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OLEICO+ PROJECT: OLIVE MILL WASTES AND THE SUSTAINABILITY OF THE OLIVE OIL INDUSTRY IN EUROPE

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ABSTRACT

Every year more than 15 millions tones of olive mill wastes (OMW) are generated in the EU. Those wastes consist in vegetation waters, effluents from olive oil, washing, leaves and other solids coming from wet pomaces from two phase extraction systems. Each of these residues presents different challenges, and is sometimes covered by different legal frameworks at European and National level. The Oleico+ project (LIFE07INF/IT/438), brought together four European Institutions from olive oil producing Countries, Greece, Italy, Spain and Portugal, to seek and select a set of environmental friendly technologies for the remediation or valorization of OMW, and to raise the awareness of olive oil stakeholders for an environmental sustainable olive mill waste management. The OMW management is becoming a critical issue for the sustainability of olive oil industry, because of the increasing quantities generated, the public environmental awareness and stricter environmental laws. Challenges posed by the OMW management are as diverse as the context of olive production itself. In all cases olive mill owners are in the top of an economic sector of major social and environmental importance in some of the more vulnerable Mediterranean regions of Europe, in an environment of depressed olive oil prices and a several of legal constrains and regulations. In this paper we examine the different contexts of OMW generation and management, their respective waste-streams and legislative frameworks. The work will also compare the situation across the four Member States, and presents the different technologies selected for the "Awareness Raising Campaign for the Treatment and Valorization of Olive Mill Wastes" now occurring in all Member States.

Keywords: OMW, olive oil, pomaces, leaves, wastewaters,legislation

INTRODUCTION

According with the figures of International Olive Council, the worldwide consumption of olive oil increased of 78% between 1990 and 2010 [1]. This increase in consumption fuelled an increase on the production of 81% in the same period, for which the UE was the main contributor with 11% increase in production in the last 20 years [2].

The increase of olive oil production implies a proportional increase in olive mill wastes (OMW), comprising stones, pulp, olive vegetation water and depending on the extraction process other effluents from water input in the process. On average, olive oil is less than 20% of the olive fruit [3]. Olive oil is a natural product, extracted using mechanical and thermal processes, therefore OMW are also natural products. But if in nature olives fell in the soil go through a natural degradation process slowly releasing their components, the massive quantities of "natural" OMW released during the olive mill season (average 100 consecutive days every year) present high values for most pollution parameters, particularly the organic loads (up to 160 g/l COD), and phenolic compounds that difficult its biodegradability. Several studies have proven the negative effects of OMW on soil microbial populations, on aquatic ecosystems and even in air medium [3,4,5,6,7]. The research to treat and valorize these wastes is still in full swing [8,9,10], to name jus a few of the innovative research trying to recover some of the valuable compounds of OMW.

The OMW management is becoming a critical issue for the sustainability of olive oil industry, because of the increasing quantities generated, the public environmental awareness and stricter environmental laws. In this paper we examine the different contexts of OMW generation and management, their respective waste-streams and legislative frameworks in countries involved in LIFE OLEICO+ Project.

OLIVE MILL WASTES

Types and relative quantities of OMW are first dependent upon extraction systems. Olive mill extraction systems have been going through a large technological evolution in the last 20-30 years. The traditional press systems that generated a dry pomaces or *orujo* (Spain) and olive vegetation water or *alpechin* (OMW) as main byproducts, gave room to more efficient and economic continuous extraction systems by centrifugation. These continuous systems are named 3-phase continuous (3PC) when they separate olive oil from olive vegetation water (OVW) and pomaces, and 2-phase continuous (2PC) when the outputs are olive oil and pomaces mixed with the vegetation water (alperujo), here named two-phase olive mill waste (TPOMW).
In mountain regions of extensive olive groves, olive mills are generally small press to medium 3PC extraction. In regions of intensive olive growing, new 2PC olive mills of large capacity produce enormous quantities of TPOMW. Big 2PC olive mills are also confronted with the washing water from continuous extraction systems (WWC2P) that is rarely accepted in the waste water treatment plants because of its huge quantities or heavy organic contents [11]
Regions of traditional but intensive olive production typically have a mix of olive mills of different extraction systems and processing capacities.
Table 1 displays an adaptation of the average values pointed in [2] for the different types of OMW generated by each tone of olives milled. These values are used to estimate OMW quantities in this work.

Table 1 – Average quantities of effluents, wastes and byproducts of olive mills with different extraction systems, by **1 ton of crushed olives**. Adapted from [2]

Extraction System	OVW [l]	WWC2P [l]	Pomaces [kg]	TPOMW [kg]	Leaves [kg]
Press	500 (88% water)		500 (26% water)		50
3PC	1100 (94% water)		550 (40% water)		50
2 PC		150		800 (>60% water)	50

Olive vegetation water (OVW)

Olive vegetation water has been the main concern of olive mill industry, law makers and public opinion because of its heavy environment impacts: it smells and seriously disturbs fresh surface and ground water, brings insects, disturbs plant grow and germination and disturbs soil structure decreasing porosity.
European Legislation doesn't allow the discharge of olive vegetation water, and this effluent is the main reason why the European IPCC Bureau considers the 2-phase continuous system as the best technology available for olive oil production.
However the 3PC extraction systems are nearly exclusive in Greece and preponderant in Italy where it processes 64% of the olives milled
In all countries the usual destination of OVW are evaporation pounds, and or irrigation in agriculture soils. Both disposal methods are regulated whether specifically or in the scope of industrial effluents.
Evaporation pounds must have the capacity to receive all the OVW produced by the olive mill more the precipitation volume expected during de winter in those regions. For optimal evaporation climatic condition as in Alentejo south Portugal, the Water Authority requires the impervious evaporation lagoon to have a maximum deep of 50 cm to receive the OMW only, and extra 20 cm to receive the season rainfall. Area requirements are not the only drawback of evaporation ponds that also emit bad smells, attract insects and have a bad impact in landscape.
Deposition in soil is also legally regulated and implies a quantity limit of 80 cm/ha each year (in some regions of Italy this quantity is 50 cm/ha/y). Irrigation does not only require appropriate agriculture surface (in Portugal irrigation can only be made in tree crops outside buffer zones from

surface water bodies, streams, wells and inhabited areas or dwellings), but also impervious reservoirs and most often, transportation from the olive mill to the field.

Table 2 displays the estimated areas required for evaporation pounds or crops irrigation with OVW. The staggering sizes of evaporation lagoons around 3PC olive mill, with associated smell and insects shows how unpleasant this solution would be is applied universally. Remark that those estimated areas are quite conservative, both because of conservative estimation of OVW from Table 1, but also because the required deep of lagoons is the one established as minimum in a region of low rainfall and long and hot summers in south Portugal.

In Table 2 are also the estimates of required irrigation areas for the disposal of OVW of each 3PC olive mills. The last column indicates the average size of holdings with olive plantations for oil. The numbers indicate that for instance in Greece each 3PC olive mill owner would have to agree the use of OVW for irrigation with 10 owners of olives plantations.

Table 2 – Area requirements of the most used ways to dispose OVW.

Country	OVW [m3]	Area of evaporation ponds per Country [ha]	Area of evaporation ponds around 3PC mills [m^2]	tree crops area for soil disposal for each 3PC olive mills [ha]	Average olive holding [ha]
Spain	243676	85	2500	16	5
Italy	2556800	570	1600	10	1,3
Greece	1944217	430	2300	14	1,5
Portugal	110532	20	1300	8	2,6

(OVW- estimated OVW produced according to Table 1, and olives crushed from sources as in Figure 2; Area of evaporation ponds per Country [ha] – area required to evaporation ponds of all OVW produced in the country, where these ponds would have a deep of 50 cm: Area of evaporation ponds around 3PC mills – average area of evaporation ponds with capacity to evaporate OVW from 3PC mills alone. Tree crops area for soil disposal for each 3PC olive mills – if all the OVW generated were for soil disposal 80 m^3/ha tree crops. Average area of olive farm calculated from EUROSTAT 2007)

Dry Pomaces and stones

Remnants of crushed olives partially drained from OVW, coming from press or 3PC olive mills are clearly a byproduct obeying cumulatively to all requirements of the Article 5.1 Directive 2008/98/EC concerning wastes: further use of this material is certain as it have always been, traditionally in feed production and now as a valuable raw matter for pomace oil extraction industry; also its nearly solid nature doesn't imply particular environment hazards in its transport, storing or manipulation. The exhausted pomace, after oil extraction is still valuable for animal feed or energy production. Stones have been a largely used byproduct of olive mills especially for heating due to its remarkable energy content (5000 kcl/kg).

Two-phase olive mill waste – TPOMW

The 2PC extraction system that was first implemented in early 90's avoids the water input in the process and has lower operating costs. This system is largely implemented in new olive mills in Spain and Portugal, where it processes respectively 90% and 65% of the olives for oil. The new 2PC olive mills tend to have large capacities and in Portugal as in Spain olive for oil production is still increasing, therefore the production of TPOMW will increase in the near future.

TPOMW is a semi-liquid residue presenting environmental risks similar to OVW because it can spill and infiltrate. This material is also used by the oil extraction industry where it is posing new challenges for transportation, storing and drying [2]. TPOW fails therefore the strict definition of byproduct, and the environmental problems are effectively being exported to the pomace oil extraction industry, upon which new 2PC olive mills are completely dependent. Table 3 depicts the TPOMW generated in the OLEICO$^+$ countries, in tones but also in 18 000 l road tankers that must be used to transport this material from the olive mills to its usual destination: the pomace oil extraction industry units.

Washing Water WWC2PC

The two-phase continuous extraction system does also generate effluents coming from the water used to wash olives going to crush, and olive oil washing. Those effluents are also to be disposed and pose a challenge due to the dimension of 2PC olive mills. Whereas the organic load of this effluent is to as high as the olive water vegetation itself, it is still too high to be treated in waste water treatment plants [11], and tend to have high charges of pesticide used in olive crops [12]. As for OVW, these effluents tend to be disposed in evaporation ponds or disposed in the soil, but there is still no specific regulation for soil spreading. In Table 3 there is an estimation of the WWC2P by country and indicatively the average area of 0,5 m deep evaporation pond necessary to dispose this effluent, that as for OVW will certainly emit bad smells and attract insects.

Table 3 – Estimated residues of 2PC olive mills per Country. (Estimations made as in Table 2)

	Estimated TPOMW by Country [t]	Estimated TPOMW in road tanks [18000 l]	Estimated TPOMW by 2PC olive mill [m^3]	Estimated WW2PC per mill [m^3]	Estimated evaporation area around 2PC mills [m^2]
Spain	4 047 040	224836	3230	1011760	1600
Italy	7680	427	1536	1920	770
Greece	-	-	-	-	-
Portugal	165979	9221	948	41494,667	500

Leaves and other residues from olive cleaning

About 5% of olives going to crush are olive leaves and other residues removed in the olive mill. Olive leaves are usually used for small ruminant's feed, and high biodegradable, however its ever increasing quantities are starting to disturb olive mill owners. In Spain alone some 300 000 tons of leaves must be transported and disposed each year**.**

Olive mills waste streams and legal frameworks in OLEICO$^+$ Countries

All Oleico$^+$ Countries are European Union Member States, therefore obliged to comply with the EU Directives concerning water, wastes, integrated pollution prevention and control and air emissions. However the CPIP Directive applies only to olive mill producing more than 300 t of olive oil a day which excludes more than 99.9% of the nearly 10 000 olive mills operating in OLEICO$^+$ Countries**.** Most olive mills must conform to national and local regulations that differ with geographical location. Table 4 points to the main differences in legislation and environmental concerns of olive mill wastes across OLEICO$^+$ countries.

Table 4 - Olive mills waste streams and legal frameworks in OLEICO$^+$ Countries

Country	Legal Framework	Main OMW	Principal OMW destinations	Main Challenges
Spain	No specific legislation on OMW.	TPOMW (90% of processed olives**)**	Pomace oil extraction units	Due to the industry dimension all wastes olive pose challenges.
Italy	Extensive and specific legislation on OMW. TPOMW and OVW from 3PC legally equivalent. Constrains in soil spread include slope	OVW (90% of processed olives)	Soil spread	More than 5000 olive mills, scattered in territory.
Greece	Specific legislation concerning OVW	OVW from 3PC (99,9%)	Evaporation ponds	2000 olive mills.
Portugal	Specific legislation concerning OVW	30% of OMW are OVW and 50% TPOMW	TPOMW to pomace oil extraction OMW – soil spread and evaporation ponds	Sector still evolving at fast rate. OVW main concern of olive mill owners.

Oleico$^+$- Project

The Oleico$^+$ project selected a set of technologies able to treat, and some of them valorize the olive mill wastes. Selected technologies characteristics are summarized in Table 5, and are being promoted in the Awareness Raising Campaigns now in force in OLEICO$^+$ participating countries. This selection considered: patent and publications, type of technology (input residues), environment impact (balance of water, energy, and other products, production of waste and air emissions), status of technology (existing plants), and economic data (associated costs and net income value). The ranking of technologies was performed by weighting each of the parameters above.The eco-sustainability performance of the different technologies was heavily affected by

energy consumption and its consequent carbon dioxide emissions. The occurrence of bad smells and landscape impacts of facilities did also affect this parameter. Only one technology achieved the three smiles classification the Phytoremediation [13], because of its benign impact on landscape after construction and low energy consumption. But this technology requires large implantation areas depending on the amount of OMW to treat.
The Biocombus technology [14], has a positive Net Present Value, but has also a heavy impact on landscape.

Table 5. Selected technologies of olive mill wastewaters

Technology	INPUT	Process	Output	Eco-sustainability
Electro-coagulation device [15]	100 – 55000 m^3/y OVW	Electro-chemical	Clarified water	☺
Evaporation-Hydrolysis-Oxidation	2000 – 36 000 m^3/y OVW	Thermal	Clarified water Bio fuel	☺☺
Phytoremediation [13]	50 – 10 000 m^3/y	Biological	Word biomasa	☺☺☺
Aerobic biological treatment [16]	30 m^3/d	Biological	Clarified water	☺
TIRSAV [17]	All OMW more than 2000 t/y	Physical	Mixed compound for other industries	☺☺
Co-digestion system applied to waste water treatment plants [18]	5 t/day OVW	Biological	Clarified water and biogas	☺☺
Biocombus [14]	All OMW more than 2000 t/y	Physical	Industrial pellets	☺☺
Composting (3 technologies)	All OMW more than 200 t/y	Physical and biological	Organic fertilizers	☺☺

However the main purpose of the European Awareness Raising Campaign on Olive Mill Wastes is exactly to raise the awareness among the sector stakeholders, about the environmental sustainability of this economic sector that is crucial in some of the most economic, social and environmental vulnerable regions of Europe. Olive oil industry provides invaluable contribution for the economy and employment of all producing regions, and also landscape and biodiversity protection for most of them [19].
The valorization or the economically viable treatment of olive mill wastes may come to prove very important for the industry, in a moment of depressed olive oil prices. And, as the olive oil production continues to increase, problems posed by the environmental impact of those wastes may become unbearable burdens for the sector sustainability, in regions where the maintenance of this activity is of utmost importance [19]

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