The energy management of olive mill solid waste

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Abstract
The energy potential of solid olive waste is being examined. These residues fall into two main categories, namely pomace (olive cake) and prunings. The estimated amount of these residues in Europe is about 1.5 million tons, including stones/pits and olive pomace cake with an energy content of approximately 4000kcal/kg. In Spain and Italy current applications include co-generation of heat and power using large and medium scale installations. The simplest way to utilize olive solid residues for energy production is by direct combustion; this can take place however, only after olive pomace is dried. From 0.230kg approx. of dried pomace 1kwh$_e$ can be produced. Potential energetic implementations in certain areas in Greece are presently evaluated, with focus in the region of Chania, in Crete.
Keywords: olive solid residues, olive pomace, pits, prunings.

1. INTRODUCTION

The olive oil production chain is an important agro-alimentary branch in Europe. The EU is the biggest world producer of olive oil (80% of total) with about 12000 olive mills most of which are SME's [1]. Greece devotes 60% of its cultivated land to olive growing. Greece holds the third place in world olive production with more than 132 million trees, 3000 mills and 220 bottling companies which produce approximately 350000 tons of olive oil annually, out of which 82% is extra-virgin. About 30% per cent of Greek oil is produced in the island of Crete, 26% in Peloponissos (southern peninsula), 10% in the Aegean island of Lesvos, 10% in the Ionian Islands (Adriatic Sea) and the remaining 24% is scattered around the rest of the country. Olive groves represent 20.5% of total farmland and olive oil production 14% of total plant production. In approximately 1200000 hectares of land, grow over 140000000 trees. Only one sixth of those trees are intended for table olive production [2].

Olive mill technology generates a variety of wastes both solid and liquid. Solid wastes are generated also in the olive groves during pruning of olive trees. In this category of wastes are included: the olive leaves, prunings and the virgin pomace resultant from olive oil extraction which includes olive pits. Extensive study in this field has been undertaken in the Intelligent Energy Europe (IEE) project "MORE" [3]. Leaves can be used as animal feed, as fertilizer or in the production of compost, while olive prunings, pits, dried or exhausted pomace can be used for energy production. Liquid wastes are known as Olive Mill Waste Water (OMWW) and are used in some cases as additives for the manufacture of cosmetics and also for biogas, since substantial amounts of unrecoverable oil and fine residues of pomace remain in the particles of OMWW.

There are three different olive oil production processes: a) traditional pressing process, b) 3-phase decanter process, c) 2-phase decanter process. The main olive solid residues which are generated during the olive oil production are the pomace also called virgin pomace or olive pomace or crude olive cake. The virgin pomace is the residual paste after the olive oil extraction. It is constituted from a mixture of olive pit/stone, olive pulp & skin, as well as pomace olive oil plus the water added in the olive mills. The moisture content is about 25-60% depending on the olive oil production process (Table 1 & Figure 1). The pomace oil can be separated in two ways: i) using solvents (traditional method), and ii) through physical extraction or centrifugation (second centrifugation). According to the traditional method, pomace oil is extracted from the dried pomace (8% moisture approximately) using a solvent (hexane). The stone can be separated too from the olive pomace in order to be sold as a biofuel [4].

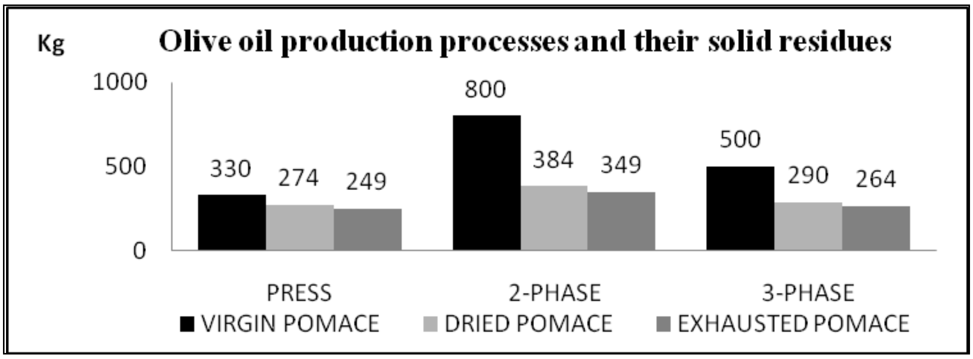

Figure 1: Pomace (Olive cake) obtained from different oil extraction methods, processing 1tn olives.

Table 1. Types and content of olive pomace

Olive Pomace	Pomace oil		Moisture		Pulp&skin	Pits
Virgin	●	2.5%	●	25-60%	●	●
Dried	●	2.5%	●	8-12%	●	●/-
Exhausted			●	8-12%	●	●/-

Normally, drying takes place in rotary heat dryers called “trommel”, as shown in Figure 2, in which both the product (pomace) to be dried and the hot drying gases are introduced at high temperatures (400 to 800°C). When the pomace leaves the “trommel”, it should have the appropriate moisture content of approximately 8% [5]. The system used for the drying process is a rotating cylinder heated internally by hot gases fed from a combustor or burner situated in the front part of the cylinder.

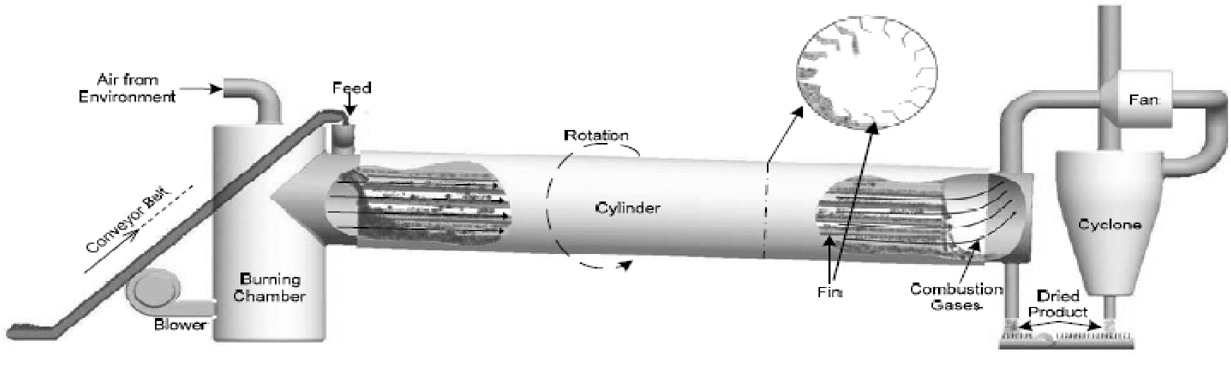

Figure 2. Material and air flow through a rotary drum dryer (trommel) [6]

The traditional use of exhausted pomace is as fuel in drying ovens or steam boilers because of its thermal capacity. The pomace oil extraction industry is a high energy consumer, particularly at the pomace drying stage and during extraction with solvent. This fact, together with the increasing demand for electrical energy has led the sector to propose electrical cogeneration projects, such that, by exploiting the calorific potential of the exhausted olive pomace (biomass), it is possible to generate electrical energy and exploit the residual thermal energy for the stages of drying and oil extraction with a solvent. Similarly, the ashes produced in combustion are used to manufacture fertilizers, given their high soluble potassium content. And finally, what is perhaps the newest use of olive mill wastewater, complex agro industries are integrally exploiting the pomace with evaporators/concentrators capable of removing the olive mill wastewater and exploiting the residual energy of the exhaust steam from electricity generating turbines

The following two types of energetic applications of the olive solid residues are used:

- Thermal application: The biomass (olive solid residues) is used for heating and sanitary hot water (SHW); also at industrial level for steam process that comes from reused residues.
- Electrical application: The technology used for obtaining electricity is the Rankine vapor cycle, with generation or co-generation (heat+electricity) electrical plants (steam conventional cycles). Another alternative is the electricity generation through gasification processes. The optimal electrical energy plant size is between 10 to 25 MW, the normal size is 25 MW so that it is the most profitable.

2. APPLICATIONS FOR ENERGY PRODUCTION

2.1 Thermochemical process (C/N>30, moisture <50%)

2.1.1 Combustio process

The simplest way to exploit olive solid residues for energy production is by direct combustion. Advantageous features of these kinds of boilers are the high thermal efficiency, the low operation cost and the need of non frequent cleaning. Despite an often simple construction, most of the automatically fired boilers can achieve an efficiency of 80-90% and a CO emission of approximately 100ppm. For some boilers, the figures are 92% and 20ppm, respectively. An important condition for achieving these good results is that the boiler efficiency during day-to-day operation is close to full load. For automatic boilers, it is of great importance that the boiler nominal output (at full load) does not exceed the maximum output demand in winter periods. [8].

2.1.2 Gasification process

The gasification process can be broken down into three phases. The first phase is a process of pyrolysis during which the pomace is converted, after heating, into char and volatile matter, such as steam, methanol, acetic acids and tars. The second phase is an exothermic reaction in which part of the carbon is oxidized to carbon dioxide. In the third phase, part of the carbon dioxide, the volatile compounds and the steam are reduced to carbon monoxide, hydrogen and methane. This mixture of gases diluted with nitrogen from the air and unreduced carbon dioxide is known as producer gas. If the original feedstock is charcoal, then the gasification process becomes two-phased, and the amount of tar produced is cut down [9]. Tar production in this case seems to be the major problem which this procedure faces, since it is formed at a temperature of ≈800°C and disturbs the fluidization. Another problem to solve during this process is the gas cleaning from tar and other suspended solids that come from fluidized bed or chars. Ash-related problems including sintering, agglomeration, deposition, erosion and corrosion, due to the low melting point ash of agro residues consist a main obstacle for economical and viable application of this conversion method for energy exploitation of the specific residues [10].

2.1.3 Pyrolysis process

Pyrolysis is the transformation of a compound or material into one or more substances by heat alone (without oxidation); in other words thermal decomposition. Pyrolysis is somewhat similar to vaporization, however, it is a relatively slow chemical process compared to the vaporization. The temperature at which pyrolysis occurs depends on the fuel type and the heating rate. Coal for instance, pyrolises at about 420^{o}C. This temperature is below the spontaneous ignition temperature of coal. Pyrolysis products consist of volatile gases, liquids (tar), and char generally. Products range from lighter volatiles to heavier tars. The composition of the volatile matter (gases), products of pyrolisis, depends also on the fuel. Pyrolysis of biomass is the thermal degradation of the material in the absence of reacting gases, and occurs prior to or simultaneously with gasification reactions in a gasifier [9]. The liquid fraction of pyrolisised biomass consists of an insoluble viscous tar, and pyroligneous acids (acetic acid, methanol, acetone, esters, aldehydes, and furfural). The distribution of pyrolysis products varies depending on the feedstock composition, heating rate, temperature, and pressure.

2.2 Biochemical process (C/N<30, moisture >50%)

2.2.1 Anaerobic digestion

Anaerobic digestion is appropriate for high humidity treatment of virgin pomace, since a watery mean helps the process. The fuel used will be the one which could be digested, depending on the fat material, humidity, etc. Degasified two-phase pomace can be energy used in a biomass direct combustion thermoelectric power station. Biogas can be used to generate heat and/or power, as well as treated as a transport fuel. The digested residual, on the other hand, can be applied to the land-farm, instead of inorganic fertilizers to improve soil fertility.

2.2.2 FERMENTATION PROCESSES

Currently many technologies are been developed in order to obtain liquid bio fuels (ethanol) from lingo-cellulosic materials. Two main lingo-cellulosic materials sources exist in the olive oil sector: the two-phase or three-phase pomace, and the olive grove pruning. Research in three-phase pomace (which could be also extended to two-phase pomace), is done by separating the extracted pulp from the pit fragments, using temperatures between 190-236 ºC and time periods between 120-240 seconds. This process has achieved a selective solvolysis of their main compounds (lignin, hemi cellulose and cellulose) [11]. After a fast auto hydrolysis process (steam explosion) the result is one soluble and another insoluble fragment.

3. A CASE STUDY OF THE REGION OF CHANIA IN CRETE

3.1 OLIVE PRODUCTS AND BY-PRODUCTS PRODUCTION (2000-2008)

The following data were collected for the region of Chania selected as the focus of potential energy uses of solid olive by-products

Table 2: Data for the region of Chania, Crete, [12]

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Olive trees	7168383	7.208.740	7.153.282	7.230.080	7.243.181	7.194.863	7.185.143	7.346.328	7.382.913
									in MT
olive oil	38.676	36.493	38.993	36.574	28.959	29.323	39.203	37.605	38.180
olives	181.820	175.990	180.082	179.994	163.452	190.442	188.244	190.172	191.729
prunings	143.368	144.175	143.066	144.602	144.864	143.897	143703	146.927	147.658
pomace									**in MT**
virgin	90.910	87.995	90.041	89.997	81.726	95.221	94.122	95.086	95.864
dried	52.728	51.037	52.224	52.198	47.401	55.228	54.591	55.150	55.601
exhausted	48.000	46.461	47.542	47.518	43.151	50.277	49.696	50.205	50.616

These quantities are plotted in Figure 3 below to compare yearly quantities between the different residue types.

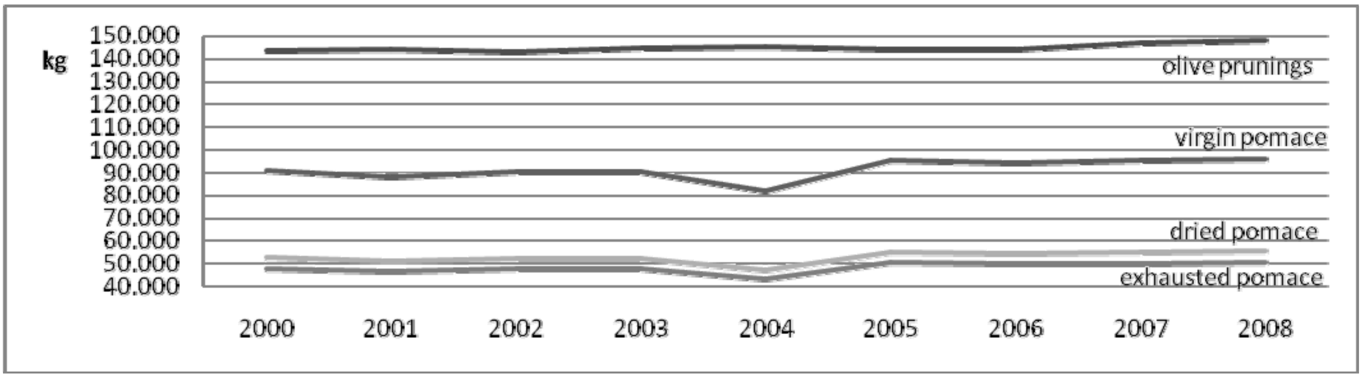

Figure 3. Olive solid residues production in chronological order.

3.2 OLIVE PRODUCTS AND BY-PRODUCTS PROJECTION (2009-2016)

An equation of the type "a+bx" was used to predict future values of a variable "y" using linear regression for known present data of "x", where:

$$a = \bar{y} - b\bar{x} \quad (1) \qquad \text{and} \qquad b = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2} \quad (2)$$

The forecasted values are tabulated below in metric tones (MT).

Table 3. Forecasting with trend of olive solid residues for the region of Chania, Crete.

	2009	2010	2011	2012	2013	2014	2015	2016
Olive trees	7.419.498	7.456.082	7.492.667	7.529.252	7.565.836	7.602.421	7.639.006	7.675.590
								in MT
olive oil	38.756	39.332	39.908	40.484	41.060	41.636	42.211	42.787
olives	193.286	194.843	196.400	197.957	199.514	201.071	202.628	204.185
prunings	148.390	149.122	149.853	150.585	151.317	152.048	152.780	153.512
pomace								**in MT**
virgin	96.643	97.421	98.200	98.978	99.757	100.535	101.314	102.092
dried	56.053	56.504	56.956	57.407	57.859	58.311	58.762	59.214
exhausted	51.027	51.438	51.850	52.261	52.672	53.083	53.494	53.905

Furthermore, using the calorific values of Table 4, the energy output (in GWh) of the solid residues was calculated and is shown in Table 5 below.

Table 4: High Heating Values of olive solid residues

	kcal/kg
virgin pomace	1800
dried pomace	4750
exhausted pomace	4500
olive prunings	4332

Table 5. Energy output in GWh obtained from the forecasted residue quantities

	2009	2010	2011	2012	2013	2014	2015	2016
virgin pomace	202	204	206	207	209	210	212	214
dried pomace	310	312	315	317	320	322	325	327
exhausted pomace	267	269	271	273	276	278	280	282
olive prunings	747	751	755	759	762	766	770	773

Based on the above energy content of dried pomace, the equivalent quantities of fossil fuels that can be replaced are calculated and shown in Table 6.

Table 6. Fossil fuels energy equivalent quantities to be replaced by dried pomace

	2009	2010	2011	2012	2013	2014	2015	2016
Diesel oil (MT)	25.907	26.116	26.325	26.534	26.742	26.951	27.160	27.368
LPG (MT)	23.561	23.751	23.941	24.131	24.320	24.510	24.700	24.890
Lignite (MT)	93.533	94.286	95.040	95.793	96.547	97.300	98.054	98.807
Natural Gas (MT)	23.225	23.412	23.600	23.787	23.974	24.161	24.348	24.535
Coking coal (MT)	39.539	39.858	40.177	40.495	40.814	41.132	41.451	41.769

4. CONCLUSIONS

The energy potential of solid olive residues such as pomace (in virgin, exhausted or dried form) and prunings is quite appreciable even though hugely unused in Greece. The available technologies can utilize the energy content of these residues to produce heat and electricity in local co-generation plants. Based on the past quantities, a forecast model was used to predict future residue values and their corresponding energy equivalents. Similar energetic applications are already in the production phase in Spain and in the development stage in Italy. The region of Chania is an excellent source of solid olive residues and a potential user of the energy content of these by-products.

References

1. UNCTAD based on data from the International Olive Oil Council (IOOC) 2005 + “The olive oil sector in the European Union”, EC, DG for Agriculture
2. www.e-toon.net/en/doc/Greek%20Sector%20Overview.pdf (accessed December 2008)
3. www.moreintelligentenergy.eu/public/file/download/More_WP3_D3_1_final.pdf (accessed January 2009)
4. www.eubionet.net/GetItem.asp?item=file;4950 (accessed December 2008)
5. Sanchez Moral P., Victoria Ruiz Mindez M., 2006. Production of pomace olive oil, Enero-Marzo, 47-55
6. Tsourveloudis N. C., Kiralakis L., Rotary Drying of Olive Stones: Fuzzy Modeling and Control
7. www.eubionet.net/GetItem.asp?item=file;5001 (accessed December 2008)
8. Fokaides,P.A., Dr. Tsiftes, K, 2007. Utilisation of Olive Husk in energy sector in Cyprus Renewable Energy Sources & Energy Efficiency, 28-30.
9. http://www.handbook.ifrf.net (accessed December 2008)
10. http://www.brdisolutions.com/pdfs/bcota/abstracts/29/z262.pdf (accessed January 2009)
11. http://www.e-toon.net/en/doc/Catalogue%20of%20Energy%20Technologies.pdf (accessed December 2008)
12. Number of olive trees and quantities of olive oil and olives olive oil were given by the Hellenic National Statistical Service.