Olive oil plant operation redesign

Introduction

Cradle to cradle approach demands for the incorporation of production by-products and "waste" to other uses. In the industrial sector this can be more or less programmed, predicted and suitably designed before the operation of a company. However in the primary production sector agricultural products cannot be "designed" and therefore we have to invent solutions and develop ideas having the products as prepared by nature. In our era the scientific knowledge (biology and chemistry) has produced wonderful results regarding the utilization of plant tissue and remains in other uses of increased added value. Thus on one hand novel innovative products of high added value can be produced, while on the other hand pollution of the environment can be eliminated since harmful materials are not anymore rejected to soil, water, air etc.

Olive oil production in Greece is a procedure practiced for millenniums. Greece is third world producer of olive oil having more than 3.500 oil presses all over the country. The olive tree cultivation occupies 75% of the total area covered with fruit trees. The process for the olive oil production starting from the fruit to the final product does not require the use of any chemical substance. During this process apart from olive oil, a series of byproducts is produced. Among them the oil stones which include the solid milled constituents of the fruit, mainly the milled stones and the aqueous waste. Aqueous waste consists of a liquid fraction of the fruit sap and the water used in the various stages of the olive oil production in the oil press. Basically it is an aqueous phase containing a variety of substances like carbohydrates, nitrogen compounds, organic acids, poly alcohols, poly phenols and some small quantity of olive oil. It is emphasized that olive oil production is an environmental friendly process and no other toxic substances like heavy metals or synthetic organic compounds are involved.

The problem

The olive oil industry continues to be one of the most heavily polluting ones among the food industries. The waste products derived from olive oil extraction are vegetation water (an aqueous colloidal effluent) and a solid residue, mainly comprising of the olive skin, cell content and stone (olive husk). The direct impact of aqueous phase waste to the environment is the aesthetic degradation due to its very bad smell and dark color. Additionally, it may cause eutrophic phenomena in cases it is ending to areas with low water circulation (sea gulfs, lakes, etch.), because of its high organic load.

In the water apart from converting its color to black it is causing a series of chemical reactions which subtract the available oxygen from it. This results to the massive death of fishes and the excess growth of algae. It is estimated that only in Greece, over 1.150.000 tons of this material, are rejected every year to the environment. Out of them 58% ends to the sea and lakes, 11, 55% directly to the sea and 19, 5% in huge dugouts in the ground and it is absorbed by the underground water table. The byproducts of the olive

oil production constitute one of the most serious environmental problems in the Mediterranean countries. The main environmental impacts are:

1) Danger for the aquatic life
2) Downgrading-deterioration of the soil quality
3) Difficulty of carbon degradation
4) Phytotoxicity
5) Development of an oily - lipid layer on the water surfaces
6) Unpleasant smell
7) The management of phenols and the high organic load

The main post-press treatment for the solid residue is the solvent extraction of husk oil, following which the solid is compressed into briquettes and used as fuel, or is used as compost. In some cases the waste is just rejected to the environment without any treatment at all.

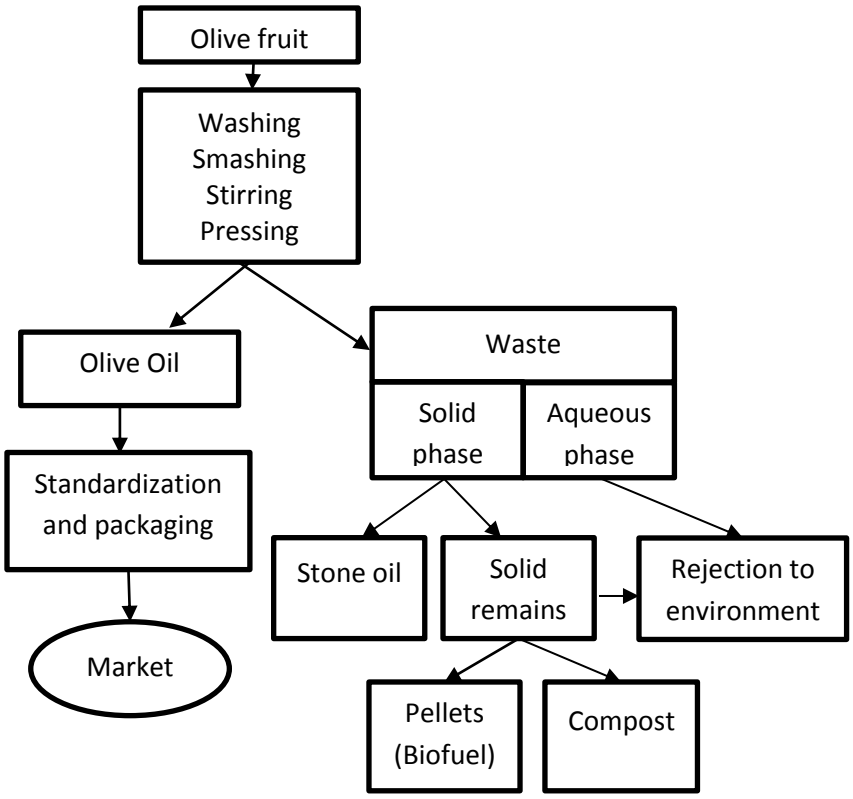

Figure 1. Current structure of olive oil industry in Greece.

Objectives of the C2C project

In terms of implementing C2C philosophy to the olive oil production there are several technical issues that should be addressed.

- The waste that is created through the whole operation should be treated in such a way that any useful material contained in, should be utilized in the development of new, innovative products of high added value coming to the market, creating extra income and work places with a parallel

environmental protection and prevention of pollution. In other words these substances shout be incorporated into the "technical cycle".

- Any organic matter that cannot be further utilized (due to technical problems or due to financial unsustainability) should return to nature and become "food" after its proper treatment through composting, or in other words, it should follow the biological cycle.
- The energy used in the production process should be of renewable origin, while any possible energy source should be examined and treated appropriately, especially if it can be combined with pollution prevention.

The goals of this project are:

- The recovery of polysaccharides and relevant hydrocolloids from olive processing waste.
- The utilization of products in other uses
- The elimination of waste
- The recovery of energy
- The mutual symbiosis of olive oil plant with other companies (agricultural companies, other industrial companies of the area), or the expansion of its activity to new sectors.

Scientific and technical approach

Of the two phases of waste, aqueous has attracted most of the attention concerning the recovery of potentially useful products, mainly focused in the reclaim of polyphenols and related antioxidant compounds. Patents exist for the recovery of dietary fiber and polyphenols from olive wastewater or of further oil, fuel and electricity. Of interest remains the possibility of recovering food-grade materials of high added value from the solid olive waste. Compression of olives for the removal of oil results in the rupture of the fruit cell walls. Although cellulose is the principal polysaccharide of the fruit body, other polysaccharides of putative technological importance co-exist with the insoluble polysaccharide.

The components of the olive paste comprise of two main fractions, one being soluble in successive elution with aqueous buffers, and another being an insoluble cellulosic residue. Most of the non – cellulosic polysaccharides extracted under the above process can be precipitated by ethanol. The above suggest that compressed oil paste is a promising source of water-soluble polysaccharides. Sequential extraction and fractionation of olive pulp has shown that the above polysaccharides compose mainly of uronic acid, rhamnose, arabinose and galactose. The different quantity of polymers existing in the olive pulp, are reported to be pectic polysaccharides rich in uronic acid, pectic polysaccharides rich in arabinose, arabinose -rich glycoproteins, xyloglucans, and glucuronoxylans. Enzymic treatment was originally proposed in order to disrupt the olive cells, as to increase the oil yield and for other technological considerations. Treatment of olives with pectinolytic enzymes during compression is reported to increase the yield of pectin polysaccharides during aqueous extraction. A sequential extraction process initially developed for the extraction of pectin from apple, has been utilized for the isolation of

hydrocolloids from olive. AIS is reported to yield fractions with a non-cellulosic polysaccharide content close to 50%. This suggests, again, that compressed olives after oil extraction can be a valuable source of water –soluble polysaccharides.

The high organic load of the aqueous phase waste, in function with the presence of the poly phenols does not allow its immediate release to the environment and its previous treatment is necessary. For the treatment and release various methods have been applied at experimental and applied scale. However all of the used methods have not yet succeeded in producing satisfactory results due to technical or economical disadvantages. These methods are:

1) Collection of the liquid waste in pools and dugouts. This method is related with aesthetic problems and difficulty to estimate the capacity of the pools or dugouts.
2) Conversion of the three phases oil presses to two phases. This is reducing significantly the amount of the required water in the oil press and consequently reduces the amount of the liquid waste. This method translocates the problem from the liquid waste, to a mixture of stones and aqueous phase waste.
3) Conversion of the liquid waste to soil improving compost. This method requires a big market for the distribution of the product.
4) Chemical oxidation and anaerobic digestion. These techniques require cost for construction and operation.
5) Fractionation using natural precipitation. By using this method in order to succeed enough purification of the liquid waste has to be combined with one of the previous methods.

The phenols contained in the aqueous phase waste, are very important antioxidants and with suitable treatment and at suitable concentrations they can be converted to pure biological products sold at very high prices. They can be used either alone or as supplements to drinks or foods so that they obtain the majority of the positive properties of the olive oil. One significant attribute of these substances is fact that they are also used in the pharmaceuticals and cosmetics industry.

On the other hand, extraction and utilization of hydrocolloids from olive waste has not been the subject of extensive or rigorous research in the past. Review of the literature on the composition of processed olive paste suggests that it comprises to a large extent of putative thickeners and emulsifiers, that is non - cellulosic polysaccharides. Such materials form the basis for the manipulation of the texture and stability of emulsions, foams, and dispersions in general. Most foods are colloidal entities, and their texture, rheology, stability, and overall acceptability are subject to their properties as colloidal dispersions. There is a quite significant demand on behalf of the food industry for such materials due to the existing trend for low-calorie food and convenience food. Most low-calorie food products are related to emulsions of low fat content, where hydrocolloids play the role of thickener/ viscosity. Convenience food are one of the major trends of the global food market In this food category, viscosity enhancers and gelling agents, due to their ability to control and modify the texture of the food, are one of the most important components.

Existing technologies

A lot of work has already been done in this field during the last 15-20 years especially in the countries of the Mediterranean basin, since they are suffering of the environmental impacts of olive oil industry. Research except of scientific results has produced also ready to apply methodology and practical tools for the issue, many of which have been patented.

- Olive mill waste water has been studied for Chemicals, Gas production, Agronomic reuse, Biomass, Food and Energy.
- Olive stone has been studied for Agronomic, Food and Energy uses.
- Olive mill waste water and pomaces have been studied for Agronomic reuse, Energy, Chemicals and Food uses.

A list of all available data about studies, countries of study, dates, practical applications, research projects and relevant patents are presented in the Appendix 1 of this report.

Expected benefits in local and international level

The adoption of C2C concept and its incorporation into the olive oil sector practice, brings a big number of advantages for the company, the local community the country and the world.

- The problem of olive oil production waste could be eliminated and this would be the biggest achievement in terms of environmental protection.
- Novel innovative products could be developed and new markets could be created resulting in increased income for the people involved in the agriculture and food sector.
- Energy cost could be lowered or even energy balance could be positive since energy needed to operate an olive oil plant is not that high, and operation period is two to three months per year while energy can be produced all year round.
- New work positions could be created contributing to the fight against unemployment.

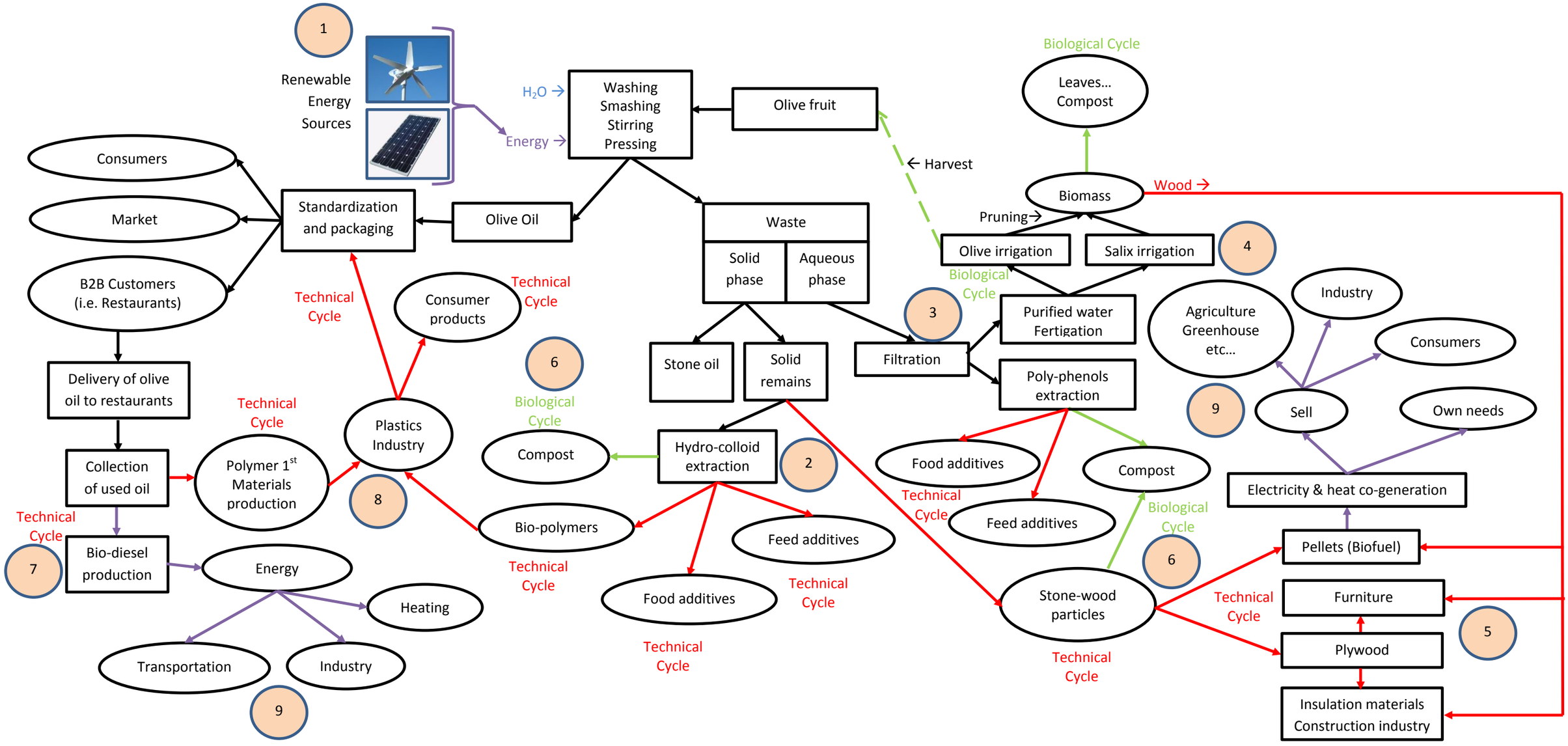

Figure 2. Proposed operation model. Project: Cradle to Cradle operation of olive mill industry, implementing waste elimination through integration to technical and biological cycles, energy production from renewable sources, by-products and waste utilization

Description of the proposed operational model

The current situation of the olive oil mill under study is a typical one. Although the owner has made significant progress in terms of waste management, by producing pellets for heating of by collecting used oil from restaurants, he has not managed to close the cycles and thus a big amount of progress and improvement still remains to be done.

Our main contribution to the successful adoption of C2C philosophy to the operation of the olive oil mill can be summarized to the following points. These points are highlighted in Figure 2 with the respective numbers in orange circles.

1. Utilize renewable energy sources. In the area the olive mill is situated most of the year there is wind while for 9 months at least there is sunshine. Therefore, both solar panels and wind turbines can be used.
2. After the stone oil reclaim, solid waste can be further treated. The products that can be reclaimed are bio-polymers which can be used in plastic industry for the production of bio-plastics. Also polysaccharides can be used in food and feed industries as ingredients of high functional and nutritional value. The rest of organic material can be composted and directed to the biological cycle (see point 6).
3. Aqueous phase can be filtered. Purified water can return to agriculture for irrigation purposes. Solid content can be treated and polyphenols can be reclaimed. They are of high nutritional and functional value and their price in the market is quite expensive.
4. Except of olive groves, and other cultivated species the excess of water can be used to irrigate other plants such as plants in uncultivated natural land, recreation parks etc. These places can be a refuge for wild animals and this way we can Celebrate Biodiversity. It is of big interest to cultivate wood giving or energy plant because their products can be utilized in the technical cycle and for energy uses.
5. Wood produced by several cultivations (including olives) and from solid olive oil mill waste can enter the technical cycle producing furniture, plywood, insulation materials or pellets. A small fraction which cannot be used for the upper purposes can be composted and enter the biological cycle. Pellets can be burned in steam turbines producing energy in forms of electricity and heat (co-generation). These energy sources can be consumed in energy demanding agricultural activities such as greenhouse, fish production etc. industrial and community uses respectively.
6. Compost is the last product made from organic materials that cannot be utilized in any other use.
7. The company is active in collecting old-used oil quantities from restaurants. They forward it to oil companies. Instead of this the olive mill can extend its activity to include Bio-diesel production. Bio-diesel is a source of high value energy. It has multiple uses such as transportation, industry or home, school, community buildings and other facilities heat fuel.

8. The used oil quantities contain a lot of chemical substances that have a good potential to be incorporated into the technical cycle as ingredients of chemical products, such as polymers for plastic objects production. These can be packaging materials to be used in several companies products, consumer goods etc.
9. Energy production can be realized if biodiesel is used as fuel to motor electric generators. The produced electricity can cover the olive mill's energy needs and if also can sell electricity to industrial and consumer customers.

Appendix I

Studies of olive oil mill waste managements, country, year, pilot plant, patents and research projects

Olive mill wastewater management

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Biomass production	Isrim	Italy, 2004	A new application of phytodepuration as a treatment for the olive mill waste water disposal	EP1216963	Italy (Paciano)	LIFE04 ENV/IT/000409
Gas production	Choi Eui-So	Korea, 2008	Production method of methane gas from olive mill waste	KR20080028247	no	---
Gas production	Pizzichini, Russo	Italy, 2007	Process for recovering the components of olive mill wastewater with membrane	EP1773721	no	---
Gas production	Knobloch Michael	Germany, 2002	Process and apparatus for treating wastewater from oil plant processing and cereal processing	DE19829673	Crete (Greece)	LIFE99 ENV/D/000424
Gas production	S. Sayadi (Centre de Biotechnologie de Sfax)	Tunisie	Production method of methan gas from treated olive mill wastewater.	----	Tunisie	---
Gas production	Martins Dias Susete Maria; Maggiolly Novais Julio; Costa Guedes Da Silva Manuel J	2001	A process for the treatment of liquid effluents by means of clean catalytic oxidation, using hydrogen peroxide and heterogeneous catalysis	EP1097907		
Gas production	Industria Olearia Biagio Mataluni S. R.l.	Italy	RE-WASTE			
Gas production	J. Gelegenis, D. Georgakakis, Ir. Angelidaki, N. Christopoulou and M. Goumenaki	Greece 2007	Optimization of biogas production from olive-oil mill wastewater, by codigesting with diluted poultry-manure			
Gas production	Diamantopoulos Evangelos; Gkizgkis Nikolaos; Georgiou Maria; Koukouraki Elisavet	Greece 2007	Co-treatment of olive-mill liquid waste and urban sewage in a high-throughput anaerobic reactor.	GR20050100539 (A)		
Gas production	Santino Di Berardino (INETI)	Portugal 2000	Integrated waste water anaerobic treatment plant includes a preparation compartment, for methanogenic treatment	PT102284		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Gas production	Isabel Maria Pires Belo (Minho University)	Portugal 2006	Biotechnological Valorization of Olive Mill WasteWaters			PTDC/AMB/69379/2006
Gas production	WWTP Forno Quente	Abrantes, Portugal	Anaerobic digestion, biogas production			
Chemicals	R. Bernini University of Tuscia	Italy, 2005/07	Method for preparing hydroxytyrosol derivatives and of hydroxytyrosol	EP 1623960, 2005 IT 2007MI01110 20070531 IT 2007MI00519 20070315	no	---
Chemicals	De Magalhães Nunes da Ponte et al	Portugal, 2008	Method of obtaining a natural hydroxytyrosol-rich concentrate from olive tree residues and subproducts using clean technologies	PCT/IB2006/052552	no	---
Chemicals	Villanova Luigi	Italy, 2006	Process for the recovery of tyrosol and hydroxytyrosol from oil mill wastewaters and catalytic oxidation method in order to convert tyrosol in hydroxytyrosol	US2006070953	no	---
Chemicals	National and Kapodistrian University of Athens	Greece, 2000	Process development for an integrated olive oil mill waste management recovering natural antioxidants and producing organic fertilizer	----	Crete (Greece)	LIFE00 ENV/GR/000671 Best "LIFE Environment projects in 2004-2005"
Chemicals	Tornberg, Galanakis,	Se-Gr, 2008	Olive waste recovery	WO2008082343	---	---
Chemicals	L.Bertin et al	Italy, 2005	Valorization of olive mill wastewaters as a renewable resource for the biological production of polyhydroxyalkanoates	----	---	----
Chemicals	Pizzichini, Russo	Italy, 2007	Process for recovering the components of olive mill wastewater with membrane	EP1773721	no	---
Chemicals	Brusadelli Enrico (Snia Fibre S.p.A.)	Italy, 1989	Process for the treatment of the effluents of the oil-mill industry	GR88100368		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Chemicals	Bruchwald-Werner sibille (Cognis Deutschland GMBH&CO. KG)	Germany, 2003	Use of extracts from olive trees as anti-dandruf agents	WO03080006		
Chemicals	Fernandez-Bolaños Guzman Juan (Consejo Superior de Investigaciones)	Spain, 2003	Method for obtaining purified hydroxytyrosol from products and by-products derived from the olive tree	WO02064537		
Chemicals	Kuno Noriyasu (Nisshim Oil Mills)	Japan, 2002	Process for producing oleanolic acid and/or maslinic acid	WO0212159		
Chemicals	Rabovskiy Alexandre (Usana Inc.)	United States, 2001	Antioxidant compositions extracted from olives and olive by-products	WO0145514		
Chemicals	Crea Roberto (Creagri Inc.)	United States, 2002	Method of obtaining a hydroxytyrosol-rich composition from vegetation water	WO0218310		
Chemicals	Crea Roberto (Creagri Inc.)	United States, 2000	Water-soluble extract from olives	WO0004794		
Chemicals	Garcia-Granados	Spain, 1998	Process for the industrial recovery of oleanolic and maslinic acids contained in the olive milling subproducts	WO9804331		
Chemicals	Richard-Elsner Christiane; Johannisbauer Wilhelm; Bonakdar Mehdi	Germany, 2003	Process for the isolation of antioxidants	EP1310175		
Chemicals	Garcia Granados Lopez de Hierro Andres	Spain, 1994	Procedure for obtaining mannitol and derived products from the branches and leaves of the olive tree and olive waste water and olive fruit stalks	ES2056745		
Chemicals	Venetsianos E. T.	Greece, 2001	A novel system for processing, treating and using olive oil waste in the production of Energy, chemical products and reuse of water	GR1003558		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Chemicals	Annesini M. C., Giona A. R., Gironi F., Pochetti F. S.P.I.-Sviluppo Processi Industriali S.R.L.	Italy, 1986	Process for the treatment of oil-containing wastewater by distillation with recovery of volatile products	IT1149119		
Chemicals	Ikemoto T.; Fukubayashi T.; Haratake A.; Kaneyama H.;	Japan, 2001	Skin cosmetic	JP2000319161		
Chemicals	Pruna Tudor	1979	Method for alcohol recovery from olive vegetation water	PT69240		
Chemicals	Bruchwald-Wener Sybille Griesbach Ute	Germany, 2003	Use of olive tree extracts in detergents, rinsing agents and cleaning agents	WO03079794		
Chemicals	Ferrer Munoz Estrella; Gibello Prieto Alicia; Martin Fernandez Margarita; Sanz Perucha Jesus; Blanco Alvarez Jesus	Spain, 1998	Process for the biodegradation of aromatic compounds and synthesisof pigmants and colorants, alcaloids and polymers, with the use of recombinant strain Escherichia coli P-260	WO9804679		
Chemicals	Faccini Giuseppe	Italy, 1996	Liquid additive for enriching natural and chemical fertilizers	ITBO950012		
Chemicals	Industria Olearia Biagio Mataluni S.R.l.	Italy	RE-WASTE			
Chemicals	C.A. Paraskeva, V.G. Papadakis, E. Tsarouchi, D.G. Kanellopoulou, P.G. Koutsoukos	Greece	Membrane processing for olive mill wastewater fractionation			
Chemicals	Isabel Maria Pires Belo Minho University	Portugal, 2006	Biotechnological Valorization of Olive Mill WasteWaters			PTDC/AMB/69379/2006

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Chemicals	J. Fernández Bolaños (CSIC)	Spain, 2008	Process for the recovery of hydroxytyrosol from oil mill wastewaters			
Agronomic reuse	Almeida Ribeiro Claro Joao Car	Portugal, 2007	Treatment ad recovery of residues and effluents from olive oil production units through the utilisation and reprocessing of cork industry waste	EP1849756		
Agronomic reuse	Castanas Elias; Andrikopoulos Nikolaos; Vercauteren Joseph	Greece, 2005	A method for the clearance of olive mill waste waters for their direct use for agricultural purposes	GR2003100295		
Agronomic reuse	Isrim	Italy, 2004	A new application of phytodepuration as a treatment for the olive mill waste water disposal	EP1216963	Italy (Paciano)	LIFE04 ENV/IT/000409
Agronomic reuse	Municipality of Kalamata	Greece, 1995	Biotransformation of solid and liquid waste of olives	---	Greece	LIFE95 ENV/GR/001092
Agronomic reuse	Murena Fabio Risvet	Greece 1989	Oil press mill waste cleaning	GR88100203		
Agronomic reuse	Sitia Development Organisation S.A	Greece, 2000	Estabilishment, operation and demonstration of an innovative closed-cycle system of oil milling waste water using the Fenton method in Sitia-Crete, and reause of treated water and by-products in agriculture	---	Greece (Sitia, Crete)	LIFE00 ENV/GR/000723
Agronomic reuse	H. Niebelschütz ARGUS	Germany	Biological degradation of omw	EP19990250098 19990331	Crete (Greece)	
Agronomic reuse	Pizzichini, Russo	Italy, 2007	Process for recovering the components of olive mill wastewater with membrane	EP1773721	no	---
Agronomic reuse	Potenz Domenico	Italy 1994	Process and plant for the treatment of the waste waters from the olive oil industry	IT1244520		
Agronomic reuse	National and Kapodistrian University of Athens	Greece 2000	Process development for an integrated olive oil mill waste management recovering natural antioxidants and producing organic fertilizer	---	Crete (Greece)	LIFE00 ENV/GR/000671 Best "LIFE Environment projects in 2004-2005"
Agronomic reuse	Tomati Umberto, Grappelli Adriana CNR	1987	Process for the purification of agricultural vegetable waste fluids in particular of vegetation waters	GR870652		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Toro Galvez Jose	Spain 2003	System for purifying waste water originating from olive processing by means of aeration, neutralisation, active carbon filtration and ozonisation	WO03000601		
Agronomic reuse	Crea Roberto	United States 2000	Water-soluble extract from olives	WO0004794		
Agronomic reuse	Siskos Dimitrios	Greece 1999	Wastewater treatment plant for olive oil processing effluents comprising a rotating biological contactor with the addition of linear or circular motion	WO9935097		
Agronomic reuse	Knudsen Carl Ticon VVS AS	1992	Process and plant for purification of agricultural waste material	WO9211206		
Agronomic reuse	Hrusa E., Siegel L., Poduska J.	1996	Process of disposing waste from the production of olive oil	CZ9401911		
Agronomic reuse	Vlissidis Apostolos; Kyprianou Dimosthenes	Greece 2001	A method of processing oil-plant wastes	EP1157972		
Agronomic reuse	Burzio Fulvio; Wlassics Ivan	Italy 1992	Detoxification of vegetation liquors	EP520239		
Agronomic reuse	Sapia Francesco; Sapia Peppino; Sapia Maria; Sapia Saverio	Italy 1991	Plant to depollute waste water, particularly water from olive crushers.	EP0451430		
Agronomic reuse	Bernardini Ernesto	Italy 1991	Process and installation for the degradation of impurities in waters originating from olives-treating plants	EP0441103		
Agronomic reuse	Cannazza Simon N.	1989	Carrier and reactor for biological treatment of liquids and use thereof	EP324314		
Agronomic reuse	Poglio Achille	Italy 1991	A process and plant for disposal of organic effluents	EP421223		
Agronomic reuse	Hidalgo Cicuendez Arturo	Spain 1997	Industrial process for the treatment, recycling and conversion of olive juice and olive waste into pure organic fertilizers	ES2103206		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Soriano Carrello Jesus; Fernandez del Campo; Cueva J. A.	Spain 1994	System for the utilization of olive waste water in the stabilization of soils	ES2051242		
Agronomic reuse	Arroyo Salas Jose Maria; Llamas Marcos Argimiro; Galilea Egizabal Purification	Spain 1993	Fertiliser mixt. contg. aq. residues from olive oil presses	ES2037606		
Agronomic reuse	De Lara Garcia Rafael	Spain 1991	Procedure for treatment of olive waste water for the purification thereof and obtaining byproducts with agronomic or industrial uses	ES2019830		
Agronomic reuse	Dorsch Serrano Fernando	Spain 1990	Process for treating "alpechin" (olive-oil-production liquid aqueous residue) in olive-oil factories	ES2011366		
Agronomic reuse	Don Francisco M.; Vidal Torrents; Don Miguel; Montero Puig; Don Jose Lostao; Camon	Spain 1984	Organic fertilisers mfr. from e.g. urban waste	ES8402554		
Agronomic reuse	Jose Garrido	Spain 1969	Process for obtaining organic fertilizer by spontaneous or controlled fermentation of concentrated olive mill wastewater	ES348517		
Agronomic reuse	Xenopoulou Caterina	Greece 2001	Use of the Mediterranean sea grass posidonia oceanica for the production of organic compost and compost for agriculture with co-composting of organic waste from agricultural, animal or industrial units.	GR1003611		
Agronomic reuse	Venetsianos E. T.	2001, Greece	A novel system for processing, treating and using olive oil waste in the production of Energy, chemical products and reuse of water	GR1003558		
Agronomic reuse	Ernesto Bernardini	1989, Italy	Olives processing water purification	IT1206049		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Fortunato Vittorio	1988, Italy	Physico-chemical treatment of waste water	IT1191528		
Agronomic reuse	Socogin S.R.L.	1985, Italy	Olives processing waste water treatment	IT1110321		
Agronomic reuse	Becherer Geb.; Becherer E.; Dietz W.	1989, Germany	Process for treating a solution in particular for wastewater purification	DE3804573		
Agronomic reuse	Vila Reyes Joan	1997, Spain	Biological process for purifying liquid residues with high contaminating content and/or high toxicity, particular liquid purine and olive mill wastewater	ES2108658		
Agronomic reuse	Calaf Nolla Domenec	1997	Method for the purification of organic wastes resulting from the production of oil	ES2101651		
Agronomic reuse	Dorsch Serrano Fernando	1992, Spain	Improved process for the treatment and purification of olive mill wastewater and utilization of wastes in olive oil palnts	ES2028497		
Agronomic reuse	Ballester Diaz L.; Garcia V. A. F.; Perez Amer J. P.	1991, Spain	Installation for the integral purification of olive waste water	ES2021191		
Agronomic reuse	Sempere Eugenio Bellido	1986, Spain	Purificn. of sludge and residual water from olive oil mills	ES8607039		
Agronomic reuse	Vega Cardenas Enrique	Spain 1998	Process for obtaining recyclable waste products derived from olives	ES2116923		
Agronomic reuse	Martins Dias Susete Maria; Maggiolly Novais Julio; Costa Guedes Da Silva Manuel J	2001	A process for the treatment of liquid effluents by means of clean catalytic oxidation, using hydrogen peroxide and heterogeneous catalysis	EP1097907		
Agronomic reuse	Bernardini Ernesto S.I.B.E.	Italy 1989	Treating waste-water from oil olive prodn.	IT1211951		
Agronomic reuse	Marketing Futura Sas	Italy	Omenzym			
Agronomic reuse	Birame Boye Cyclus depuration industrial	Spain	Electrocoagulation			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Industria Olearia Biagio Mataluni S. R.l.	Italy	RE-WASTE			
Agronomic reuse	BIOTECNOLOGIE AMBIENTALI Maretto Engineering	Italy	Biomar enzymplus E161			
Agronomic reuse	Idrodepurazione S.r.l. e Idroengineering S.r.l	Italy	Humix system			
Agronomic reuse	Guida Tecnologie Srl	Italy	G NAT Natural venting Evaporator for vegetative waters			
Agronomic reuse	OMEOFRANZ Tecnologie biologiche e servizi	Italy	Catalytic/enzymatic method			
Agronomic reuse	Garcia Moreno Angel	Spain, 1998	Integral process for the industrial utilization of the bitter waste liquid from olive pressing ("alpechin") and its purification in oil mills (presses) and centres for purifying the two phases resulting from olive oil extraction	ES2110912	---	
Agronomic reuse	Chatzipavlidis, Flouri, Balis	Greece 1993	Bio-fertilization of olive mills liquid wastes	GR93100432 A		
Agronomic reuse	Local Development Union of Amaliada	Greece 1992	Amaliada agricultural waste water treatment and recycling project			LIFE92 ENV/GR/000051
Agronomic reuse	Neskakis Apostolos	Greece 2000	WAWAROMED Project title: Wastewater recycling of olive mills in Mediterrenean countries - Demonstration and sustainable reuse of residuals			ICA3-CT-1999-00011
Agronomic reuse	G. Tziotzios, S. Michailakis and D.V. Vayenas	Greece	Aerobic biological treatment of olive mill wastewater by olive pulp bacteria			
Agronomic reuse	A. Katsoni, Z. Frontistis, N. P. Xekoukoulotakis, E. Diamadopoulos and D. Mantzavinos	Greece	Wet air oxidation of table olive processing wastewater: Determination of key operating parameters by factorial design			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Elefsiniotis Georgiou Labros	Greece 2002	Cleaning of liquid effluents from processing in an olive mill with olive oil recovery	GR1003920 (B1)		
Agronomic reuse	D.Atanassova, P. Kefalas, C. Petrakis, D. Mantzavinos, N. Kalogerakis and E.Psillakis	2004	Sonochemical reduction of the antioxidant activity of olive mill wastewater			
Agronomic reuse	Gotsi, M. / Kalogerakis, N. / Psillakis, E. / Samaras, P. / Mantzavinos, D.	Greece 2005	Electrochemical oxidation of olive oil mill wastewaters			
Agronomic reuse	Ginos, A. / Manios, T. / Mantzavinos, D.	Greece 2005	Treatment of olive mill effluents by coagulation–flocculation–hydrogen peroxide oxidation and effect on phytotoxicity			
Agronomic reuse	G. Aggelis, D. Iconomou, M. Christou, D. Bokas, S. Kotzailias, G. Christou, V. Tsagou and S. Papanikolaou	Greece 2003	Phenolic removal in a model olive oil mill wastewater using Pleurotus ostreatus in bioreactor cultures and biological evaluation of the process			
Agronomic reuse	Poulios, I. Kyriacou, G.	Greece 2002	Photocatalytic degradation of p-coumaric acid over TiO2 suspensions			
Agronomic reuse	Waste Management Laboratory - University of the Aegean	Greece 2002	Construction of a wastewater management pilot plant for the Olive Mill owned by “Theodoros Giannakas” (Afalonas, Municipality of Mytilene, Lesvos). - NAIAS		yes	NAIAS
Agronomic reuse	Envitec S.A. - Technical & Enviromental Projects	Greece 2006	E H O® (EVAPORATION - HYDROLYSIS - OXIDATION)			
Agronomic reuse	Justino Nuno	Portugal, 2005	Development of a new mobile waste water treatment process for sme olive mills			INCO EVK1-CT-2002-30018
Agronomic reuse	BBF – Tec. Ambiente	Portugal	Olive mill wastewater treatment by Electrocoagulation (Sielec system)			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Jaime Belèm	Portugal, 1999	Supported development management of olive-oil production in North Alentejo			LIFE97ENV/P/000153
Agronomic reuse	JHB – Tec. Ambientais	Portugal	Electrocoagulation			
Agronomic reuse	António Manuel Cardoso Ferreira and José Manuel Cardoso Duarte (INETI)	Portugal, 2002	Aerobic bioreactor JACTO for effluent treatment	PT9559		
Agronomic reuse	Ana Vieira (INETI)	Portugal, 2001	Water recovery from olive mill wastewaters after photocatalytic detoxification and desinfection			FAIR983807
Agronomic reuse	José Duarte (INETI)	Portugal, 2004	Mediterranean usage of biotechnological treated effluent water using Jacto reactor and photoreactors			INCO ICA3-CT-1999-00010
Agronomic reuse	José Duarte (INETI)	Portugal, 2001	JACTO, Jet-Loop Reactor: A New System for the Treatment of Agro-Industrial Effluents			POCTI/BIO/41253/2001
Agronomic reuse	Knobloch Michael	Germany, 2002	Process and apparatus for treating wastewater from oil plant processing and cereal processing	DE19829673	Crete (Greece)	LIFE99 ENV/D/000424
Agronomic reuse	Escola Profissional Desenvolvimento Rural Serpa	Portugal	Composting technology based on controlled anaerobic fermentation (FACA)			
Agronomic reuse	M. López (University of Granada)	Spain, Morocco 2007	Absorption of polyphenols from olive oil mill wastewaters by sawdust and biodegradation by the fungus Phanerochaetae chrysosporium			
Agronomic reuse	J. Beltrán et al (Universty of Extremadura)	Spain, 2000	Degradation of olive mill wastewaters previously treated by an ozonation stage has been studied by an aerobic biological oxidation			
Agronomic reuse	Novoltec automatización S.A.	Spain 2008	Purification of industrial process OMW through electrolysis, oxidation, flocculation and flotation in which oxidizable substances are eliminated as polyphenols			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	E. Sánchez-R. Borja	Spain	Aerobic degradation kinetic of the effluent derived from the anaerobic digestion of two-phase olive mill solid residue			
Food	Tornberg, Galanakis,	Se-Gr, 2008	Olive waste recovery	WO2008082343	---	---
Food	Carmelo Vaccarino S.N.C.	1990, Italy	Olive oil prodn. water purificn.	IT1214359		
Food	Vitagliano Michele	France, 1976	Paste for feeding animals obtained from the by-products of olives and its process of making	PT64109		
Food	Georgoudis Dianellos	1997	Method of extraction of olive paste from vegetable water and its use as a foodstuff	WO9728089		
Food	Garcia Moreno Angel	Spain, 1998	Integral process for the industrial utilization of the bitter waste liquid from olive pressing ("alpechin") and its purification in oil mills (presses) and centres for purifying the two phases resulting from olive oil extraction	ES2110912	---	
Energy	Vega Cardenas Enrique	Spain 1998	Process for obtaining recyclable waste products derived from olives	ES2116923		
Energy	Manuel Gonzalez Longoria	Spain, 1984	Solid organic fuel prepn.	ES8404708		

Olive stone management

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	Benavent Miquel Canet	Spain, 2008	Procedure for the industrialization of olive oil press by-products and the product obtained	US2008146828	---	
Agronomic reuse	José Ramón Perán González	Spain, 2005	Three-step procedure and construction of a pilot plant to convert the waste to liquid and solid fertilisers and irrigation water.	---	Spain, (Baena)	LIFE05 ENV/E/000292
Agronomic reuse	R. Altieri, A. Esposito ISAFoM-CNR	Italy, 2004	Olive mill wastes management: a novel approach working at milling level for recycling in agriculture all kinds of effluents	RM2004A000084	Italy (Cilento and Vallo di Diano National Park)	LIFE00 ENV/IT/000223 LIFE05 ENV/IT/000845
Agronomic reuse	J. Cegarra (CSIC) Murcia	Spain, 2007	Composting, AL was co-composted with grape stalk, olive leaf, cow bedding (bulking agents) using forced ventilation assisted by mechanical turning.	---	Spain	---
Agronomic reuse	JR. Perán, A. Lara Fundación CARTIF	Spain, 2007	General plan for the integral treatment, management and valorisation of waste generated during the production process of virgin olive oil Three-step procedure and construction of a pilot plant to convert the waste to liquid and solid fertilisers and irrigation water.	---	Mobile plant and industrial plants in Spain (Baena)	---
Agronomic reuse	Fuentes Cardona S. A.	Spain 1995	New method for the treatment of pulp originating from the extraction of olive oil	ES2076899		
Agronomic reuse	Olmo Peinado Jose Maria	2000	Process for treatment and recycling of sludge by-product from milling olives in oil mill, comprises separation- extraction- pyrolysis or carbonization- gasifying combustion cycle	ES2150360		
Agronomic reuse	G. Rodriguez CSIC	Spain	Whole utilisation of olive oil industry by-products			
Agronomic reuse	Patrick Martin	Greece 2001	RECOVEG Recycling horticultural wastes to produce pathogen suppressant composts for sustainable vegetable crop production			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	UCASUL	Portugal, 2001	Drying of bagasse and extraction of oil, spread on the ground for fertilization.			
Agronomic reuse	M. Romero Portocarrero Orobaena, SAT	Spain 2007	Plant of Composting of Alperujo I. Alperujo and olive leaf. System Windrow.		Baena Spain	
Agronomic reuse	G. Gómez Sosa (Los Remedios)	Spain	Plant of Composting of alperujo II. Alperujo and sheep manure. System by mechanical turning. Windrow.		Olvera, Spain	
Agronomic reuse	G. Martinez (University of Córdoba)	Spain	Composting alperujo with other agricultural waste		Pozoblanco, Spain	
Agronomic reuse	M. Vicent	Spain, 2008	Plant of composting of alperujo by mechanical turning. "Volteadora autopropulsada". Mix of alperujo and chicken manure		Guadalcazar. Córdoba. Spain	
Agronomic reuse	E. Prat	Spain, 2008	Plant of composting of alperujo by "Volteadora de canjilones en trinchera"		EDAR Manresa. Barcelona. Spain	
Agronomic reuse	I. Sampedro Quesada. (CSIC Granata)	Spain	Decrease in the phytotoxicity of dry alperujo by arbuscular fungi		Spain	
Chemicals	G. Rodriguez CSIC	Spain	Whole utilisation of olive oil industry by-products			
Chemicals	M. D. Luque de Castro et al	Spain	Exploitation of agricultural by-side products from the Mediterranean basin: olive and vineyard industries.			
Chemicals	Fernandez-Bolaños Guzman Juan Consejo Superior de Investigatione	2003	Method for obtaining purified hydroxytyrosol from products and by-products derived from the olive tree	WO02064537		
Chemicals	Kuno Noriyasu Nisshim Oil Mills	Japan 2002	Process for producing oleanolic acid and/or maslinic acid	WO0212159		
Chemicals	Garcia-Granados	1998	Process for the industrial recovery of oleanolic and maslinic acids contained in the olive milling subproducts	WO9804331		

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Chemicals	Fernandez Bolaños Guzman Juan; Heredia Moreno Antonia; Felizon Becerra Blanca; Guillen Bejarano Rafael; Jimenez Araujo Ana; Rodriguez Arcos Rocio	Spain 2000	Process for obtaining mannitol from pulp extracted from olives	ES2143939		
Chemicals	Martinez-Nieto Leopoldo; Garcia-Granados Lopez de Hierro Andreas	Spain 1994	Procedure for obtaining mannitol and derived products from waste from the olive process according to the two- phase procedure	ES2060549		
Chemicals	Probelte Pharma S.A et al	Spain, 2008	Process and apparatus for the production of hydroxytyrosol	PCT/IB2008/000 173	no	
Chemicals	Rabovskiy Alexandre (Usana Inc.)	United States, 2001	Antioxidant compositions extracted from olives and olive by-products	WO0145514		
Food	G. Rodriguez CSIC	Spain	Whole utilisation of olive oil industry by-products			
Food	Molina Alcaide Eduarda; Yanez Ruiz David Rafael; Adelmajid Moumen	Spain, 2003	Compound feed for ruminants, based on olive extracts consists of a product incorporating dried olive skin and combustion ash	ES2180423		
Food	Fuentes Cardona S. A.	Spain 1995	New method for the treatment of pulp originating from the extraction of olive oil	ES2076899		
Food	E. Molina Alcaide (CSIC)	Spain, 2007	Use of alperujo and olive leaf in the diet of goats			
Food	J. Alvarez Rodríguez (CITA, Aragón)	Spain 2009	Nutritive value of crude and extracted two-stage olive cakes			

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Energy	Fuentes Cardona S. A.	Spain 1995	New method for the treatment of pulp originating from the extraction of olive oil	ES2076899		
Energy	Cohen De Pinho E Costa Daniel	Portugal 1997	High efficiency low power cogeneration systems using industrial residuals as fuel			THERMIE 1 IN./00401/94
Energy	Oleícola El Tejar	Spain 1994	Plant of cogeneration of Energy from alperujo and gas		Palenciana Spain	
Energy	J.L. Casimiro Valoriza Energía	Spain, 2008	Co-generation plant using alperujo, pulp, olive leaf and branches.		Puente Genil Spain	

Olive mill waste water + pomaces management

Category of use	Contact person (Organisation)	Country, year	Process	Patent	Pilot Plant	Project
Agronomic reuse	R. Altieri, A. Esposito ISAFoM-CNR	Italy, 2004	Olive mill wastes management: a novel approach working at milling level for recycling in agriculture all kinds of effluents	RM2004A000084	Italy (Cilento and Vallo di Diano National Park)	LIFE00 ENV/IT/000223 LIFE05 ENV/IT/000845
Agronomic reuse	Galvagno Mauro Eniricerche S.p.A.	Greece, 1988	Process for purifying the vegetation liquors produced by oil presses	GR89100788 A		
Agronomic reuse	A. Lara Fundación CARTIF	Spain	General plan for the integral treatment, management and valorisation of waste generated during the production process of virgin olive oil		Mobile plant and industrial plants in Spain	
Agronomic reuse	Municipality of Kalamata	Greece, 1995	Biotransformation of solid and liquid waste of olives			LIFE95 ENV/GR/001092
Agronomic reuse	Vlysidis Apostolos	Greece, 1998	A method for the beneficial use of liquid waste with a high organic load after co-processing, composting and humus formation with solid organic refuse and agricultural by-products	GR97100075		
Agronomic reuse	Lara F. A.; Antolin G. A.; Peran G. J. Ramon;	Spain, 1996	Process for the purification and utilization of liquid and solid waste products produced by an olive mill	ES2084564		
Agronomic reuse	Cores R. A.; Espejo-Saavedra	Spain, 1996	Process for the decontaminating treatment of olive mill wastes and installation for effecting such treatment	ES2087032		
Agronomic reuse	Patrick Martin	Greece 2001	RECOVEG Recycling horticultural wastes to produce pathogen suppressant composts for sustainable vegetable crop production			QLRT-2000-01458
Energy	Galvagno Mauro Eniricerche S.p.A.	Greece, 1988	Process for purifying the vegetation liquors produced by oil presses	GR89100788 A		

Energy	Bonfitto Emanuele E.R.S.A.; E.N.E.A.	Italy 1991	Process for the purification of olive mill vegetation water	IT1231601 B		
Energy	Almeida Ribeiro Claro Joao Car	Portugal, 2007	Treatment ad recovery of residues and effluents from olive oil production units through the utilisation and reprocessing of cork industry waste	EP1849756		
Chemicals	Fernandez-Bolanos Guzman Juan Consejo Superior de Investigaciones	Spain, 2003	Method for obtaining purified hydroxytyrosol from products and by-products derived from the olive tree	WO02064537		
Chemicals	Kuno Noriyasu Nisshin Oil Mills	Japan, 2002	Process for producing oleanolic acid and/or maslinic acid	WO0212159		
Chemicals	Garcia-Granados	1998	Process for the industrial recovery of oleanolic and maslinic acids contained in the olive milling subproducts	WO9804331		
Chemicals	Lara F. A.; Antolin G. A.; Peran G. J. Ramon;	Spain, 1996	Process for the purification and utilization of liquid and solid waste products produced by an olive mill	ES2084564		
Chemicals	Cores R. A.; Espejo-Saavedra	Spain, 1996	Process for the decontaminating treatment of olive mill wastes and installation for effecting such treatment	ES2087032		
Chemicals	Probelte Pharma S.A et al	Spain, 2008	Process and apparatus for the production of hydroxytyrosol	PCT/IB2008/000173		
Chemicals	Rabovskiy Alexandre (Usana Inc.)	United States, 2001	Antioxidant compositions extracted from olives and olive by-products	WO0145514		
Food	Pieralisi Gennaro; Fedeii Enzo; Lanzan Armando; Ponzetti Araido	Italy, 1987	Process for the elimination of vegetation waters resulting from olive oil extraction	ES8708149		
Food	Vaccarino Carmelo S.N.T. Sviluppo Nuove Tecnologie S.N.C.	1987	Sistema per l'utilizzazione integrale delle acque di vegetazione delle olive e di altri effluenti agroindustriali mediante miscelazione con le sanse e successiva estrazione con solvente, previo trattamento con carbonato sodico	PT85790		
Food	Lara F. A.; Antolin G. A.; Peran G. J. Ramon;	Spain, 1996	Process for the purification and utilization of liquid and solid waste products produced by an olive mill	ES2084564		