Fuel Fluidized Bed Combustor", Energy Procedia, Vol. 37, pp.1275-1282, 2013.
[3] M. Varol, A.T. Atimtay, H. Olgun and H. Atakül, "Emission Characteristics of Co-Combustion of a Low Calorie and High Sulfur- Lignite Coal and Wood chips in a Circulating Fluidized Bed Combustor: Part 1. Effect of Excess Air Ratio", Fuel, Vol.117, pp. 792-800, 2014.
[4] M. Abu- Qudais and G. Okasha, "Diesel Fuel and Olive–Cake Slurry: Atomization and Combustion Performance", Applied Energy, Vol. 54, pp.315-326, 1996.
[5] M. I. Al-Widyan, G. Tashtoush and A. M. Hamasha, "Combustion and Emissions of Pulverized Olive–Cake in Tube Furnace", Energy Conversion and Management, Vol. 47, pp.1588-1596, 2006.
[6] T.M. Alkhamis and M.M. Kablan, "A Process for Producing Carbonaceous Matter from Tar Sand, Oil Shale and Olive Cake, Energy", Vol. 24, pp.873-881,1998.

[7] H. Topal, A. T. Atimtay and A. Durmaz, "Olive Cake Combustion in a Ciculating Fludized Bed", Fuel, Vol. 82, pp.1049-1056, 2003.
[8] J.C. Van Dyk, S.A. Benson, M.L.Laumb and B Waanders, "Coal and Coal Ash Characteristics to Understand Minereal Transformations and Slag Formation", Fuel, Vol. 88, pp.1057-1063, 2009.
[9] A.T. Atimtay and M. Varol, "Investigation of Co-Combustion of Coal and Olive Cake in a Bubbling Fluidized Bed with Secondary Air Injection", Fuel, Vol. 88, pp.1000 -1008, 2009.
[10] O. Akpulat, M. Varol and A.T. Atimtay, "Effect of Freeboard Extension on Co- Combustion of Coal and Olive Cake in a Fluidized Bed Combustor", Bioresourse Technology, Vol. 101, pp.6177-6184, 2010.
[11] M. Varol and A.T. Atimtay, "Combustion of Olive Cake and Coal in a Bubbling Fluidized Bed with Secondary Air Injection", Fuel, Vol.86, pp.1430-1438, 2007.
[12] M. Hiltunen, V. Barisic and E. C. Zabetta, "Combustion of different Types of Biomass in CFB Boilers", 16 th European Biomass in Conference Valencia Spain June 2-6, 2008
[13] T. Miranda, A.Esteban, S. Rojas, I. Mantero and A. Ruiz, "Combustion Analysis of Different Olive Residues, International Journal of Molecular Sciences", Vol. 9, pp.512-525, 2008.
[14] O.Y. Toraman, H. Topal, O. Bayat and A.T. Atimtay, "Emission Characteristics of Co_ Combustion of Sewage Sludge With Olive Cake and Lignite Coal in a Circulating Fludized Bed", Journal Of Environmental Science and Health, Vol. A39, pp.973-986, 2004.
[15] M. Abu-Qudais, "Fluidized-Bed Combustion for Energy Production from Olive Cake", Energy, Vol. 21, pp.173-178,1996.
[16] A.T. Atimtay and H. Topal, "Co-Combustion of Olive Cake with lignite Coal in a Circulating Fluidized Bed", Fuel, Vol. 83, pp.859-867, 2004.
[17] L.Arnesto, A.Bahillo, A. Cabanillas, K. Veijonen, J. Otero, A. Plumed and L. Salvador, "Co-Combustion of Coal and Olive oil Industry Residues in Fluidised Bed", Fuel, Vol. 82, pp.993-1000, 2003
[18] Turkey Ministry of Environment and Urbanization. http://www.csb.gov.tr ; 2009.