Fermentation of Olive Cake to Produce Hot Water

Taha M. Rababah[1] and Mohamad I. Al-Widyan[2] , Khalil Eriefej[3]

[1,3] Department of Nutrition and Food Technology, [2]Department of Biosystems Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid, 22110

trababah@just.edu.jo

*Address inquires to Dr. Taha Rababah; Tel: 00962-2-7201000; Fax: 00962-2-7095147; Email: trababah@just.edu.jo or rebabah@yahoo.com

Abstract

Recycling of agricultural wastes and their utilization as alternative energy sources for different useful purposes is important for economical and environmental reasons. These wastes are high in lignocellulose and low in digestibility and nutritive value in terms of energy. The objective of the present work was to explore the possibility of building a system that contains of a combination of geothermal component (water well (pit)) and heat recovery from the process heat of the biological fermentation of olive cake that is produced in large quantities as a by-product of olive pressing for hot water production in an attempt to reduce the diesel fuel consumption at the mill. The chemical composition results showed that olive cake is rich in crude fiber and N. F. E and contains moderate amount from crude protein and fat and a good amount from ash. The moisture contents and water activity values ranged from 33.3 to 35.6% and 0.93 to 0.96, respectively. The total counts, the thermophilic bacteria and the total mold count of fermentation periods ranged from 2.1×10^8 to 2.4×10^8, 1.7×10^4 to 1.9×10^4 and 1.5×10^2 to 1.7×10^2, respectively. The temperature results showed that the well and the covered tank lead to a rise in water temperature before entering the boiler in the range of 7 to 13 ^oC. The system effected significant raises in water temperature entering the boiler ranging from 19 ^oC up to 25 ^oC, which holds a promising potential for the system to satisfy much of the mills needs at this range of temperature before entering the boiler provided a large enough pile (pile scale up) is used to handle larger flow rates.

Key words: Fermentation, hot water, olive cake

Introduction

In Jordan, there are more than 110 olive milling factories that process olive fruits for olive oil production. Three major products are produced by these mills, namely, olive oil, wastewater, and solid residues. The latter is also known as olive cake and locally known as "jift". Numerous researches have investigated the olive oil industry byproducts and waste. The solid waste was extensively investigated as an energy source, oil source, animal feed, and other purposes. The wastewater was also investigated and several researches attempted to improve the quality of the wastewater for better utilization in many areas such as crop irrigation and crop fertilization.

Recently, strong correlation was observed between olive oil production and environmental pollution and researchers became concerned with the basic issue of the wastes produced after extracting oil from the fruits. Aqueous sludge, which makes about 45 to 54% of total waste is treated by using different methods such as chemical, biochemical and electrochemical treatments, supercritical extraction and separation processes based on membrane technology (Israilides and others 1997; Rivasand others 2001; Vitolo and others 1999). The olive cake, which is also considered a major pollutant, constitutes more than 80% by weight of the olives consumed and depends on olive varieties and the extraction process. Generally, olive cake is utilized as a fuel due to its high energy content, and as a raw material for soap making due to its high-quality variable oil content of about 5 to 8%. However, these application areas require drying of the olive cake from a moisture content of 20 to 45% to approximately 5 to 6%, a process that is regarded as energy intensive.

During olive oil production, mills need large amounts of hot water obtained from boilers that operate on diesel fuel. The energy annual bill averages about JD 10,000 per mill and is projected to be doubled with the continuous increases in diesel fuel prices. The mill uses large amounts of hot water at about 60 to 70 ^{o}C for about four to five months, which is the length of the annual pressing season. In addition, some mills have on-site olive oil storage facilities for filling and exporting purposes. These storage facilities also require additional large volumes of hot water at 30 to 40 ^{o}C for oil processing.

Olive processing yields enormous quantities of solid waste after the separation of the aqueous phase. This residue contains 4 to 9% of olive oil, depending on the extraction system used: continuous or discontinuous pressure (Ammar and others 2005). Chemically speaking, this waste is a ligno-cellulosic organic material (Boskou, 1996). In different countries, this by-product is burned for heat generation. However, since the enactment of international regulations limiting the emission of CO_2, this practice has been prohibited, thus requiring new solutions. Water well can keep the water warm especially during winter season. The fermentation process that including using a combination of water well needs to be investigated.

The current practice regarding hot water production for the milling process at the mill under consideration as well as in many other mills involves transporting water from nearby springs and storing them in bear (uninsulated) metal tanks on the rooftop of the mill and then feeding this water to the diesel–fired boiler. Given that most of the milling season coincides with the cold winter season in Jordan, and given that ambient temperatures in Ajloun area where the mill is located are very low and even get close to zero during part of the milling season, large sensible heat is needed to raise the water temperature to up to 60 to 70 ^{o}C. This fact is reflected in substantial diesel fuel requirements that under current price trends present a heavy toll and a major operational expense of the mill.

Based on the above, it may be obvious that the energy bill especially that pertains to hot water makes a major operational cost and any reductions in energy expenses will effect significant savings in the running costs of operating the mill.

The aim of the present work was to explore the possibility of building a system that contains of a combination of geothermal component (water well (pit)) and heat recovery from the process heat of the biological fermentation of olive cake that is produced in large quantities as a by-product of olive pressing for ho water production in an attempt to reduce the diesel fuel consumption at the mill.

Materials and Methods

Proximate Chemical Analysis

Proximate analysis was carried out according to the procedures outlined by the AOAC (1984).

Determinations of pH

The regular pH meter was used to determine the pH of fermented and unfermented olive cake. Six measurements were taken for each sample. The measurements were averaged.

Water Activity

The regular water activity instrument was used to determine the water activity of fermented and unfermented olive cake. Three determinations (about 25 grams) were taken for each measurement. The measurements were averaged.

Microorganism Examinations

Sample preparation (dilution preparation)

Twenty five gram was taken from fermented and unfermented olive cake and added to 250 ml from Pepton water to a dilution of 1:10.

Total count (TPC)

From the previous solution, 0.1 and 1 ml were put in Petri dishes and plate count Agar that was prepared in slandered methods was poured on them. After that, the dishes were put in an incubator for 24-48hr at 37 °C. The colony was account after the growth.

Total thermophilic bacteria

From the previous solution, 0.1 and 1 ml were put in Petri dishes and plate count Agar that was prepared in slandered methods was poured on them. After that, the dishes were put in an incubator for 24-48 hr at 50 °C. The colony was account after the growth.

Total Molds Counts

From the previous solution, 0.1 and 1 ml were put in Petri dishes and Potato Dextrose Agar that was prepared in slandered methods was poured on them. After that, the dishes were put in an incubator for 3 to 5 days at 25 °C. The colony was account after the growth.

Building the System (Combination)

The system proposed in this work relies on utilizing a combination of alternative renewable energy sources for hot water production. A schematic of the proposed and implemented system in this work is shown in Figure 1. The sources included an attempt to utilize geothermal energy by digging a ground pit (well) with a total capacity of 20 m^3 of water. The well (first station) receives water from tankers that bring the water from nearby springs. A pump is utilized to pump the water to the partially buried tank (second station) that is covered with olive cake for utilizing the compost process heat to further heat the water. Water then leaves the tank to a heat exchanger that is completely inserted into an olive cake compost pile (third station) where temperature reaches 60 to 70 ^oC due to the biological activity in the pile (See Figure 2 below).

It was decided to install a 100-meter long heat exchanger made of aluminum tubes with an internal diameter of 18 mm. The tubes were wound as shown in Figure 3 below in the Engineering Workshops of Jordan University of Science and

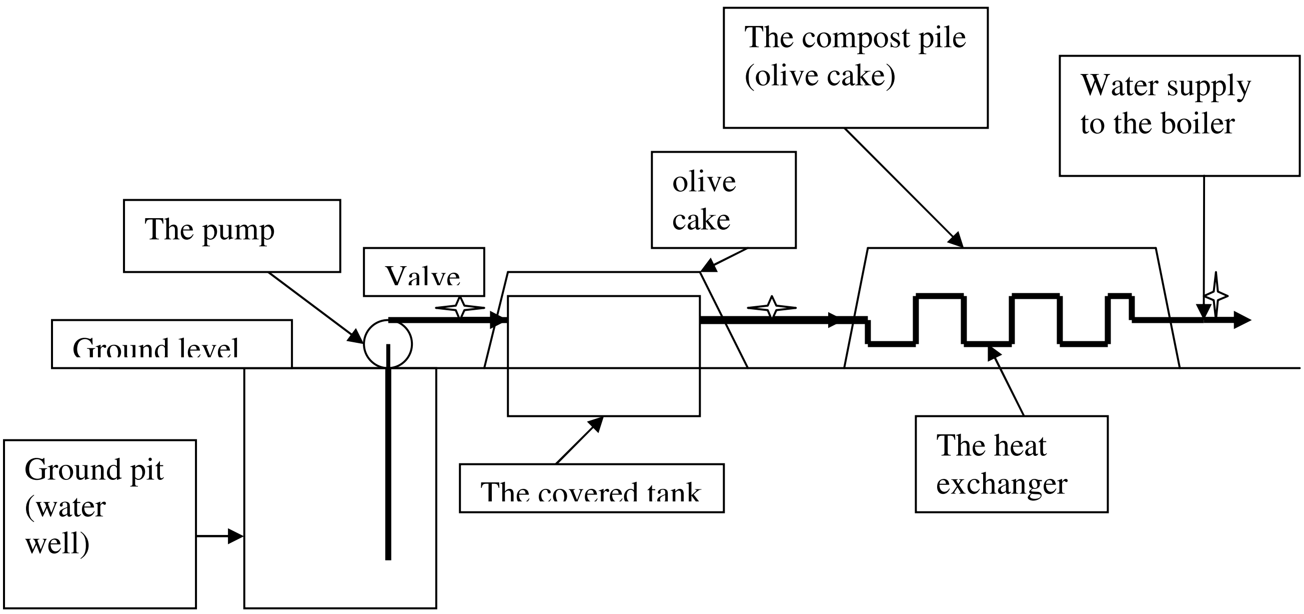

Figure 1. A schematic diagram of the proposed combined system for hot water production at the olive mill.

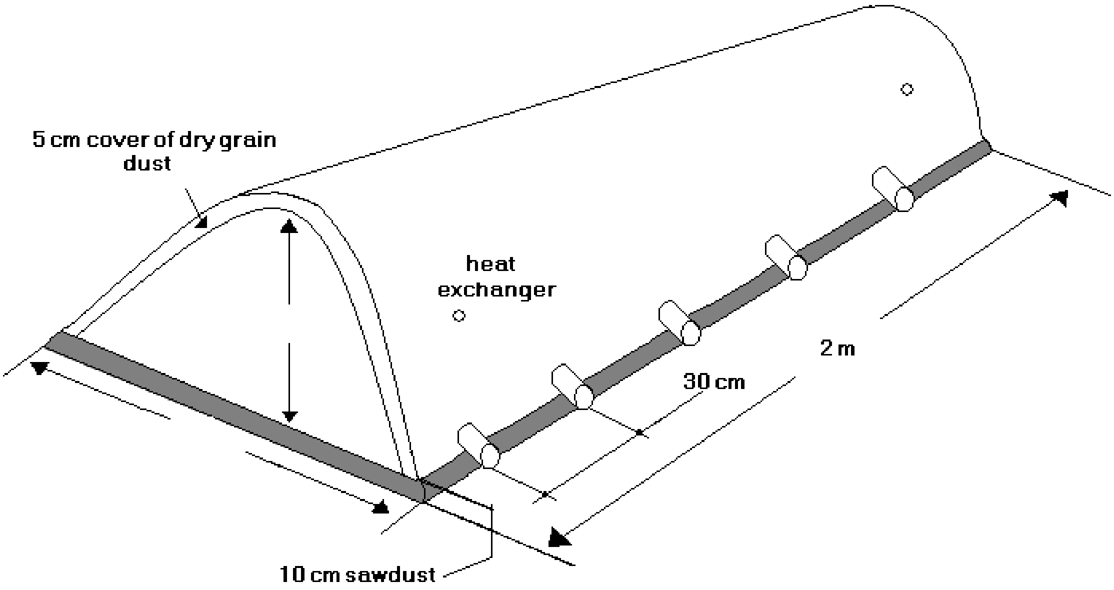

Figure 2. A schematic of the compost pile of olive cake.

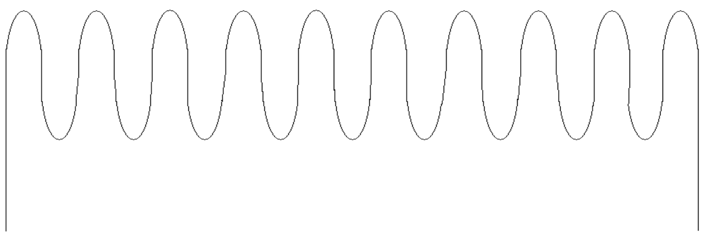

Figure 3. A sketch of the heat exchanger used in the study.

Technology to fit within a 13-meter long pile of olive cake. The water flow rate into and out of the heat exchanger at steady state conditions was measured by a calibrated (graduated) beaker with a stop watch from which the hot water volumetric flow rate was calculated.

The pile was setup as a passively aerated pile fitted with 12-inch diameter PVC perforated pipes as shown in Figure 4. A total of 12 PVC pipes were used.

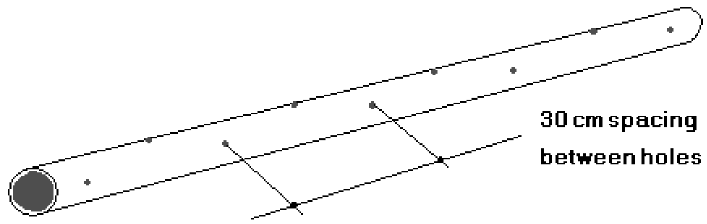

Figure 4. A sketch of the perforated pipes used for aerating the pipe.

A valve was installed at the exit point of each of the three stations and numerous measurements of water temperatures were made at these points in addition to the ambient temperature using a thermocouple along with a digital multimeter. The water temperature data were averaged for every two weeks (15 days) and reported as a single value. Water temperature measurements were started at the end of January, 2008 and extended over the following three consecutive months (till the end of April, 2008).

Results and Discussion

Chemical analysis

The chemical composition of fermentation periods of olive cake during 90 days of fermentation is shown in Table 1. As you see from the results, the unfermented (0 day) and fermented olive cake is rich in crude fiber and N. F. E and contains moderate amount from crude protein and fat. Also, the results (Table 1) showed that olive cake is contains a good amount from ash. From Table 1 it can be concluded that olive oil is rich in the nutrients which let the microorganisms to grow for long periods of times. That means these nutrients will capable the microorganisms to produce heat for long time which it the mean purpose of this study.

Table 1 shows the fermentation time for three months. As shown that no significant differences were found during fermentation. These results indicted that olive cake can be used for long time as a source of fermentation.

Table 1. Chemical composition* of olive cake during 90 days of fermentation.

Fermentation period	Dry matter	% of dry matter				
		Ash	**Crude Protein**	**Crude Fiber**	**Ether Extract**	**N.F.E**
0 day	65.3±4.4	4.4± 0.2	7.2 ± 0.5	43.6 ± 3.3	11.4 ± 0.8	32.3±2.5
30 days	66.7±4.5	4.6± 0.3	7.1 ± 0.4	44.0 ± 3.8	11.3 ± 0.7	32.3±2.7
60 days	65.9±4.1	4.2± 0.2	7.4 ± 0.5	44.5 ± 3.2	11.5 ± 0.8	32.0±2.4
90 days	65.3±4.4	4.3± 0.3	7.1 ± 0.4	45.5 ± 3.9	11.4 ± 0.7	32.7±2.3

* means ± SD

Water Activity and Moisture Content

The moisture contents and water activity values of fermentation periods of olive cake during 90 days of fermentation are shown in Table 2. As you see from the results, the moisture contents of the unfermented (0 day) and fermented olive cake ranged from 33.3 to 35.6% and no significant difference was found during 90 days of fermentation. Also, the results (Table 2) showed that the water activity values ranged from 0.93 to 0.96 and no significant difference was found during fermentation, also. The high water activity could be due to the fat contents that let the water molecules to move easily in the media (olive cake**)**. Also, these results agreed with the microorganisms determinations.

Microorganism Examinations

The total counts, the thermophilic bacteria and the total mold count of fermentation periods of olive cake during 90 days are shown in Table 3. As you see from the results, the total plate count of the unfermented (0day) and fermented olive cake (during 90 days of fermentation) ranged from 2.1 x 10^8 to 2.4 x 10^8 and no significant difference was found during fermentation. Also, the results (Table 3) showed that the

Table 2. The moisture contents and water activity* of olive cake during 90 days of fermentations.

Fermentation period	**Moisture contents (%)**	**Water activity**
0 day	34.7 ± 2.2	0.95 ± 0.03
30 days	33.3 ± 2.1	0.93 ± 0.04
60 days	34.1 ± 2.5	0.94 ± 0.05
90 days	35.6 ± 2.1	0.96 ± 0.04

* means ± SD

thermophilic bacteria ranged from 1.7 x 10^4 to 1.9 x 10^4 and no significant difference was found during fermentation, also. The results in Table 3 showed that the total mold count of the unfermented (0day) and fermented olive cake (during 90 days of fermentation) ranged from 1.5 x 10^2 to 1.7 x 10^2 and no significant difference was found during fermentation. These high values of growth of both types of bacteria could be due to high available nutrients and high amounts of water activity**.** Also, the type of dominant mold was identified and the *Aspergillus* .spp was found during the fermentation periods.

<u>Temperature Measurements</u>

The data that pertain to temperature measurements over the course of the study are reported in Table 4. Noting that the ambient temperature is the baseline (reference value) that represents the current practice (without the system)**,** the data in Table 4 indicate that the well alone effected a raise in water temperature in the range of 2 to 8 ^oC with the lower values being in the warmer weather and the higher values for the cooler period that is more characteristic of the olive milling season.

Table 3. The total counts, the thermophilic bacteria and the total mold count of olive cake during 90 days of fermentations.

Fermentation period	**Total plate counts**	**Thermophilic bacteria**	**Total mold count**
0 day	2.4 x 10^8	1.9 x 10^4	1.7 x 10^2
30 days	2.3 x 10^8	1.8 x 10^4	1.6 x 10^2
60 days	2.2 x 10^8	1.8 x 10^4	1.6 x 10^2
90 days	2.1 x 10^8	1.7 x 10^4	1.5 x 10^2

Table 4. Water temperature measurements data for three months.

Temperature Measurement period	Temperature of water leaving the well (pit)	Temperature of water leaving the covered tank	Temperature of water leaving the compost pile	Average Ambient Temperature (^oC)
0-15 days	12	17	29	4
15-30 days (end of February)	12	18	31	6
30-45 days	15	20	33	9
45-60 days (end of March)	16	22	34	13
60-75 days	18	26	37	15
75-90 days (end of April)	21	26	38	19

It should be emphasized here that the well can provide this boost in water temperature at a steady basis with no regard to flow rate. That is, the well can provide the total water requirements of the mill while maintaining this temperature boost.

Also, the data indicate that the combination of the well and the covered tank lead to a rise in water temperature before entering the boiler in the range of 7 to 13 ^oC. This rise in water temperature is apparently better (higher) than that by the well alone and could lead to significant fuel savings. It should be emphasized here that, given ample time, the tank, like the well, can provide this boost in water temperature at a steady basis with no regard to flow rate. That is, the tank can provide the total water requirements of the mill while maintaining this temperature boost.

As for the whole system (the three stations), the rise in water temperature relative to the ambient is reported in the last column of Table 5 for convenience. It may be readily seen from Table 5 that, under the flow rate through the heat exchanger in this work ***(0.4 m^3/h)***, which is mainly due to limitations of exchanger pipe size and flow speed, the system effected significant raises in water temperature entering the boiler ranging from 19 ^oC up to 25 ^oC, which holds a promising potential for the system to satisfy much of the mills needs at this range of temperature before entering the boiler provided a large enough pile (pile scale up) is used to handle larger flow rates.

Table 5. Comparison of water temperature entering the boiler with and without the system.

Temperature Measurement period	Water inlet temperature to the boiler with the system (°C)	Water inlet temperature to the boiler without the system* (°C)	Effected temperature difference (°C)
0-15 days	29	4	25
15-30 days (end of February)	31	6	25
30-45 days	33	9	24
45-60 days (end of March)	34	13	21
60-75 days	37	15	22
75-90 days (end of April)	38	19	19

* Under steady-state conditions, the temperature of water entering the boiler from the rooftop tanks (without the system) is equal to the ambient.

Acknowledgements. The authors wish to express their deep gratitude to the Higher Council of Science and Technology for providing the fund (financial support) for this work and extend their thanks to the company owners for the cooperation they demonstrated throughout the conduction of this work.

References:

Al-Masri, M.R., Guenther, K.D., 1999. Changes in digestibility and cell-wall constituents of some agricultural by-products due to gamma irradiation and urea treatments. Radiat. Phys. Chem. 55, 323–329.

Ammar, E., Nasri, M., Medhioub, K., 2005. Isolation of enterobacteria able to degrade simple aromatic compounds from the wastewater from olive oil extraction. World J. Microbiol. Biotechnol. 21 (3), 253– 259.

Association of Official Analytical Chemists (AOAC). 1984. Official Methods of Analysis, 11th Edition, Washington, DC.

Boskou, D., 1996. Olive Oil: Chemistry and Technology. AOCS Press, Illinois.

Israilides, C. J., Vlyssides, A. G., Mourafeti, V. N., & Karvouni, G. (1997). Olive oil wastewater treatment with the use of an electrolysis system. Bioresource Technology, 61, 163–170.

Rivas, F. J., Gimeno, O., Portela, J. R., de la Ossa, E. M., & Beltron, F. J. (2001). Supercritical water oxidation of olive oil mill wastewater. Industrial Engineering Chemical Research, 40, 3670–3674.

SAS .2002. User's Guide. Release 8.2 Edition, SAS Institute Inc. Cary, NC.

Vitolo, S., Petarca, L., & Bresci, B. (1999). Treatment of olive oil industry wastes. Bioresource Technology, 67, 129–137.