ENERGY EFFICIENCY IN THE OLIVE GROVES AND OLIVE OIL MILLS

Fátima Baptista, Luis Leopoldo Silva, Vasco Fitas da Cruz

Departamento de Engenharia Rural, Escola de Ciências e Tecnologia, MED - Instituto Mediterrâneo para a Agricultura, Ambiente e Desenvolvimento, Universidade de Évora, Évora 7000-849, Portugal.

The assessment of energy consumption in agriculture has been focused mainly on direct energy. However, a very important part of the total energy consumed on farms is related to indirect energy, *e.g*. the energy used in the production of other inputs, such as fertilizers and others. Various studies carried out with data from olive groves with different planting intensities made possible to assess direct and indirect energy consumption, identifying the production factors with the greatest impact. In the olive mills, studies of energy consumption in the several processing phases, combined with knowledge of the energy balance, make it possible to identify critical points and the appropriate technologies to improve energy efficiency.

In the Alentejo Olive Oil Sustainability Plan (AOSP) there are chapters dedicated to Energy Efficiency in the Olive Groves and in the Olive Mills, where the criteria and categories considered for the definition of energy sustainability throughout the production chain are defined. In both, the objective is to assess the level of sustainability of the producers (pre-initial, initial, intermediate or developed).

Key-words: AOSP, sustainability, energy, olive oil

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Email: fb@uevora.pt

1. Introduction

Improving energy efficiency is an actual challenge as a way to contribute for the reduction of the negative impacts on climate and natural resources. A highly efficient energy use means to use less energy per unit of product and will contribute to reduce GHG emissions and production costs. The evaluation of energy consumption in agriculture production has been focus mainly on direct energy consumption. However, for crop production an important part of the total energy consumed on farms is related to the production of fertilizers and other inputs (p.e. agrochemicals).

In olive mills the general production process consists in olives reception, cleaning and storing, grinding and paste homogenisation, phase separation, storage and bottling. The major source of energy used in olive mills operation is electrical and thermal.

It is well-known that the main factor for CO_2 emissions during the agro-food industrial processes is energy consumption. Also, agro-food producers are aware of the importance that international markets give to food products' carbon footprint. To respond to hygiene and environmental requirements olive oil mills sector are an example of the agro-industries that presented a positive evolution with modernization and technological adaptation. These improvements are linked to the energy use performed during crop management, food manufacturing and distribution.

The main objective of this paper is to resume results of previous works with the goal of energetic analysis in olive groves and olive oil mills and to explore the results in order to develop the Alentejo Olive Oil Sustainability Plan (AOSP) to assess the level of sustainability of the olive oil chain.

2. Olive groves

A complete description of these results are available in Enoque *et al.* (2015). For the mentioned work the information was obtained from four olive groves in an intensive production system and two in a super-intensive system and the energy consumption indicators were estimated for direct and indirect energy, which allowed identifying the inputs with high impact on energy consumption and on the environment. In the following table it is presented the yield and energy consumption for the olive groves analysed.

Table 1 – Yield and energy consumption in olive groves (A-intensive system, B-super intensive system)

	A1	A2	A3	A4	B1	B2
Yield (ton ha^{-1})	8.8	6	4.5	5	10	10
Direct Energy (MJ ha^{-1})	2857.81	2557.30	2182.46	2247.32	1846.73	2224.82
Indirect Energy (MJ ha^{-1})	6261.29	7264.74	5949.24	5064.70	8047.40	14504.71
Total Energy (MJ ha^{-1})	9119.10	9822.03	8131.70	7312.02	9894.13	16729.53

It can be seen that the direct energy consumption was much lower than the consumption of indirect energy, in both production systems. This highlights the importance of indirect energy consumption in accounting for the total energy consumed in these production systems. Comparing the values of direct energy consumed in both production systems, it appears that in intensive systems direct energy consumption is almost always higher than in super-intensive systems, but with similar values in most cases. This can be explained by the longer time spent in harvesting operations in intensive olive groves. In Table 2 it is shown the energy consumption for the different inputs.

Table 2 – Energy consumption for the different inputs (A-intensive system, B-super intensive system)

Energy consumption ($MJ\ ha^{-1}$)	A1	A2	A3	A4	B1	B2
Materials	40.15	41.21	37.54	39.37	79.18	14.25
Fertilisers	3871.96	4697.78	2762.04	3280.20	5371.40	10008.63
Agrochemicals	900.12	1265.64	1259.65	485.13	1332.88	3220.80
Irrigation	1449.07	1260.11	1890.00	1260.00	1263.94	1261.04
Diesel	2857.81	2557.30	2182.46	2247.32	1846.73	2224.82
Total	9119.10	9822.03	8131.70	7312.02	9894.13	16729.53

Fertilizers are a very important factor in energy consumption, followed by diesel used for the different agricultural operations. The highest energy consumption values, in all farms, were due to the use of fertilizers. The results seem to indicate that to improve energy efficiency in olive grove production it will be essential to invest in a rational use of fertilizers. This will need fertilization programs perfectly adapted to the production systems, the variety, the crop stage and the soil characteristics, among others.

In the case of specific energy ($MJ\ ton^{-1}$) and specific productivity ($ton\ MJ^{-1}$) it can be seen that, there is some variation between olive groves (Table 3). In the case of intensive olive groves, this variation is fundamentally due to the variability of yield in each olive grove. In the case of super-intensive olive groves, there is a very large difference between the two olive groves analysed, despite having the same yield (10 ton/ha). The B1 olive grove presents values close to the A1 olive grove, due to the little difference in the yield of both. The B2 olive grove, despite having a higher yield than most olive groves in an intensive system, ends up presenting very similar specific energy and energy productivity values, which is due to the very high value of primary energy consumed (Table 2).

Table 3 – Specific Energy and energy productivity (A-intensive system, B-super intensive system)

Energy Indicators	A1	A2	A3	A4	B1	B2
Specific Energy (MJ ton-1)	1036.26	1637.01	1807.04	1462.4	989.41	1672.95
Energy Productivity (kg MJ-1)	0.97	0.61	0.55	0.68	1.01	0.60

The results obtained seem to indicate that in order to improve energy efficiency in olive grove production, it will be essential to invest in the rational use of fertilizers. To do so, it will be necessary to have fertilization programs perfectly adapted to the production system, variety, phenological state of the crop and soil characteristics, among other aspects. It should be noted that this study was carried out based on information provided by those responsible for the various farms, not having resulted from a classic investigation work, with experimental work carried out, previously outlined and monitored throughout the campaign for data collection. For this reason, these are results that illustrate case studies, which are indicators of the reality, but must be analysed taking this aspect into account. We believe that longer work is needed, with a much higher number of holdings, in order to have a representative sample that would make it possible to draw some more conclusions.

3. Olive oil mills

The TESLA project (https://teslaproject.chil.me/) financed by the European Commission under the framework of the Intelligent Energy Europe programme, had the main objective of extend the best available practices for the evaluation of the energy situation and for the adoption of improving measures amongst the European SMEs on the agro-food sector.

A complete description of the results shown here can be found in detail in Baptista *et al.* (2014a,b). Typical energy values were analysed in two mills with of 1.600 and 300 tons of olive oil per year (both two-phase oil decanter and biomass boiler). Olive oil mills have a clear seasonal activity: from November to March. Information about equipment characteristics, namely power installed, energy consumption and quantity of olives processed was recorded in olive mills in Portugal and in Spain (Cooperativas Agro-Alimentarias, 2010). Table 4 show the average values of standard production for an industry producing 300 tons of olive oil per year.

Table 4 - Values of a standard production process, industry of 300 tons of olive oil per year, from an analysis of the University of Évora of a representative olive oil mill

		VALUES OF THE TYPICAL TECHNOLOGY USED IN THE PROCESS			
PROCESS (sequential order)	TYPICAL TECHNOLOGY	Electrical power installed (kW)	Electrical energy consumption (kWh/year)	Thermal power installed (kW)	Thermal energy consumptio n (kWh/year)
Olives reception, cleaning and storage	Electrical motors	70	3.600		
Mill and paste preparation	Electrical motors, olive pit boiler	100	13.000	*175	50.000
Separation of phases (decanter) and centrifuge	Electrical motors of the two phases decanter	40	12.500		
Storage		0	0		
Bottling	Electrical motors	6	710		
Lighting and other electrical auxiliary processes	Fluorescents	1	1.350		
Thermal auxiliary processes	Heating boiler			*175	10.000
TOTAL		217	31.160	175	60.000

* Thermal power installed is referred to boiler power heating water for both processes (mill and paste preparation and thermal auxiliary processes) which cannot be considered separately.

Concerning the thermal energy consumption, we can see that biomass consumption is only used in the boiler to heat water used in the production process or for heating the building offices. In most of the olive oil mills boilers use olive pit as the source of biomass fuel, and in most cases they use the pit obtained during the olive oil production.

Figure 1 shows the energy balance (thermal and electrical energy) using the Sankey diagram for the analysed industries with 1.600 tons of olive oil processed per year. It is possible to observe the relative distribution of thermal and electrical consumption per production phase. Concerning the thermal energy, the higher consume is for the mill and paste preparation while electrical energy is mainly for the phases separation and paste preparation. This shows that measures to improve energy efficiency need to be focused on these production processes. Reception and lighting are also important, using 4% of the total energy consumption.

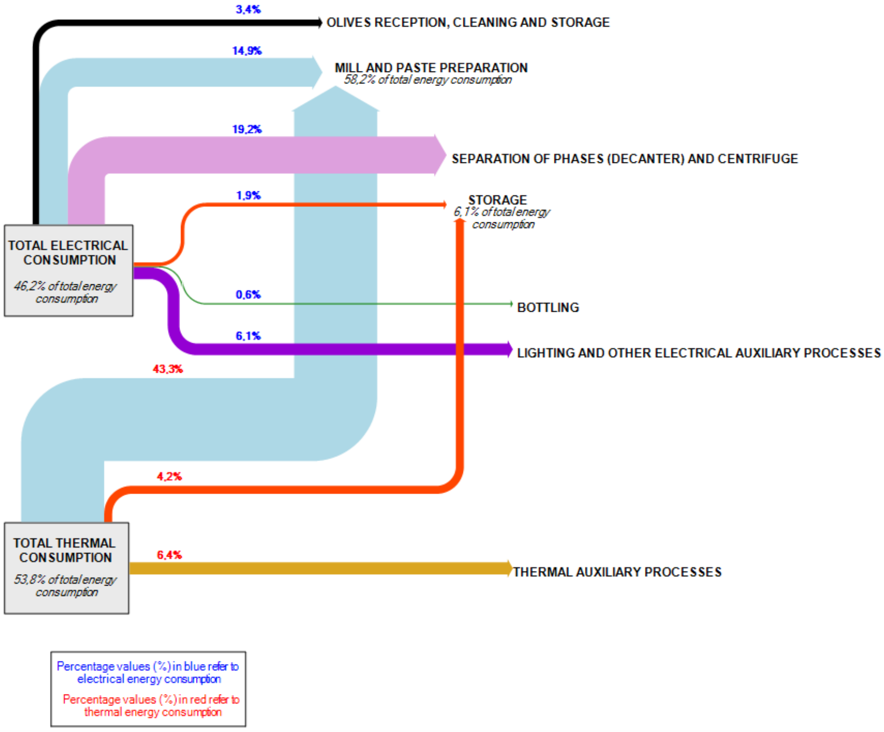

Figure 1 - Electrical and Thermal Energy Balance for the standard production industry of 1.600 tons of olive oil per year (Baptista *et al.*, 2014a, figure elaborated by Arianna Latini, ENEA)

In olive mills, it is necessary to optimise energy consumption and with that energy efficiency will be improved and will also contribute to reduce energy costs and GHG emissions. With the study of the energy consumption along the several production phases and with the knowledge of the energy balance, it is possible to identify critical points and to use suitable techniques to improve energy efficiency. These are essentially some interventions in the equipment, lighting, automation, and the use of olive pit as biomass fuel for the boilers. Also, the use of insulating material in the pipes that transport hot water can minimize heat losses and decrease energy consumption. Another important aspect is to use equipment correctly designed and adjusted for the production volume, improving the production system functioning and saving energy. Finally, a correct and frequent maintenance of the equipment is also very important to save energy.

4. Alentejo Olive Oil Sustainability Plan (AOSP)

Results from previous research has been resumed and constitute the basis, with the sector validation, for ongoing development of the Alentejo Olive Oil Sustainability Plan (AOSP). Two chapters dedicated to Energy Efficiency in the Olive Groves and in the Olive Mills are included, where the criteria and categories considered for the definition of energy sustainability throughout the production chain are defined. In both, the objective is to assess the level of sustainability of the producers (pre-initial, initial, intermediate or developed).

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