Human health benefits and energy saving in olive oil mills

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Abstract

Increasing greenhouse gas production are strictly related to high energy consumption in developed and developing country, causing indirectly human health damages. Besides every kind of industry, including agro-food industry, needs a remarkable amount of high quality energy (electrical energy). These two problems may be solved using renewable sources as biomass and agro-food chain residuals, but the effective convenience of this opportunity should be energetically and environmentally demonstrated for each case study.

In this paper energetic and environmental impacts of olive oil mill are evaluated, considering possible energetic utilization of by-product obtained during the oil extraction process. The solid content of pomace consists of crushed olive stones with a 18000 kJ/kg LHV, which may contribute to primary energy saving of the agro-food industry. This solution implies adequate requirements of thermal energy for the agro-food industry or the nearest users and implementation of suitable equipment to separate and burn this residual.

During an entire production campaign, the electric energy consumption and processed olive mass of a typical olive oil mill have been measured. The analysis has highlighted that the utilization of olive stones as solid biofuel improves some environmental indicators (greenhouse gases); nevertheless the energy balance of the extraction plant must be assessed, because the stone separation determines an high electricity requirement. The environmental impact of different scenarios of olive oil mill have been evaluated using LCA methodology in order to define possible energy process chains, to fix carefully the system boundary and to develop the allocation step.

Keywords: greenhouse gas reduction, olive oil environmental impact, olive oil by-products, olive oil mill energy saving.

Introduction

Increasing greenhouse gas production are strictly related to high energy consumption in developed and developing country, causing indirectly human health damages. On the other hand every kind of industry, including agro-food industry, needs a remarkable amount of high quality energy, i.e. electrical energy. These two opposite problems may be solved using renewable sources as biomass and agro-food chain residuals, but the effective convenience of this opportunity should be energetically and environmentally demonstrated for each case study.

In this paper energetic and environmental impacts of olive oil mill are evaluated, considering possible energetic utilization of by-product obtained during the oil extraction process. In fact, the solid content of pomace consists of crushed olive stones with a LHV of about 18000 kJ/kg, therefore this by-product may contribute to thermal energy requirements of the agro-food industry. This solution permits energy saving, but at the same time it implies adequate requirements of thermal energy for the agro- food industry or other users within a distance of few kilometres and implementation of suitable equipment to separate and burn this residual.

During an entire production campaign, the electric energy consumption and processed olive mass of a typical olive oil mill have been measured; then the feasibility of the introduction of a stone separator has been evaluated.

The analysis has highlighted that the utilization of olive stones as solid biofuel can improve some environmental indicators (i.e. greenhouse gases); nevertheless the energy balance of the extraction plant must be assessed, because the stone separation determines an high electricity requirement.

The environmental impact of different scenarios of olive oil mill have been evaluated using LCA methodology in order to define possible energy process chains, to fix carefully the system boundary and to develop the allocation step. Inventory phase of the LCA has been developed using experimental data of different operative phases.

Materials and methods

The experimental olive oil mills are located in the Province of Florence (Italy) and they are representative for small and medium size farm plants (working capacity of about 500 kg/h of olives). The olive mills considered are characterised by similar working processes, layout plant, installed electric power, working capacity, quality level of the extracted olive oil.

The olive mill monitored for electric energy consumption measurements, process olives conferred within 24 hours since collection and its layout comprises the following steps: defoliation-washing, crushing, vertical kneading, two phases centrifugal extraction, filtration with cartons.

Working process parameters are shown in Table 1: the data are referred to the overall electric power employed in each process step, including submitted equipment (transfer pumps, cleaning pumps, fans, etc.), and to the single olive lot, whose average mass value is 298,77 kg.

Another similar olive mill, using a pomace stone separator after the oil centrifugal extraction phase, is considered to evaluate the impact of stone collection on oil mill energy balance (see Table 1). Considering an average solid content about 40% on olive mass, the efficiency of the stone extraction is about 15% on olive mass.

Considering three kinds of performed operation, energy consumption shares show (see Table 2) that

- about 40% of total mill energy consumption is used in olive conditioning operation, the can be assumed as the effective energy requirement of the olive oil mill,
- about 25% of total mill energy consumption is spent for mass transfer and more than 33% of this quantity is lost in mass temperature increase as shown in Figure 1.

These results don't consider environmental impact of pomace stone separator, related to increasing equipment (stone separator, boiler, piping system) need and commodity consumption related to pomace stone separator insertion in olive mill layout. Besides, recent extra-virgin olive oil production protocols target the minimum temperature increase of processed mass for nutritional content preservation, so it is necessary to use the available potential heat energy out of the olive mill, i.e. for energy need of other farm agro-food production chains or services.

Table 1. Working process energetic parameters

		Installed power [kW]	Time [s]	% power exploitation	Energy consumption [kJ]	Specific energy consumption [kJ/kg]
defoliation-washing		1,77	1279,00	100,00%	2263,83	7,58
crushing	cutting	5,50	1279,00	51,40%	3615,733	12,10
	auxiliary equipment	1,86	1279,00	100,00%	2378,94	7,96
kneading		1,10	3600	100,00%	3960	13,25
extraction	centrifugation	15,00	1926	56,00%	16178,4	54,15
	auxiliary equipment	1,50	1926	100,00%	2889	9,67
filtration		0,75	242	100,00%	181,5	0,61
TOTAL		27,48	8326,00	66,26%	31467,4	105,32
stone separator		15,00	1926	66,26%	19141,2	64,07
TOTAL with stone separator		42,48	10252,00	66,26%	50608,60	169,39
Increasing due to stone separator insertion		15,00	1926,00	-	19141,20	64,07

Table 2. Analysis of energy utilization in the process

	Absolute value [kJ]	Specific value [kJ/kg]	%
Mass temperature increase energy consumption	10798,58	36,14	34,31%
Mass transfer energy consumption	7531,77	25,21	23,94%
Mass transformation energy consumption	13137,06	43,97	41,75%
Total energy consumption	31467,40	105,32	100,00%

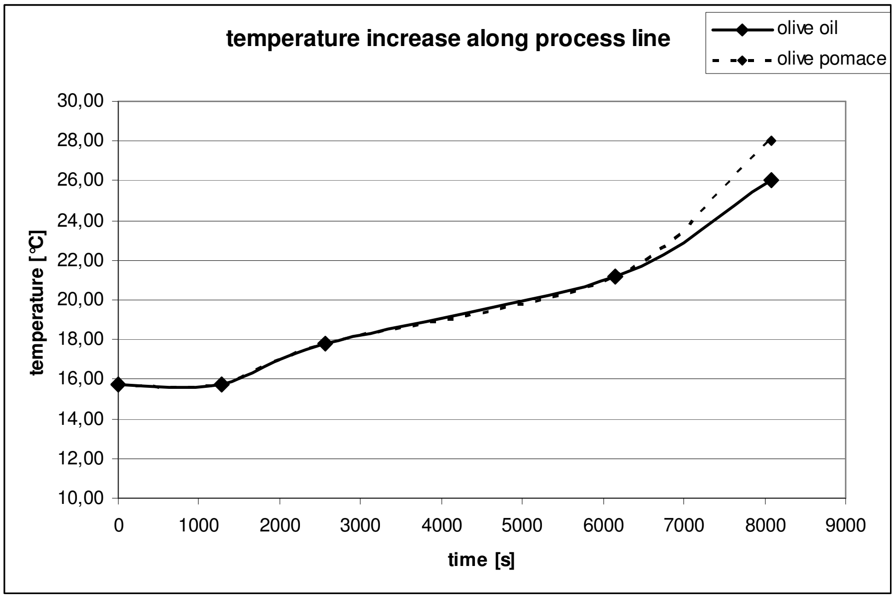

Figure 1. Temperature increase along the process line.

For environmental impact of pomace stone separator implementation in olive oil mills, an LCA analysis has been carried out. An olive oil production chain can consist of several processes: olive trees cultivation (soil preparation, fertilization, etc.), olives collection, olives transport from field to oil milling plant, olive oil extraction through mechanical plant. Along the whole agricultural chain, all emissions (GHG, air emissions and resources use) must be accounted.

In the energy-environmental analysis of production systems the following steps will be considered: system boundaries identification, reference energy system definition, all inputs and outputs (mass and energy) identification and quantification, energy embodied in facility infrastructure identification, distribution system analysis and by-product analysis.

In the present paper just considers the extraction process of olive oil, defining different case studies:

1. extraction process with oil production and pomace treated as waste (reference case);
2. extraction process with oil production and pomace used as fertiliser;
3. extraction process with oil and pomace stone productions;
4. extraction process with oil and pomace stone productions, using pomace residue as fertiliser.

The work has been developed in order to evaluate the environmental impact of olive oil production considering different possibilities for the by-product reuses (the reference case of the LCA hypothesise that the two phases pomace is treated as waste).

Concerning the milling plant, an operating time of 1200 hours for year has been considered hypothesizing that the plant will work continuously during about 2 months. The milling plant is able to treat 500 kg/h of olives using 792 kJ/kg of electricity supply without separation machine.

The work has supposed a fertiliser supplies of about 0,002750 kg of phosphorus, 0,006143 kg of calcium, 0,005143 kg of nitrogen, 0,009107 kg of potassium per each kg of pomace.

With the aim to evaluate correctly the possibility of energetic use of pomace stones the allocation of this co-product has been carried out using as replaced process the process of natural gas production (considering the Italian mix).

Results

As shown in Table 1, the insertion of stone separator in layout olive mill determines power, time and energy consumption increase. Considering olive mill energy efficiency related to stone separation insertion, crushed stone collection allows to make 44,82 kg of crushed stones available for each olive lot entering the process, using additional 64,07 kJ of electric energy (stone separator) for each kg of worked olives. It means that the consumption of about 19000 kJ of electric energy makes about 807000 kJ of potential heat energy available.

Analysing the LCA analysis results a significant benefit of the use of pomace as fertiliser (the spreading in field can reduce the amount of fertilisers) has been detected. Nevertheless the energy use of pomace stones has highlighted a consistent electricity consumption increase (more than 60%) due to separation equipment.

The LCA analysis main indicators for hypothesized scenarios are shown in Table 3.

Table 3. LCA results by GEMIS for 1000 kg of produced olive oil (CER = Cumulated Energy Requirement; CMR = Cumulated Material Requirement).

Emissions	CO_2 equivalent [tons]	SO_2 equivalent [kg]	NOx [kg]	HCl [kg]	Particulates [kg]
oil mill 1	8,0	7,26	8,36	0,02	0,72
oil mill 2	2,1	3,68	5,82	0,00	0,33
oil mill 3	8,2	7,32	8,37	0,02	0,73
oil mill 4	2,6	3,73	5,82	0,00	0,34

CER	Sum [MWh]	Non renewable %	Renewable %
oil mill 1	3,39	99,2	0,8
oil mill 2	1,61	98,9	1,1
oil mill 3	3,02	98,6	1,4
oil mill 4	1,24	97,4	2,6

CMR	Sum [kg]	non renewable [kg]	renewable [kg]	other [kg]
oil mill 1	$5,5\ 10^3$	$5,7\ 10^1$	$5,4\ 10^3$	3,7
oil mill 2	$1,4\ 10^3$	$-6,7\ 10^2$	$2,1\ 10^3$	3,2
oil mill 3	$5,9\ 10^3$	$5,8\ 10^1$	$5,9\ 10^3$	3,7
oil mill 4	$1,8\ 10^3$	$-6,7\ 10^2$	$2,5\ 10^3$	3,1

Conclusions

This work has shown some interesting aspects of olive mill by-product utilization:

- pomace stone separation allows the olive mill to have a significant thermal power available with a minimum increase of electric energy consumption;

- field distribution (scenarios 2 and 4) determines strong reduction of emissions, especially GHG ones (about 75%), half energy (CER) and raw material (CMR) consumption;
- stone pomace recovery (scenario 4) determines additional energy savings, but causes increase of raw material consumption and mainly an increase of GHG emission with respect to the field distribution of the whole pomace mass (scenario 2).

As a conclusion, the availability of an additional thermal power from pomace stone energetic exploitation (scenario 4) for the single olive mill or farm allows a significant energy saving but as a draw back causes a GHG emission increase in olive oil production chain.

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