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D 4.3: Current process description Olive oil mills (English)

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Transfering
Energy Save
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About this report

This report has been develop in the framework of the TESLA project (Intelligent Energy in Europe) and has been founded by the European Commission.

1. Introduction

Olive trees growth is geographical limited due to soil and climate requirements. It's a crop specially adapted to the Mediterranean conditions, namely, climate conditions, and therefore it´s one of the predominant crops of the Mediterranean region. Olive trees originated in Anatolia (Turkey) 8000 years ago and from there spread to the middle orient, North Africa and the south of Europe.

Over time, it has assumed a great importance in the economy, culture and social life of the Mediterranean Basin civilizations.

Olive oil production it's an essential sector in the structure of the agricultural production of southern Europe countries. Olive annual production it´s not stable. Yields are very dependent on climatic conditions, and generally a year with good yields is followed by a lower yield year.

Nevertheless, improvements made in the last decade in the breeding of cultivars able to give more stable yields and the introduction of irrigation allowed a decrease in the differences of annual production between successive years. At the same time the improvements and modernization of olive mills, and oil extraction processes, allowed to obtain higher olive oil production, with higher quality. Traditional olive mills, that generated great quantity of sub products and waste, causing high environmental impacts, were replaced, first with threephase continuous centrifugation systems olive mills and after that with the "ecological" two-phase centrifugation systems olive mills that have a significant less water consumption and waste production.

Near 95% of olive groove production is in the Mediterranean Basin. In 2010/2011, the countries from the European Union (Spain, Italy, France, Greece and Portugal) were responsible for 71.8% of the world olive oil production (Fig. 1).

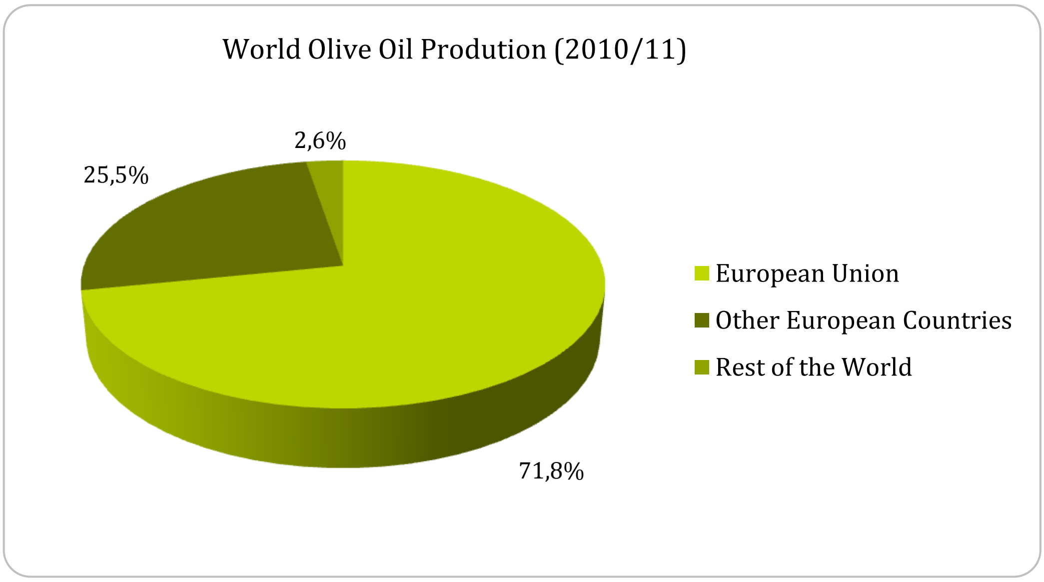

Figure 1. World olive oil production in 2010/11. Source: IOC (2011)

World olive oil production (fig. 2) showed some yield variability in the past decade, with some stability between 2005/06 and 2008/09, and a slight increase in 2009/10 and 2010/11. The world consumption showed less variation during this period.

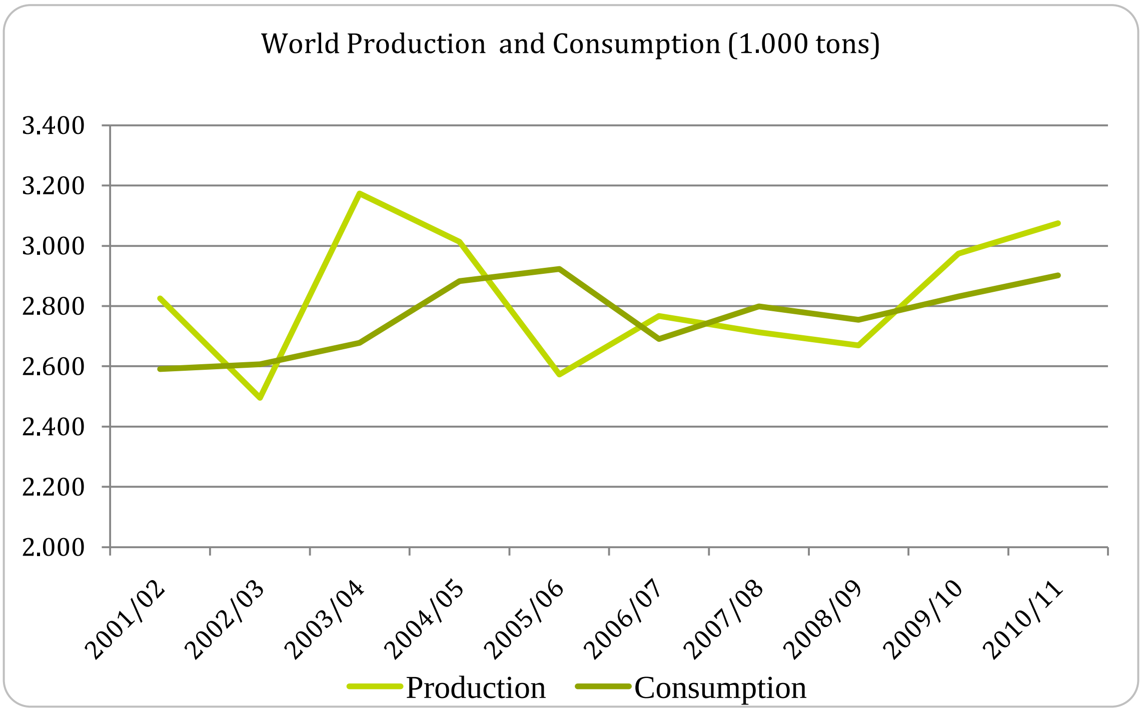

Figure 2. Evolution of world production and consumption of olive oil. Source: IOC (2013)

2. Sector characteristics

2.1. Olive oil manufacturing process

The production processes considered in this document deals with the olives arriving in the olive mills until the bottle of the olive oil.

After harvesting, there is a limited period of 24 hours, to produce the olive oil, in order to avoid olive fermentation and degradation, which would decrease the olive oil quality.

2.1.1 Cleaning and washing

As soon as olives arrive in the olive mill, they are cleaned and washed. This process is performed by a cleaning machine (fig. 3), which separates the olives from other vegetal materials (leaves, branches) and soil attached to the olives during the harvesting and collecting of olives in the field, and washes them. In the washing process there is consumed about 10 to 12 L of water per 100 kg of olives.

Figure 3. Cleaning and washing machine

After this process olives are transported by crawlers (fig. 4) to the storage containers were they stay until the beginning of the next processing stage. Before entering the storage container, they pass through a balance (fig. 5) and are weighted.

Figure 4. Crawlers

Figure 5. Balance

Figure 6. Storage containers 1

Olives are separated in different storage containers (fig. 6) according to their variety and quality, determined in the previous phase.

This first processing stage (from harvesting to the beginning of processing) should be done as quickly as possible. A long storage time leads to the deterioration of olives and decreases the olive oil quality.

2.1.2. Grinding

In this stage olives are crushed in a steel drum mill (fig. 7) originating an olive paste. The purpose of crushing the olives is to tear the flesh cells to facilitate the release of the oil from the vacuoles. The pit or seed of the olive represents 25% of the olive weight but has less than 1% of oil content. Most of the olive oil comes from the olive pulp, which has an oil content of about 15%.

It is necessary to take special attention to the grinding time and the grinding degree, which depends on the sieve mesh size of the steel drum mill. A long grinding process may increase oxidation of the paste and reduce the flavour of the olive oil. In modern steel drum mills the grinding process takes about 20 minutes.

Figure 7. Steel drum mill 1

2.1.3. Malaxation (or beating)

After grinding, the paste is stirred slowly in a mixer (fig. 8). Olive paste is beat and mixed, with the objective of making the paste uniform, continuing the release of the oil from the olive pulp cells and break up the oil/water emulsion allowing small oil drops to combine into larger drops, which facilitates the mechanical extraction of the oil.

The horizontal mixer (fig. 8) has 3 cylindrical double wall tanks with pierced blades. These blades have a rotation speed of 20 rpm, to allow a slow mixing. The processing capacity of the machine is of 10.000 kg of paste per hour.

The mixing process is done with moderate temperatures (between 25ºC to 28ºC), maintained by the heated water used in the mixer.

Figure 8. Horizontal mixer

These temperatures facilitate the release of the oil, without changing its organoleptic characteristics. Mixing time and temperature are the two parameters to have in consideration in this stage of the process. Longer mixing times (Table 1) will increase oil yield, decreasing the oil content of the pomace (the solid residue after the separation of the olive oil), but allows a longer oxidation period that decreases shelf life.

Temperature influences directly the olive oil viscosity. A higher temperature will allow high olive oil yields, since it facilitates, in the next phase, a better separation of water and oil. However, if the olive paste temperature is too high it can produce a reduction of olive oil quality, producing olive oils with a pronounced bitterness (Petrakis, 2006).

Table 1- Influence of malaxation time in oil extraction yield (Adapted from Di Giovacchino et al., 2002)

Determinations		**Malaxation time (min)**		
		15	**45**	**90**
Olive oil extraction yield (%)		78,5	82,8	85,7
Olive pomace	Quantity (Kg/100 kg olives)	71,7	71,9	71,5
	Moisture (% on fresh pomace)	57,7	58,2	58,9
	Oil (% on fresh pomace)	4,4	3,6	3,1
	Oil (Kg/100 kg olives)	3,1	2,6	2,2
Vegetable waste water	Quantity (L/ 100 kg olives)	25	20	20
	Oil (% on vww)	2,8	2,1	1,6
	Total oil lost in by-products (Kg/100 kg olives)	3,8	3,1	2,5

2.1.4. Separating oil from water and solids

The next step consists in separating the oil from the rest of the olive components (solids and vegetable water). Traditionally this used to be done with presses, but now it is done by centrifugation processes, in large capacity horizontal centrifuges (decanters) (fig. 9).

Figure 9. Horizontal centrifuge (Decanter)

The centrifugation process can be a three-phase centrifugation that allows to separate the oil (oil phase), the water (water phase), and solids (solid phase), or a two-phase process separating only the oil from the wet pomace. The high centrifugal force created in the decanters allows the phases to be readily separated according to their different densities.

In the three-phase oil decanters, a portion of the oil polyphenols is washed out due to the higher quantity of added water (when compared to the traditional method), producing a larger quantity of vegetation water that needs to be processed. The two-phase oil decanters use less water quantity in the oil extraction process, producing significant less waste water, and thus reducing the phenol washing. The used water is expelled by the decanter together with the pomace, resulting in a wetter pomace (62 to 75 % water content). This creates a higher quantity of pomace compared to the three-phase decanters (Table 2).

In each extraction process (two-phases or three-phases) the results of the components are different (Table 2).

Table 2 – Quantities of each phase in different centrifugation processes (Adapted from Petrakis, 2006)

Determinations		Centrifugation process	
		2-phase	3-phase
Olive oil extraction yield (%)		86,1	85,1
Olive pomace	Quantity (Kg/100 kg olives)	72,5	50,7
	Moisture (% on fresh pomace)	57,5	52,7
	Oil (% on fresh pomace)	3,16	3,18
	Oil (% of dry matter)	7,44	6,68
Vegetable waste water	Quantity (L/ 100 kg olives)	8,3	97,2
	Dry residue (% on vww)	14,4	8,5
	Oil (g/L)	13,4	12,6
	Total oil lost in by-products (Kg/100 kg olives)	2,42	2,8

After leaving the decanter the oil and vegetable water go through a 3200 rpm vertical centrifuge (fig. 10) for the removal of natural sediments and for the separation of the small quantity of vegetation water remaining in the oil.

Figure 10. Vertical centrifuge

The pomace goes through a sieve were the biggest solid particle (olive pits) are separated from the rest of the pomace. This solid residue particles can be used as fuel in a biomass boiler (fig. 11) to heat water, that is used in the horizontal mixer (fig. 8) and other equipment that require warm water for their operation. It can also be used to warm part of the olive mill installations, since they release heat during its passage through the pipes. 10 kg of olive pit per hour will produce 41 000 kcal. With an efficiency of 85%, we have 34 850 kcal/h.

The remaining pomace is sold for producing pomace olive oil. It is transported to specialized facilities called extractors which heat the pomace between 45ºc and 50ºc and can extract up to 2 litres of oil per 100 kg of pomace using adapted two-phase decanters. The price of pomace depends on its availability in the market and the pomace oil concentration. Small olive pits can be sold by 3-4 euros per ton.

Figure 11. Boiler

2.1.5. Storage

After passing through the vertical centrifuge, the olive oil, completely clean, is weighed (fig. 12) and goes into stainless steel containers (fig. 13), where it stays for a period of approximately 2 to 3 months. This period is sufficient to make a final clean-up of the olive oil, by deposition of the particles in suspension, leading to a higher quality olive oil.

Figure 12. Oil weighing process

Figure 13. Olive oil stainless steel storage container

2.1.6. Bottling

After the storage period the olive oil is ready for consumption. It is bottled in glass bottles (fig. 14) and becomes ready to enter in the commercial circuit.

Figure 14. Olive oil bottling process

3. General data on olive oil production

Olive oil production in the four countries analysed in this report (Spain, France, Italy and Portugal) present significant differences, as shown in figure 15. Spain is by far the bigger olive oil producer contributing with 52% to 74% of the total olive oil production of the four countries. Italy follows Spain with 23% to 46% and Portugal and France are very behind with values between 2% to 3%, and 0.2% to 0.4%, respectively.

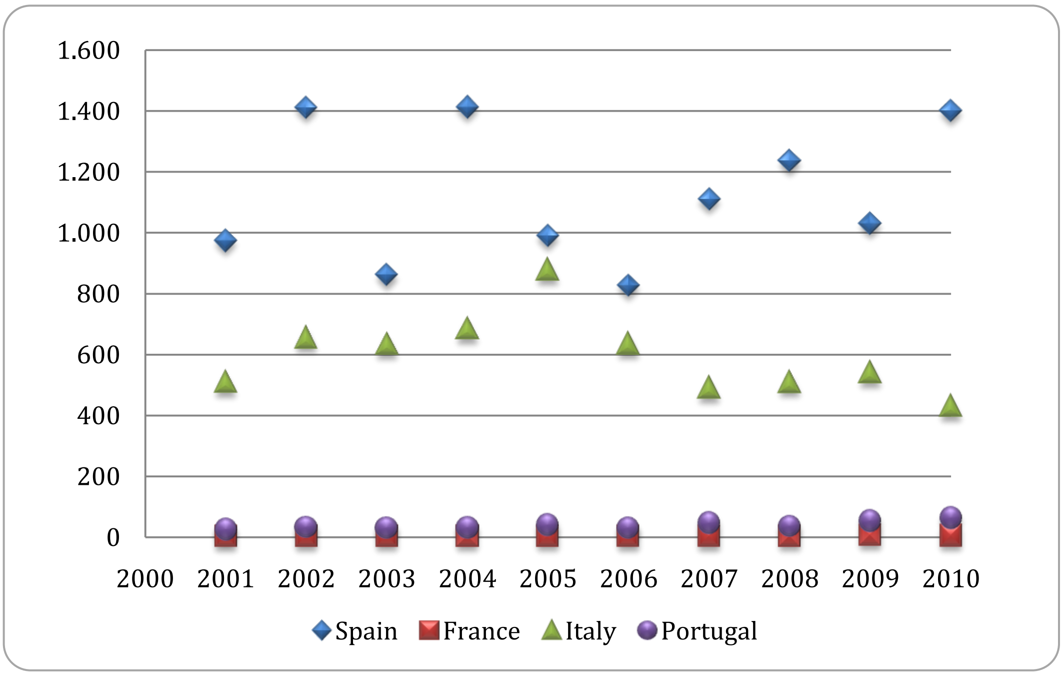

Figure 15. Olive oil production (1000 tons).Source: IOC (2013)

3.1. Portugal

Olive grove plantation areas (fig. 16) decreased from 2000 to 2001 and then stabilized until 2009 when they had a slight decreased. Between 2009 and 2011 the planted area increased, but it is still below the 2000 year values. The increase in olive groove areas in the last few years led to an increase of new olive mills and the modernization of existent ones, from traditional to three phase and two phase olive mills. It also led to the investment in infrastructures to transform and use the pomace from olive oil production. Table 3 shows the characterization of the olive sector in 2011.

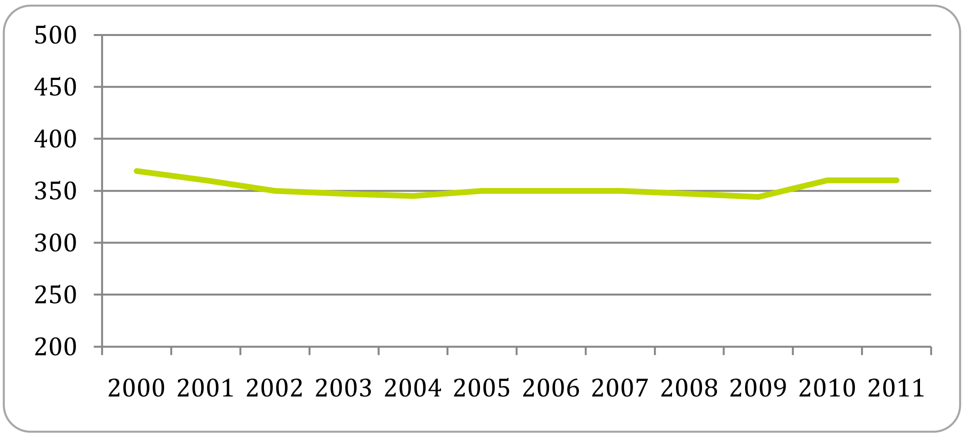

Figure 16. Olive grove areas in Portugal (1000 ha). Source: IOC (2013)

Table 3 – Characteristics of the Portuguese olive sector (INE, 2013)

Olive groves for olive oil production (ha)	338 048
Produced and processed olives (ton)	510 733
Olive productivity (kg olives/ha)	1 511
Number of active olive mills	527
Total olive oil production (ton)	76 203
Olive oil productivity (kg olive oil/ha)	225
Olive yield in oil	15%
Olive oil importations (ton)	51 880
Olive oil exportations (ton)	57 533
Exportation-Importation balance (ton)	5 653
Olive oil stock variation (ton)	-3 661
olive oil consumption (ton)	74 211
Olive oil consumption per capita (kg)	7,0
Self-sufficiency in olive oil	103%
Olive oil importations (thousands of euros)	99 265
Olive oil exportations (thousands of euros)	154 569
Exportation-Importation balance (thousands of euros)	55 304
Average unit value of importations (euro/kg)	1,91
Average unit value of exportations (euro/kg)	2,69
Average unit balance of exportations-importations(euro/kg)	0,77
Resident population (annual average value)	10 557 560

The increase in olive grove areas and the modernization of olive mills led to the increase in olive oil production (fig. 17).

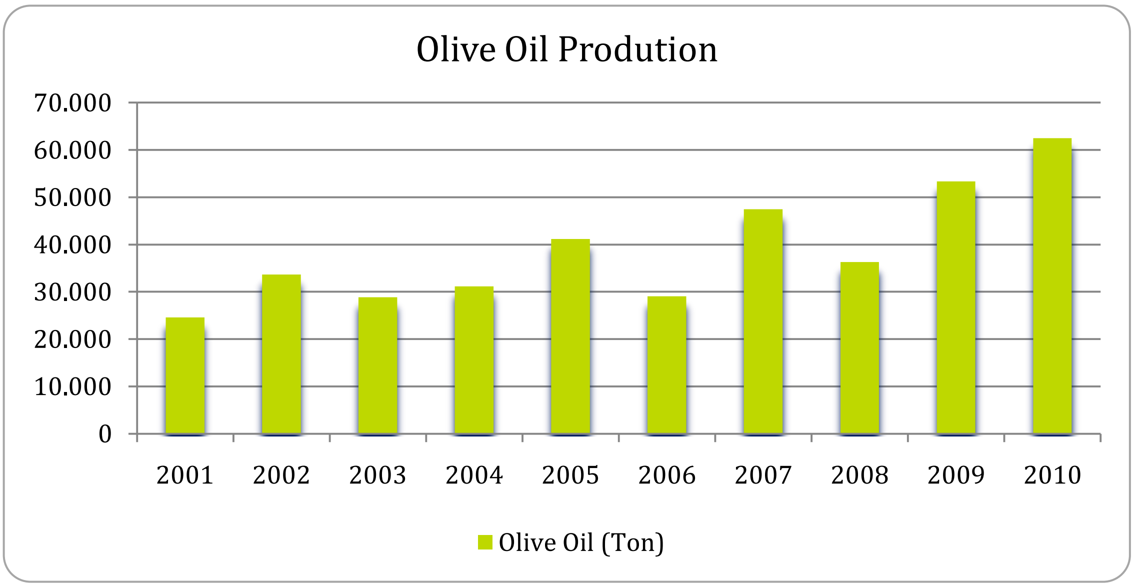

Figure 17. Olive oil production in Portugal. Source: IOC (2013)

According to the Portuguese National Statistics Institute (INE) in 2011, there were a total of 527 olive mills in Portugal. Its distribution in the different regions of Portugal is presented in figure 18. To note that there aren´t any olive mills in the Azores and Madeira islands.

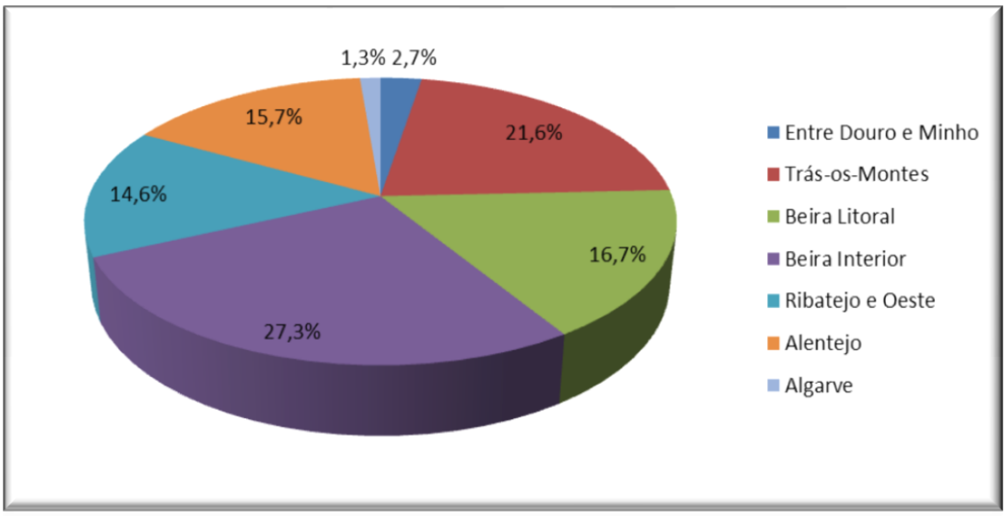

Figure 18. Percentage of olive mills in the different regions of Portugal (Source: INE, 2013)

There has been a significant conversion of olive mills traditional process of oil extraction to the more modern and efficient extraction processes. Figure 19 shows the evolution in the last years, with the decrease of traditional olive mills and the increase in the continuous two-phase and three-phase olive mills. Although the number of traditional olive mills is still high, it has being declining over the years. The two-phase olive mills show the opposite trend and its number is already similar to the traditional ones.

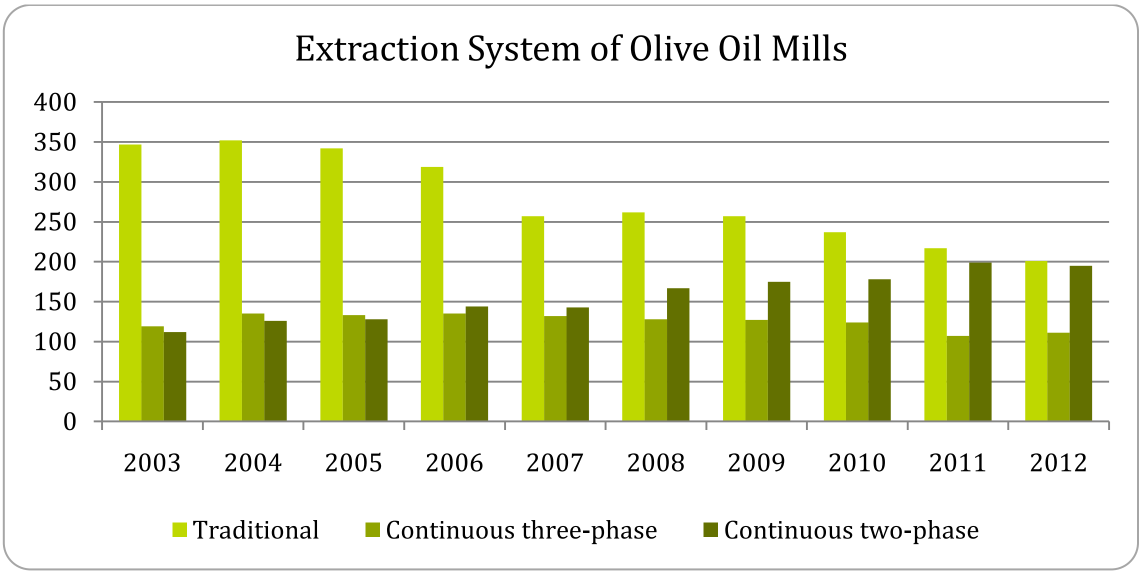

Figure 19. Number of olive mills with different olive oil extraction systems (INE, 2013)

In Portugal, the number of olive oil mills in 2011 was 527 (INE, 2013). A mill with a production higher than 920 tons of oil/year is considered big; with a production lower than 95 tons of oil /year is considered small. The production value of the sector in the country was of 330 millions of euros/year in 2010 (INE, 2013).

3.2. Spain

Spain is the biggest olive oil producer in the world, with average annual productions around 750 thousand tons, with a maximum of 1,4 million tons (fig. 20).

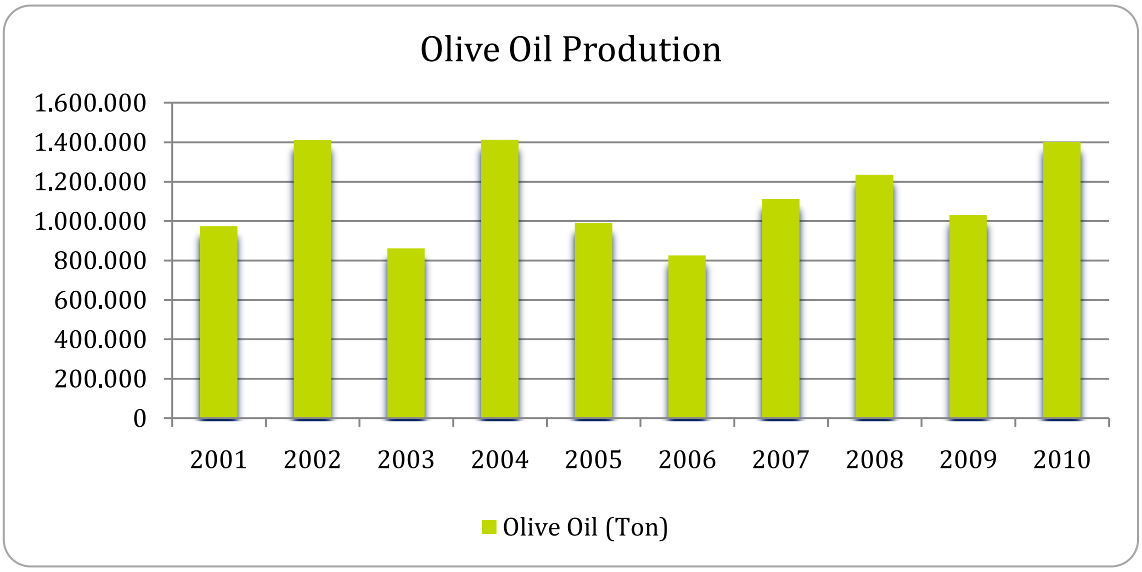

Figure 20. Olive oil production in Spain (source: IOC, 2013)

The area of planted olives has increased in the last years, and has now more than 300 million olive trees, that occupied an area of about 2,5 million hectares (fig. 21), representing more than 25% of the world area planted with olive trees (Source: ASOLIVA), and 50% of the EU-27 planted area (EUROSTAT, 2009).

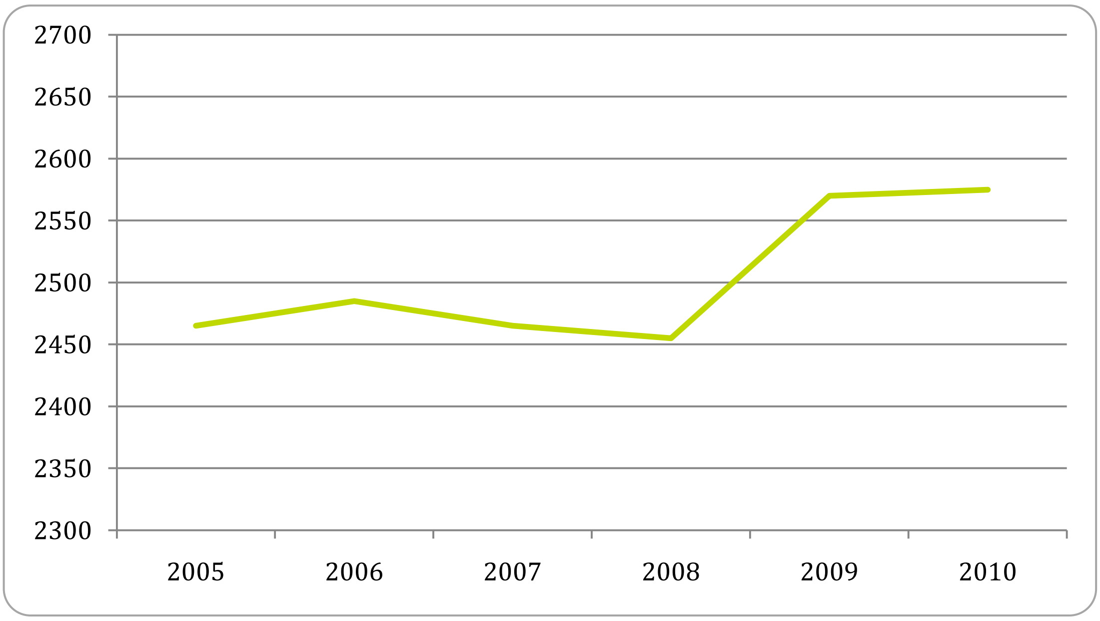

Figure 21. Olive trees planted areas in Spain (1000 ha) (source: IOC)

It is one of the most important crops in the country, which in a few decades has become a pioneer in research and technology development of the olive sector.

It is possible to find olive groves in 34 of the 50 Spanish provinces, although 60% of Spanish olive groves are located in the Andalucia province. The Andalucia province has 84% of olive grove planted areas, followed by Castilla- La-Mancha (5,7%) and Catalunya (2,3%) (Anuario de Estadistica Agraria - MAPA, 2009).

In 2010, Spain had 1750 olive mills. Most of them have being modernized and equipped with two-phase decanters. Nowadays 75% of Spain olive mills are two-phase olive mills, which allowed to increase the olive oil quality and to reduce the amount of waste waters.

Olive mills have different sizes, being the most commons those that produce between 20 to 100 tons of olive oil per month. In Spain, a mill with a production higher than 5.000 tons of oil/year is considered big; with a production lower than 1.000 tons of oil /year is considered small. Olive mills with great processing capacity (from 1000 to 2500 tons/month) are very important to the total national production, and even though they represent only 11% of the total number of olive mills in Spain, they are responsible for 34,05% of the national olive oil production.

Associated with the olive mills there are other infrastructures that work in the olive sector. Spain has 6260 factories that extract oil from olive pomace. This pomace is still a significant source of oil, which is extracted by physical or chemical means. The product, known as olive pomace oil, has an annual production of 56 thousand tons (Source: AAO). There are also 1519 packing factories, 90% of which are associated with olive oil mills.

The production value of the sector in the country was of 2.400 millions of euros/year in 2010. Spanish olive oil is exported to more than 100 countries in the 5 continents (ASOLIVA). Olive oil exportations inside the European Union (intra-EU trade) totalize 656.334 tons. The top destinations were Italy (422.768 ton), France (84.387 ton), Portugal (74.938 ton), United Kingdom (32.692 ton), Belgium (8.760 ton), Netherlands (8.037 ton) and Germany (7.191 ton). Outside the European Union were the United States (56.941 ton), Australia (24.153 ton), Japan (16.337 ton), Brazil (12.374 ton), China (11.316 ton), Russia (9.308 ton), Mexico (7.497 ton) and South Korea (7.293 ton) (EUROSTAT, 2010).

3.3. France

In 2011, there were in France, 5,1 million olives scattered by 55.000 hectares. Olive groves occupied less than 0,18% of utilised agricultural area (UAA), and the average tree density was 86 trees/ha. Olive trees are presented in near 29.243 agricultural farms, but 85% of them have less than 2 hectares of olive trees. Olive trees are not an important crop in France, and most of the olive groves are old plantations (in 64% of the total planted area trees have more than 50 years). New olive groves (less than 5 years old) represent only 4% of total planted area. Nevertheless, olive planted area has being increasing (fig. 22) in the last few years, and there is an expectation for having near 59.700 hectares of olive trees in 2014 (IOC). Due to climatic constrains, most of olive groove areas are limited to the south of France.

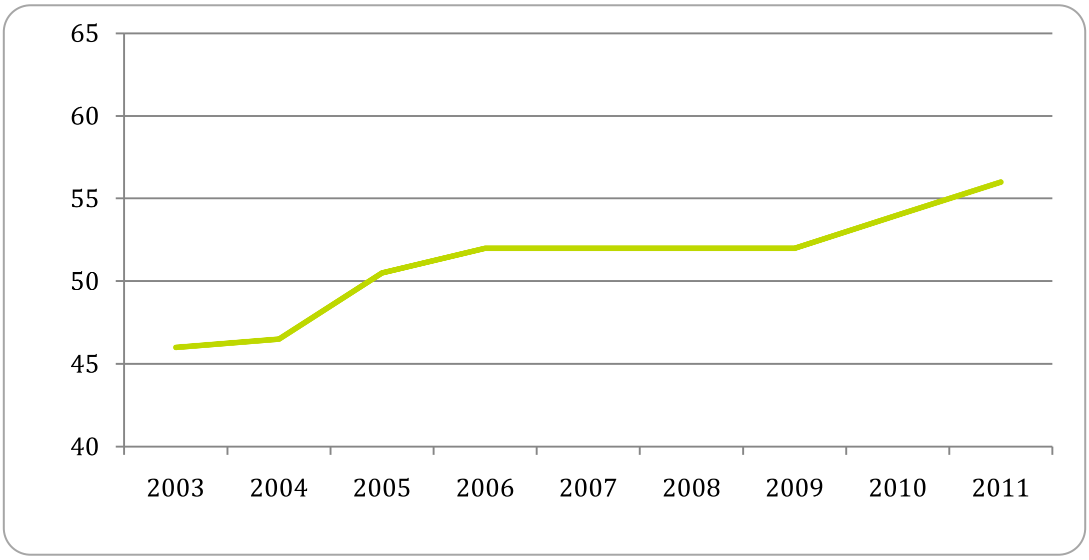

Figure 22. Olive trees planted areas in France (1000 ha) (source: IOC, 2013)

Figure 23 shows the evolution in olive oil production since 2001. There was an increase from 2001 to 2003, then it stabilized, decreased in 2007, and then it has being increasing significantly. In 2009, there was an abnormal olive oil production (7.000 ton) due to very favourable climatic conditions. In 2010, olive oil production was 5.700 tons, including 250 tons of biological olive oil.

In 2009 there were 254 olive mills in France, most of them of small or medium size, with a total processing capacity of 21 tons/years.

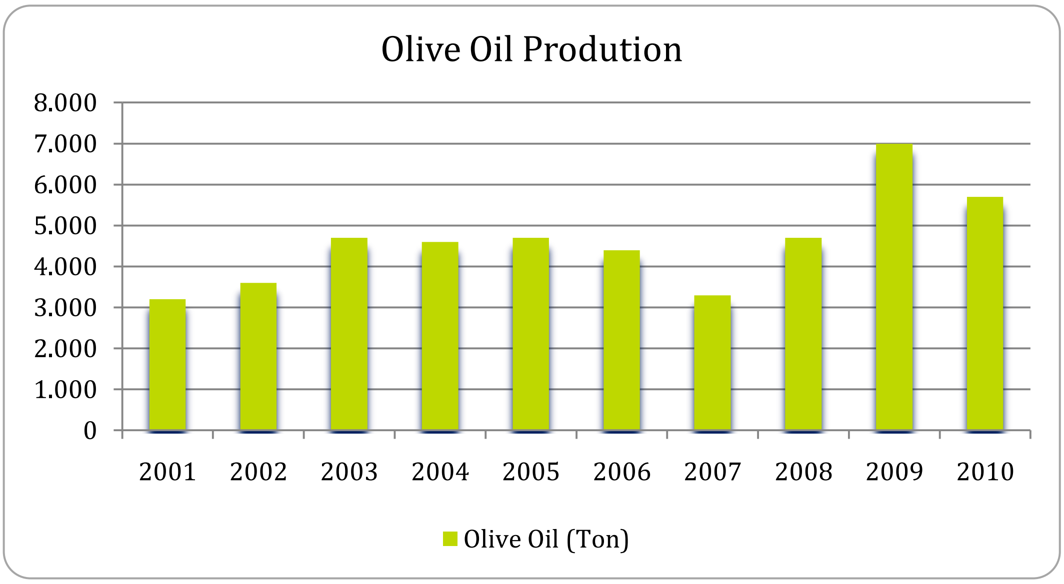

Figure 23. Olive oil production in France (source: IOC, 2013).

In the last decade olive oil consumption increased from 92.000 tons (2001) to near 115.000 tons (2010). However, this increase is not national, it only occurred in certain regions of France.

France exports an average annual value of 1.230 tons of olive oil, and according to the Eurostat (2010), inside the EU, this olive oil goes mainly to Belgium and Italy. Olive oil is also imported, mainly from Spain (84.387 tons in 2010).

3.4. Italy

In 2010 there were about 179 million olive trees, planted in 1,35 million hectares, which represents a tree density of 165 trees/ha. In general, Italian olive groves are small (70% have less than 2 ha). Olive yield is about 3.000 kg/ha. Figure 24 shows that olive trees planted areas did not increase significantly in the last few years.

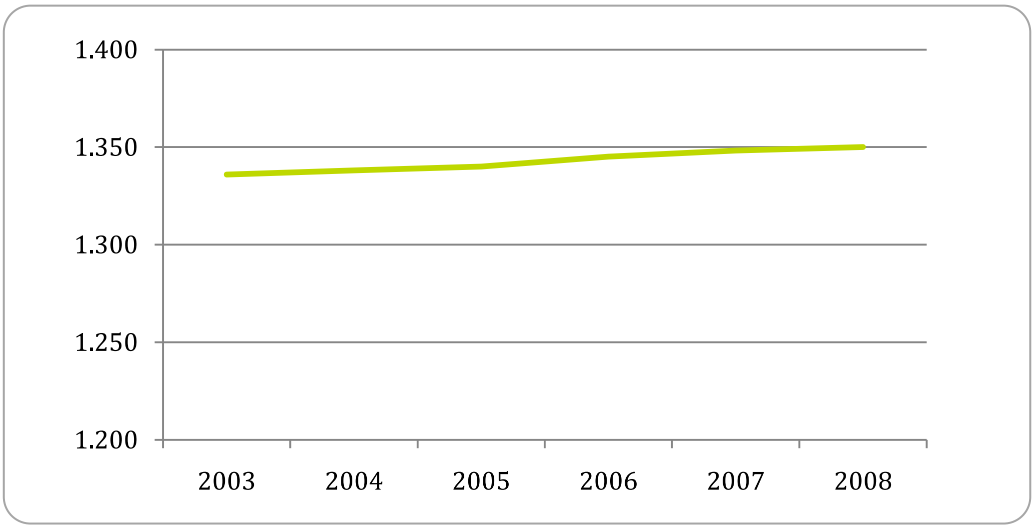

Figure 24. Olive trees planted areas in Italy (1000 ha) (source: IOC, 2013)

Olive oil production (fig. 25) had ups and downs, with the highest value of the decade in 2005 (near 880 thousand tons). Annual olive oil yield in this decade is generally between 500 to 600 tons/ha. In 2011 there were 4809 olive mills in Italy.

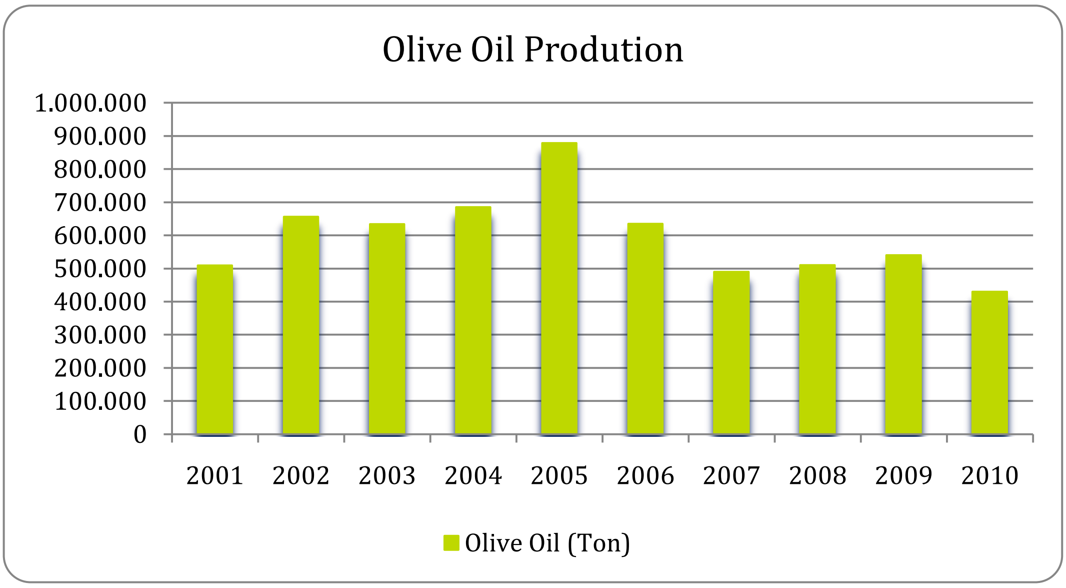

Figure 25. Olive oil production in Italy (source: IOC, 2013)

4. General data of energy consumption in olive mills

In the following paragraphs typical energy values are shown for two types of mills of different size. Olive oil mills have a clear seasonal activity: from November to March, in the four countries studied, with small differences depending on the country. Typical electrical energy cost in the industry is about 0.08 to 0.12 euros/kWh; typical thermal energy cost in the industry is about 0.015 to 0.02 euros/kWh, the biomass is produced by the own industry.

4.1. Mean values with industry size of 1.600 tons of olive oil per year (two phases oil decanter and biomass boiler)

Typical ratio, electrical energy consumption/production: 180 kWh/ t of oil

Typical ratio, thermal energy consumption/production: 210 kWh/ t of oil

Typical electrical power installed: 1600 kW

Typical thermal power installed (boiler/vehicles/etc.): 1280 kW boiler, 50 kW vehicles

4.2. Mean values with industry size of 300 tons of olive oil per year (two phases oil decanter and biomass boiler)

Typical ratio, electrical energy consumption/production: 104 kWh/ t of oil

Typical ratio, thermal energy consumption/production: 343 kWh/ t of oil

Typical electrical power installed: 208 kW

Typical thermal power installed (boiler/vehicles/etc.): 175 kW boiler

5. Industrial processes and energy consumption

The major source of energy for olive mills operation is electrical. From the olives reception, through cleaning and washing, grinding, mixing and beating, centrifugation and bottling, all machines work based on electricity. In some cases they also use hot water, which is heated in a boiler that burns olive solid residues.

5.1. Mean values with industry size of 1.600 tons of olive oil per year (two phases oil decanter and biomass boiler)

Table 1 shows average values of a standard production process of a two-phase olive mill with a biomass boiler.

Table 1. Values of a standard production process, industry of 1.600 tons of olive oil per year, from an analysis of six olive oil mills (Cooperativas agroalimentarias, 2010).

		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 consumption (kWh/year)**
Olives reception, cleaning and storage	Electrical engines	750	21.000		
Mill and paste preparation	Electrical engines, biomass boiler	400	93.000	870	270.000
Separation of phases (decanter) and centrifuge	Electrical engines of the two phases decanter	170	120.000		
Storage	Electrical engines, biomass boiler	170	2.000	200	26.000
Bottling	Electrical engines	70	4.000		
Lighting and other electrical auxiliary processes	Fluorescents	40	38.000		
Thermal auxiliary processes	Heating boiler, transport			260	40.000
	TOTAL	1600	288.000	1330	336.000

5.2. Mean values with industry size of 300 tons of olive oil per year (two phases oil decanter and biomass boiler)

Table 2 shows average values of a standard production process of a two-phase olive mill with a biomass boiler.

Table 2. Values of a standard production process, industry of 300 tons of olive oil per year, from an analysis of the University of Evora of a representative olive oil mill

		VALUES OF THE TYPICAL TECHNOLOGY USED IN THE PROCESS				
PROCESS (sequential order)	**TYPICAL TECHNOLOGY**	**CAPACITY (t/hour or l/hour)**	**Electrical power installed (kW)**	**Electrical energy consumption (kWh/year)**	**Thermal power installed (kW)**	**Thermal energy consumption (kWh/year)**
Olives reception and cleaning	Electrical engines	40 t/hour	42	2.306		
Storage	Electrical engines	80 t (2-3 days)	22	1.214		
Hammer mill	Electrical engines		42	1.230		
Paste preparation (mixer)	Electrical engines, olive pit boiler	25 t/hour	55	12.136		
Separation of phases (decanter)	Electrical engines of the two phases decanter	1.000 l/hour (oil)	22	6.670		
Centrifuge	Electrical engines		18	5.558		
Storage			0	0		
Bottling	Electrical engines	25 t/hour	6	711		
Lighting and other electrical auxiliary processes	Fluorescents		1	1.350		
Thermal auxiliary processes	Heating boiler	10 kg pit/hour			175	103.000
TOTAL			208	31.175	175	103.000

6. Alternative technologies and new perspectives

In order to save energy in the olive mills it is necessary to improve the reception of olives in the olive mill. The management of olives reception, avoiding processing peaks due to high volume of olives entering in the olive mill, will improve the operation of olive mills machines and thus save electrical energy.

The installation of more efficient lamps will allow some energy saving. Automation of some devices used in the olive mill, assuring that electricity consumption is made in time periods were it is cheaper can also lower electricity costs. Table 3 shows some points were the system can be improved in order to have high energy efficiency.

Table 3. Alternative technology / systems that improve the energy efficiency of the process

PROCESS (sequential order)	TYPICAL TECHNOLOGY	Factors influencing energy consumption in the typical technology	ALTERNATIVE TECHNOLOGY / SYSTEMS	Estimated energy saving (%)	Estimated installation cost	Estimated payback period (years)
Olives reception and cleaning	Electrical engines, compressors	Product volume, process peaks	Management avoiding process peaks	10%	Low	1
Paste preparation	Electrical engines, biomass boile	Product volume	Mills of hammers rotantes (listello rotante)	25%	High	8
Separation of phases	Electrical engines of the two phases decanter	Product volume	Stainless steel decanting tank (instead of vertical centrifuge)	40%	Medium	3
Separation of phases	Electrical engines of the two phases decanter	Product volume	OLEOSIM system (instead of vertical centrifuge)	35%	Medium	4
Storage	Electrical engines, biomass boiler	Product volume	Use of biomass as fuel instead of diesel	40%	High	6
Storage	Electrical engines, biomass boiler	Product volume	Boiler automation	10%	Low	1
Lighting	Fluorescents	Lamp efficiency	More efficient lamps	30%	Medium	4
Lighting	Fluorescents	Lamp efficiency	Electronic ballasts	12%	Medium	3
Thermal auxiliary processes	Heating boiler, transport	Outside temperature	Pipe thermal insulation	10% (thermal)	Low	1
Thermal auxiliary processes	Heating boiler, transport	Boiler efficiency	Use of biomass as fuel instead of diesel	40%	High	6

7. Conclusions

The modernization of olive mills resulted in a switch from the classic or traditional systems to the three phases and recently to the two phases olive mills. This contributed to the reduction of the waiting time to process olives, which is reflected in an increase of the olive oil quality. This system has also contributed to a substantial decrease in the environmental impact caused by the effluents of the mills, since continuous two-phase systems reduce significantly the production of vegetable water. This technology is even more relevant when there is lack of water in the region. Solid residues from the olive oil processing can be used in the mill, for heating the water used in the machines, and can also be sold.

8. References

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