UNIVERZA NA PRIMORSKEM
FAKULTETA ZA MATEMATIKO, NARAVOSLOVJE IN
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MASTER'S THESIS

EVA RACKI

MASTER'S THESIS
(MAGISTRSKO DELO)

WASTE IN OLIVE OIL PRODUCTION IN SLOVENIA
(STRANSKI PRODUKTI OLJČNE INDUSTRIJE V SLOVENIJI)

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Waste in olive production in Slovenia

(Stranski produkti oljčne industrije v Sloveniji)

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Izvleček: Proizvodnja oljčnega olja je v Sloveniji omejena predvsem na slovensko Istro. Nekaj oljčnih nasadov najdemo tudi na Goriškem in v nekaterih delih Goriških Brd. S hitro razširitvijo oljarske industrije je v Sloveniji je posledično prišlo do večjega onesnaževanja okolja z več izpusti. Stranski proizvodi oljčne industrije, kot je odpadna voda, oljčne tropine in nekateri drugi stranski proizvodi, ki nastanejo s proizvodnjo oljčnega olja, vsebujejo strupene snovi, ki lahko negativno vplivajo na lokalno okolje. Zaradi velike preobremenitve in posebnosti onesnaževal v oljarski industriji je učinkovita obdelava stranskih proizvodov v industriji oljčnega olja poglavitnega pomena. Obdelava večine stranskih proizvodov oljčne industrije še vedno ni popolnoma znana. To predstavlja ogromno težavo, saj velika večina oljarjev, stranskih produktov, ki nastanejo pri proizvodnji oljčnega olja ne prijavi. Prav zaradi prej naštetega razloga, se je potrebno zavedati, da so v omenjenih stranskih produktih oljčne industrije prisotne snovi, ki lahko negativno vplivajo na biotsko raznovrstnost.

Po drugi strani pa lahko ti stranski produkti predstavljajo kakovostne vire, ki jih je mogoče uporabiti v mnogih drugih proizvodnih procesih (proizvodnja energije, kompostiranje, namakanje kmetijskih zemljišč ...).

Raziskovalna metoda v tej magistrski nalogi je bila vprašalnik, ki sem ga poslala proizvajalcem oljčnega olja v Sloveniji. Vprašalnik sem sestavila tako, da na začetku obsega nekaj osnovnih vprašanj o pridelavi oljčnega olja v Sloveniji. Sledijo vprašanja glede odpadkov in stranskih produktov oljarske industrije, kateri so glavni stranski produkti in kakšen je vpliv le-teh na okolje.

Iz analize vprašalnika sem ugotovila, da le nekaj manjših oljarn v Sloveniji prakticira primere dobre prakse (na primer ogrevanje hiš z energijo pridobljeno iz stranskih produktov oljarn in pridobivanje energije iz stranskih produktov). Glavni razlog zato je, da pri sami pridelavi oljčnega olja nastanejo velike količine stranskih produktov, ki jih uvrščamo med odpadke, in, ki lahko brez pravilnega ravnanja povzročajo resne okoljske težave. Ena od težav pa je tudi zelo zapletena zakonodaja glede ravnanja s stranskimi proizvodi oljčne industrije v večini evropskih držav.

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Abstract: Oil production in Slovenia is mainly limited to Slovenian Istria. We can also find some olive groves in the Goriška Region and in some parts of Goriška Brda. Fast expansion of the olive oil industry in Slovenia was inevitably followed by environment pollution with multiple discharges. Despite their biodegradable nature, discharges from mills pose a serious threat to local environments. By-products, such as olive mill wastewater (OMWW), olive pomace and some other by-products that are produced through olive oil production, contain toxic substances, which can have a negative impact on local environments. Due of massive overburdening of nature and specifics of the pollutants from the olive oil industry, effective treatment of by-products in olive oil industry is still a very important and a very urgent issue. By-products occurring in the olive oil industry are still uncontrolled. This is a significant problem, because some producers of olive oil do not record these by-products. Thus, due to the reasons mentioned above, it is necessary to realize this given problem and understand that some by-products and, consequently, the substances we find in these products are very harmful to the environment and overall biodiversity. On the other hand, these by-products represent quality resources, which can be used in many other processes (energy production, composting, irrigation of agricultural land etc.).

The research method used in this master's thesis included a written questionnaire, sent to producers of olive oil in Slovenian Istria. The questionnaire begins with basic questions about olive oil production in Slovenia. Next, there are questions regarding waste and by-products in olive oil production, what the main by-products from production of olive oil are, the quantity produced, and what effects the by-products can have on the environment.

By the questionnaire results, I found out that only a few of the olive oil mills in Slovenia are using some of the good practices (like heating houses with the energy from olive oil production and producing energy from olive oil production). I think that the main reason for that is that olive fruit processing results in large amounts of residues, also considered waste, and, without the right treatment, uncontrolled disposal of olive fruit residues can cause serious environmental problems. One of the problems also stems from very complex regulatory and legislative frameworks regarding olive oil production by-products in some countries as well as a lack of such frameworks in others.

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1 INTRODUCTION

Olive oil is juice, squeezed from the fruit of olive tree (*Olea europea*; family *Oleaceae*), a traditional tree in the Mediterranean. Oil production in Slovenia is mainly limited to Slovenian Istria. We can also find some olive groves in the Goriška Region and in some parts of Goriška Brda.

Fast expansion of the olive oil industry in Slovenia was inevitably followed by environment pollution with multiple discharges. Despite their biodegradable nature, discharges from mills pose a serious threat to local environments. By-products, such as olive mill wastewater (OMWW), olive pomace and some other by-products that are produced through olive oil production, contain toxic substances, which can have a negative impact on local environments. Consequently, these substances can also inhibit environmental self-cleaning ability, which is essential when dealing with such a huge amount of direct discharge.

Due of massive overburdening of nature and specifics of the pollutants from the olive oil industry, effective treatment of by-products in olive oil industry is still a very important and a very urgent issue. By-products occurring in the olive oil industry are still uncontrolled. This is a significant problem, because some producers of olive oil do not record these by-products. Thus, due to the reasons mentioned above, it is necessary to realize this given problem and understand that some by-products and, consequently, the substances we find in these products are very harmful to the environment and overall biodiversity. On the other hand, these by-products represent quality resources, which can be used in many other processes (energy production, composting, irrigation of agricultural land etc.).

1.1 MOTIVATION

The primary purpose of the master's thesis is to determine and examine what are the main by-products from production of olive oil, how many of them there are and what effects some of the by-products can have on the environmental and overall biodiversity. As part of this research, we developed and distributed questionnaires to producers of olive oil in Slovenian Istria. The questionnaire was used to determine which by-products emerge in the process of oil production and in what quantity. We also assessed what the manufacturers currently do with these by-products. In addition, we wanted to research how these side products affect the environment.

1.2 OBJECTIVES

The primary objective of the master's thesis was to assess the availability and environmental impact of olive oil mill by-products in Slovenian Istria. We try to define the problem of by-products generated through the process of olive oil production. In addition to the negative effects that some of the by-products and some substances they contain may have on the environment, the objective is also to confirm whether it is also possible to reuse some of the by-products in other processes and whether they can be successfully used in other life cycles. To determine the severity of the problem and representation of by-products in the olive oil industry in Slovenia, we compiled a questionnaire that was sent to olive oil producers in Slovenian Istria (Appendix 1).

2 THEORETICAL PART / LITERATURE REVIEW

2.1 PREVALENCE OF OLIVE OIL IN SLOVENIA

Diffuse distribution of olive groves is typical for olive oil production in Slovenia. This is particularly influenced by the segmentation of the terrain and unfavourable design of plots of agricultural land. The result of such diversification is the deteriorating accuracy of data about oil industry in the area (Mavser et.al 2008).

Slovenia has approximately 1,900 hectares of olive groves (Ministry of Agriculture, Forestry and Food). Number of olive groves fluctuates from year to year. Annual quantities also fluctuate from 1996 to 2008 they averaged 1,700 tonnes of olive trees and 306 tonnes of olive oil, while in recent years, the quantity of olive oil is reaching 500–700 tonnes. Exports of Slovenian olive oil are negligible, while imports amount to 1,500 tonnes. Slovenian olive oil is reaching high prices on the market, around 11 to 13 euros per litre. If we compare the Slovenian production of olive oil to the Member States of the European Union, we can determine that it is negligible in terms of volume; however, Slovenian olive oil is reaching high prices and is deemed to have very high quality on the market. Slovenia and also other countries of European Union usually have small (0.3 ha) and scattered olive groves. Only around 4% of the oil producers have groves larger than 1 ha (Ministry of Agriculture, Forestry and Food).

Thirty-three olive oil producers were registered in OU Koper and 3 mills in OU Nova Gorica in 2015 (Annex 2: Olive Mills in the Register of Food Establishments OU Koper, OU Nova Gorica).

Several types of olives grow in Slovenian Istria.

“Istrska belica” is the most widespread type of olives grown in Slovenia. According to some data, this type originates from Trieste (Timor 2017). Istrska belica has closed and vertical growth, a fact that can cause growers some problems during the growth. This type of growth causes problems with shaping the crow. This type of olive matures late, depending on the ambient temperature, somewhere between November to December. It is characterized by high fertility and a high content of oils (around 17%). Olive oil from this type is very fresh, bitter, spicy and with a high content of biofenols (Timor 2017). Istrska belica tolerates low winter temperatures, however, it is very sensitive to olive flock (Vesel et al., 2010).

Leccino is the second most abundant variety in Slovenian Istria, behind Istrska belica. It has been cultivated in Istria since 1940. Because of its great adaptability, this is one of the most widely cultivated varieties in the world. It is large, with a big trunk, long branches as well as large, round and robust foliage. Fruit bearing branches are short and hanging. Flowers are very large compared to other varieties and grow separately. Bifurcation of the main bush-shaped branches is quite low. It is an early variety (September, October), and is resistant to lower temperatures. It is good for large plantations with good, deep soil. Quality of the oil is excellent, with intensely fruity olive fragrance if harvested as the drupes darken. It is softer, rounder, sweeter and less pungent if harvested after the drupes are completely dark. The oil yield is moderate. Olives can be preserved (black olives in brine), but the olive pit is quite large thus lowering its market value (Istra gourmet 2013).

Štorta is also a very widespread type of olive that grows in Slovenia. It is characterized by more elongated, cylindrical and slightly curved asymmetrical fruits. It is very suitable for investment into it, because its meat is good deviates from the pits (Timor 2017).

Buga is an autochthonous type of olive grown in Slovenian Istria. Its oil is milder in taste. Fruits from this type of olive are very small and do not contain lots of oil. They can be harvested in late October.

Črnica is an autochthonous type of olive that grows in Slovenia Istria. It has lower oil content, but the oil is of good quality. Very often, it is inoculated with Istrska belica. The fruits are medium large, black at the time of harvest.

2.2 PREVALENCE IN OLIVE OIL PRODUCTION IN THE WORLD

Fragmentation of olive groves, especially in mountain areas, is typical for the countries of the European Union. Fragmentation is a major problem. Because olive groves are scattered all around the country, there can be many problems. Some mills have groves scattered all around the country, so there are difficulties during a harvest. Along with this, there are also material costs. One of the problems is also ownership. Different small groves have different owners, and because these groves are small and very close to each other it may be problematic to determine, which groves belong to which owner. The average size of plantations of olive cultivation is very small. In Italy, the average size of an olive grove is less than 1 hectare, in Portugal 1.8 hectares and in Spain 7.7 hectares (Beaufoy 2000).

The table below (Table 1) represents areas of olive groves and the numbers of growers in the European Union.

Table 1: Total Area of Olive Groves and the Number of Growers in the European Union (Boskou 2006)

Country	Total Area of Olive Groves (ha)	Number of Growers
Spain	2,423,841	396,899
Italy	1,430,589	998,219
Greece	1,025,748	780,609
Portugal	592,436	117,000
France	39,421	19,271
Slovenia	1,968	33
EU	5,449,035	2,311,998

Olive oil has always had a very important function as a commodity, even nowadays. It has always been an important raw material for the Mediterranean region, because they are producing somewhere around 98% of all olive oil and edible olives.

The production of olive oil in Slovenia represents a very small fraction of the worldwide production. European Union countries still represent by far the largest share of worldwide production of olive oil (74–80%). This figure is conservative, as it accounts only for producers receiving subsidies and does not count small producers (Boskou 2006).

The table below (Table 2) represents the quantity of olive oil produced in different periods (1985–1989 5-year average and 2001–2005 5-year average).

Table 2: Quantity of Olive Oil Produced in Different Periods (Boskou 2006)

Country	**5-Year Average (1985-1989)**	**5-Year Average (2001-2005)**
	1000 tonnes	**1000 tonnes**
Spain	505.03	1,154.25
Italy	498.28	683.98
Greece	278.05	375.08
EU	1,1315.83	2,248.75
Tunisia	94.50	123.75
Turkey	83.75	107.25
Syria	57.45	136.00
Morocco	35.75	63.75
Slovenia	200	523
Rest of the World	78.35	132.88
World	1,665.63	2,812.38

From 1985 until 2005, we can see that the global olive oil production increased by 70%, from around 1.7 to 2.8 million tonnes of olive oil. As we can see from Table 2, the largest share in 2005 was contributed by Spain. The second largest producer was Italy, followed by Greece. Combined countries of the European Union contributed 74-80%, other Mediterranean countries around 15–20%, and the rest of the world around 5%. Slovenia is counted among the countries which produce small amounts of olive oil, because average production between 2001 and 2005 was just around 523 tonnes of olive oil (Table 2).

2.3 TECHNOLOGY OF OLIVE OIL PRODUCTION

Olive oil production starts during olive harvesting. The method for processing olives into olive oil is carried out in several stages. When olives reach optimum ripeness, they need to be harvested. This normally happened just before they start to fall from the tree. Newer and bigger specially grown olive trees are often mechanically harvested by machines with mechanical scrapers. It is recommended that when the olives are harvested, they be rapidly delivered to the presser, to avoid the disintegration of the olive oil inside the olive.

There are several types of olive oil, which are separated based on what way the oil has been obtained. Broadly speaking, we separate virgin olive oil and the oil obtained from the residue remaining from the manufacturing of virgin oil. Virgin olive oil is olive oil, which has been obtained solely by mechanical processing which does not alter the natural composition of the oil. Mechanical processes include washing with water, settling, centrifugation, cold pressing and filtration. No processes may raise the oil temperature above 30 °C (Boskou 2006).

2.4 THE PROCESS OF OLIVE OIL PRODUCTION HAS SEVERAL PHASES

2.4.1 Washing and milling the olives

The olives are rinsed in cold water and then passed between rollers along a conveyer belt. This machinery, often called the olive crusher, breaks down the cells and de-stones the olives (“How products are made – Olive oil”. www.madehow.com/Volume-3/Olive-Oil.html. Accessed on 6th August 2018.).
In the initial phase, it is necessary to remove any impurities from the cumulative weight that we can find among the olives (leaves, branches and dirt). This is done with strong air vacuums (Boskou 2006).

2.4.2 Creating olive paste

CREATING OLIVE PASTE: The milled olives travel from the mill into vats, and slowly turning blades mash the olives into a homogenized paste.

2.4.3 Cold pressing the olive paste to extract the oil

The oil is extracted by loading the paste into a hydraulic press. The olive paste is evenly spread over hemp pressing bags or disks covered with synthetic fibres.

The term cold-pressing refers to the fact that the oil is extracted without heating the paste, further ensuring the purity of the oil. The oil that is squeezed is a reddish mixture of the oil and the inherent vegetable water. This is the oil that receives the appellation of "extra-virgin" olive oil. The paste is removed from the bags and run through several more presses to obtain the lesser grades of oil that remain ("How products are made – Olive oil". www.madehow.com/Volume-3/Olive-Oil.html. Accessed on 6th August 2018.).

2.4.4 Separating solid and liquid fractions (marc/oily mash and vegetation water)

First stage of separating solid and liquid fractions is compression: different phases can be separated by the process of compression, where we apply the oily mash to the filter cloth and compress it under high pressure (400 bar). The general products formed in this phase are oily mixture and extract. The oily mixture is centrifuged further, resulting in oil and vegetation water. This is composed of primary water, which is heavily laden with scrap material that was not eliminated in the previous processes. The next phase is centrifuging. This is the separation of light (lower density) of the substance from the denser by using centrifugal force. Lighter substances accumulate closer to the axis of rotation, while the heavier are pushed to the periphery. Due to the rotation, a little bit of the oil turns into an emulsion, which goes as vegetation water from the centrifuge. There are two types of centrifugation. The first type is called a three-phase centrifuge where there is a bit of hot water added to the oily mixture, which contributes to the separation of the mixture during centrifugation. The products of this process are grains, oily mash and vegetation water. Second type of centrifugation is two-phase centrifugation. During this process, there is no water added to the mixture in the centrifuge, which is especially important in areas with limited water supply. Products gained using this technology are just oily mash and pomace with higher water content (Di Giovacchino et al., 2002a). Three-phase continuous centrifugation process for olive oil extraction is a phase for olive oil extraction, where olives are washed, crushed and malaxed, and then lukewarm water is added to a horizontal centrifuging (40–60 L / 100 kg fruit weight), separating pomace from the oily must (oil +

wastewater). This process incorporates three main phases. We have the oily phase (20%), solid residue (30%), consisting of olive pulp and stones, which together form an olive cake, and there is also a third phase, aqueous phase (50%), which consists from water content of fruit and process water as well as water which is used to wash olives. From this, we get another olive oil by–product, OMWW. Such dilution increases the difference between the specific weights of liquid and solid phases needed to obtain their separation (solids > liquid). A 3-phase centrifuge at the end generates the three final products – oil, pomace and wastewater, based on which it was also named, i.e. 3-phase (Di Giovacchino et al., 2002a).
2-phase centrifuging is an extraction system, which is also known as "ecologic" or "water-saving", as it requires no addition of water and reduces wastewater generation up to 80%. The concept of functioning is like that of a 3-phase centrifuging, except that horizontal centrifuge has no or lower need for adding water due to superior g values. This system delivers only two final streams – the oil and very wet olive cake as solid phase, known as alperujo (Niaounakis et al., 2006; Tsagaraki et al., 2007; Di Giovacchino et al., 2002a).

2.5 TYPES OF OLIVE OIL

Depending on the type of technological production process and the quality parameters, we classified olive oil into several categories and subcategories.

2.5.1 Virgin olive oil

The specialty of virgin olive oil is that this type of olive oil is obtained from olives exclusively with mechanical processes. This kind of olive oil is virgin, because it is not chemically or thermally treated, and this kind of oil contains no additives (Ministrstvo za kmetijstvo, gozdarstvo in prehrano, Direktorat za varno hrano, 2007).

There are several subcategories of virgin olive oil:

2.5.1.1 Extra virgin olive oil

Extra virgin olive oil is virgin olive oil of the highest quality and category. It is obtained directly from olives, and this type of subcategory has the highest percentage of included free fatty acids in the form of the oleic acid, resulting in 0,8 g per 100 g ("Naše oljke". https://oljkacom.wordpress.com/2016/10/31/vrste-oljcnega-olja/. Accessed on 27th August 2018).

2.5.1.2 Virgin olive oil

Virgin olive oil is also produced directly from olives and solely by mechanical processing methods and has a high percentage of included free fatty acid resulting in oleic acid presence around 2 g per 100 g (Breznik et al. 2007).

2.5.1.3 Lampante virgin olive oil (lighting oil)

Lampante olive oil is a subcategory of virgin olive oil, which is unsuitable for consumption and is used solely for technical purposes. If we wanted to use this type of oil for food purposes, it would have to undergo pre-processing (Breznik et al. 2007).

2.5.2 Refined olive oil

Refined olive oil is made by refining virgin olive oil without affecting and altering the original triglyceride structure. It has a free fatty acid content, expressed as oleic acid ("Naše oljke". https://oljkacom.wordpress.com/2016/10/31/vrste-oljcnega-olja/. Accessed on 15th August 2018).

2.5.3 Mixture of refined olive oil and virgin olive oil

This blend of olive oil is made by mixing the refined olive oil and any type of virgin olive oil except for the lampante virgin olive oil. It has a free fatty acid content, expressed as oleic acid. ("Extra Virgin Olive Oil from Spain". https://www.extravirginspain.com/the-different-types-of-olive-oil.html. Accessed on 15th August 2018).

2.5.4 Crude olive-pomace oil

This type of oil is extracted from the olive pomace by means of treatment with solvents or by physical means or is an oil corresponding to lampante olive oil. This category excludes any kind of oil obtained by re-esterification and mixtures with other types of oil (Breznik et al. 2007).

2.5.5 Refined olive-pomace oil

Refined olive-pomace oil is obtained by refining crude olive-pomace oil and has a free fatty acid content, also expressed as oleic acid ("Naše oljke". https://oljkacom.wordpress.com/2016/10/31/vrste-oljcnega-olja/. Accessed on 15th August 2018).

2.5.6 Olive-pomace oil

The lowest grade of olive oil made from the by-products of extra virgin olive oil production. Olive skins, seeds and pulp are heated, and the remaining oil is extracted using hexane, a solvent. The result, pomace oil, is then put through the refining process, similar to pure or light olive oil. Pomace olive oil is bland and extremely low in antioxidants ("Extra Virgin Olive Oil from Spain". https://www.extravirginspain.com/the-different-types-of-olive-oil.html. Accessed on 6th August 2018.).

2.6 BY-PRODUCTS OF THE OLIVE OIL INDUSTRY

Olive as a fruit consists essentially of three components: 75–85% of the total weight of the olive represents the fleshy part, 12–23% is represented by the seed's cellulose shell, and finally, then there is the seed which represents 23% of the olive's whole weight (Wang et al., ur. 2010). Olive oil, which is produced from the olive fruit, has many characteristics which depend on a number of factors, primarily the climatic conditions, growth area, age and species of the olive tree, the method of oil-extraction, usage of pesticides and fertilizers and the maturity of olive fruit at the time of the harvest (Wang et al., ur. 2010).

The type of technology used in the process of oil-production influences the type and number of by-products, which appear in the process of olive oil production. The main difference lies in the amount of moisture contained in the pomace and in the amount of leachate vegetable water. The differences can also occur in the types and amounts of bio phenolic compounds and other substances that are present in the olive mill wastewater and in the pomace (MORE 2008).

Determining the amount and types of by-products in the olive oil industry is difficult. This is primarily due to the inadequate available documentation in the field, which stems from poor documenting habits of the majority of olive oil producers, who rarely record and adequately report the by-products created in the process of producing olive oil. This olive-processing process creates large amounts of by-products in the form of olive mill wastewater and olive-pomace. The uncontrolled disposal of these products directly into the environment may pose a significant threat to it. However MORE (2008) outlines, that with the help of proper processing treatment, these by-products can be very valuable, as they can be used for various reasons:

- As fertilizers and soil conditioners.
- As herbicides and pesticides.
- As animal feed or for human consumption.

- For the extraction of residue oil.
- For the extraction of organic compounds (pectin, antioxidants, enzymes, etc.).
- To produce various products (alcohol, biopolymers, etc.).
- To generate energy

2.6.1 Olive mill wastewater (OMWW)

One of the by-products generated by the three-phase continuous centrifugation process of olive oil extraction is olive mill wastewater (OMWW). Olive mill wastewater is the aqueous phase (50%), which is composed from water content of fruits and process water as well as water, used to wash the olives. Usually it is recognizable by its dark brown colour (brown purple) and a strong olive-tree scent. It is known for its high levels of chemical oxygen demand contamination (COD) (reaching to 400 g/l of KPK). COD is a parameter that indicates the amount of oxygen necessary for the chemical oxidation of organic pollution in wastewater. High levels of COD are primarily a consequence of large amounts of aromatic essences and phenolic compounds found in olives as such. The pH indicator of vegetation water reaches values between 3 and 5.9. It is also known for its high content of polyphenols, solids and oils (Wang et al., ur. 2010).

2.6.2 Olive pomace (Olive cake)

Olive pomace is another crucial by-product in the olive oil industry. It is composed of the remaining stones and fresh parts of the olives, which are generated after the three-phase continuous centrifugation process of olive oil extraction. Its characteristics are high contents of fibres and lignin, but with an extremely low protein content – comparable to that of straw. Fresh pomace can be acquired in an intact state or with larger parts of the seeds removed (Niaounakis and Halvadakis 2006).

2.6.3 Olive pulp

Olive pulp is what remains after olives are crushed and olive oil is extracted. Olive pulp contains the pulp, skins, stones and has a very high-water content of 60% (ELARD 2004).

2.6.4 Olive leaves

Olive leaves are agricultural residue resulting from the pruning of olive trees. These are obtained operations of cleaning and rinsing. This quantity can reach up to 5% of total weight of incoming raw olives (ELARD 2004). The leaves may also be considered an easily available industrial by-product. Currently this by-product is not very profitable, given that in many countries the leaves have traditionally been used only as feed for livestock (Gómez-Cabrera et al., 1992; Sánchez et al., 2002; Ruíz et al., 2004).

2.7 THE IMPACT OF OLIVE OIL INDUSTRY BY-PRODUCTS ON THE ENVIRONMENT

In the process of production of olive oil, large quantities of by-products are generated. The most important and the most frequently referred-to by-products are olive mill wastewater and olive pomace. These by-products are able to affect the environment to a larger extent than others, especially the physical, biological and chemical properties of the soil and water, thus affecting the whole biodiversity.

2.7.1 The impact of olive mill wastewater on the environment

Olive mill wastewater, generated as a by-product in the production of olive oil, constitutes a large proportion of seasonal environmental pollution. We know that olive mill wastewater contains large amounts of sugars, tannins, biopolyphenols, polyalcohols, pectin and lipids. It is a serious threat to environmental degradation.

Some countries have already acted in establishing a legal framework for controlling the olive oil production process. But there are still many countries, where these kinds of actions have not taken place, and because of this, the environmentally harmful practices are still present. Scientists have estimated that per litre of oil, around 2.5 litres of by-products are generated.

The most visible effect of the vegetation water from the production of oil is the colouring of it, because it contains large quantities of tannins, which are in the peel of the olive fruit. This gives the water a dark brown-black colour and it has a phytotoxic effect on small and large organisms. It may also contain large amounts of phosphorus, which can lead to over-flourishing of algae and consequent eutrophication of water. Through the process of cell breathing, the algae reduce oxygen levels in the water and may detrimentally affect the stability of the ecosystem. Furthermore, vegetation water usually contains large amounts of acids, minerals and other organic substances, which may be detrimental to chemical characteristics of the soil and may affect its fertility. Sedimentation in olive mill wastewater leads to a process of anaerobic fermentation of substances, where many of various gases (methane, hydrogen sulphide) are formed and cause unpleasant odours (Wang et al., ur. 2010).

2.7.1.1 Phenolic compounds in olive mill wastewater and their impact on the environment

The olive mill wastewater generated in the process of production of olive oil contains bio phenolic compounds, of which the flavonoids are commonly found and naturally occurring in barks, leaves, flowers, fruits and seeds (Bhupinder and Sharma 1998).

Olive mill wastewater produced in olive mills contains large amounts of tannins, giving it the typical dark brown colour. Tannin is a biomolecule categorized as a water-soluble flavonoid, which can be found in most plants. Only a handful of organisms (*e.g.*, some fungi and bacteria) are known to have the ability to process and digest/dissolve tannins. Although it may be degraded in aerobic or anaerobic conditions, the tannin molecules found in olives have proven to be more resistant to biological degradation (Bhupinder and Sharma 1998).

2.7.1.2 Detergents and soaps

Wide varieties of detergents and soaps are commonly found in olive oil industry as a result of washing equipment and machinery in the mill, yet they can also be of natural origin, resulting from the by-products generated from the oil extraction process. Most of these detergents and soaps are biodegradable and thus do not cause significant problems in wastewater treatment and are often completely removed from the environment after biodegradation. Nonetheless, they are difficult and slow to dissolve during the anaerobic metabolism. The polyphosphate salts, which are often added to these detergents and soaps, represent excellent nutrients for algae, which consequently causes the eutrophication of water bodies. Direct release of these pollutants into the environment can also negatively affect larger aquatic organisms, such as fish and amphibians (Wang et al., ur. 2010).

2.8 OLIVE OIL INDUSTRY BY-PRODUCT TREATMENT OPTIONS AROUND THE WORLD

2.8.1 Treatment methods for olive mill wastewater

In the process of producing olive oil, large quantities of by-products are generated which, if released into the environment, may pose a serious environmental threat. However, if adequately re-processed, these by-products can be harvested and used for various beneficial purposes. The following sections highlight some of the possible uses of olive oil industry by-products – namely olive mill wastewater and olive pomace (MORE 2008).

2.8.2 Anaerobic treatment

This treatment process involves anaerobic digestion by means of bacterial fermentation processes. Proteins, fats, and carbohydrates are transformed into acids and alcohols. Anaerobic digestion produces methane gas, which can be extracted and used for energy recovery (ELARD 2004).

2.8.3 Aerobic treatment

This process involves biological degradation by means of aerobic or oxygen consuming microorganisms, which can be fixed or suspended. Clarification of the treated water is carried out afterwards in order to further clean the effluent. Resulting sludge is usually used in land enrichment and agricultural practices (ELARD 2004).

2.8.4 Evaporation

This process must involve the heating of olive mill wastewater, so that all the water present in olive mill wastewater is evaporated (MORE 2008).

2.8.5 Composting

Composting is widely considered as one of the most affordable methods of processing olive oil industry by-products. It is a controlled bio-oxidative process, which is carried out by microorganism actions. At the end of the process, the olive pomace results in a humus-like by-product, which is biologically stable, is free of pathogens and is odour free (Mavsar et al. 2008). Compost has a good structure and is suitable for sale. It can also be used for sowing and for fertilization.

2.8.6 Irrigation of agricultural land

According to the provisions of the Slovenian legislation related to the input of olive oil industry by-products and waste substances into the soil, it is prohibited to discharge industrial wastewater directly into the ground (Decree on input of dangerous substances and plant nutrients into the soil - Official Gazette of RS, no. 35/2001; Uredba o vnosu nevarnih snovi in rastlinskih hranil v tla - Ur.l. RS, št. 35/2001). Additionally, the Regulation on limit values for the input of hazardous substances and fertilizers into the soil limits the annual input directly into the ground for nitrogen resulting from livestock manure, compost and mud throughout Slovenia. The wastewater and pomace have high nitrogen levels. The threshold value of the nitrogen input amounts to 170 kg/ha, for phosphorus (P_2O_5) 120 kg/ha and for potassium (K_2O) 300 kg/ha. Both regulations provide for stricter measures in water protection areas (Decree on the limit input values of dangerous substances and fertilizers in soil - Official Gazette of RS, no. 84/2005; Uredba o mejnih vrednostih vnosa nevarnih snovi in gnojil v tla - Ur.l. RS, št. 84/2005).

2.8.7 Centrifugation and filtration

This process involves the filtration of wastewater through its own solid residues that settle down, and in turn provide a medium for biodegradation of nutrients. Biofiltration plants eliminate about 100 per cent of solids and 70 to 80 per cent of dissolved organic compounds (MORE 2008).

2.8.8 Lime treatment

In this process, lime is used for removing a large portion of the fatty compounds present in wastewater (highly phytotoxic compounds) which can facilitate further evaporation or treatment. This process makes wastewater suitable for irrigation (MORE 2008).

2.8.9 Membrane treatment

With “membrane treatment”, we are referring to the processes such as ultra-filtering and reverse osmosis. It allows the elimination of pollutants from water by generating two currents: clean water that can be discharged directly into streams, and a high-concentration current of pollutants (ELARD 2004).

2.8.10 Treatment methods for olive pomace

The spent olives, or pomace, are usually regarded as a valuable product with multi-uses rather than waste that needs treatment. Some examples in which pomace can be treated are presented below (Ministry of Environment 2002).

2.8.11 Oil extraction

Oil is characteristically extracted using solvents such as hexane, similarly to the extraction of seed oil. Any left-over fibrous material from secondary extraction is commercially valued as fuel for pottery kilns, owing to its steady burning properties and high heat output, or it can be disposed of by burning or composting (ELARD 2004).

2.8.12 Usage as fuel

The calorific values of olive mill pomace depend on the oil and moisture content. Prior to olive mill pomace and its usage as fuel, it requires drying in large central facilities. Large central facilities produce high amounts of gases that need to be regulated. This process results in solid residues made up inert of ashes and slags, which can be used in the manufacture of cement (Sturzenberger 2007).

2.8.13 Usage for water treatment

There is also potential for using processed pomace to treat drinking water, but this potential usage is still in an experimental stage (Sturzenberger 2007).

2.8.14 Usage as feed

Olives possess high nutritional value, which allows them to be used as feed for cattle. However, they are known to rapidly degrade by fermentation. There has been some evidence, that fresh spent olives, not more than 7 days old, covered by plastic sheets, had no moulds, colour, smell, and bacteria (MORE 2008).

2.9 CURRENT STATE OF OLIVE OIL INDUSTRY BY-PRODUCT TREATMENT IN SLOVENIA

2.9.1 Direct fertilization of agricultural land by hard fraction (olive pomace)

Olive-pomace fertilization is not directly or specifically addressed within the Slovenian legislation. According to the Waste Management Act (Official Gazette of RS, no. 84/1998), olive pomace is suitable exclusively for composting and is thus required to undergo aerobic or anaerobic pre-processing. Considering the olive pomace and, its use to enrich soil may also have beneficial effects on soil fertility. However, large amounts of olive pomace could have negative impacts on soil. Due to the presence of large amounts of phytotoxic and antimicrobial substances therein, using larger amounts of olive pomace may have a diametrically opposite, negative, effect on soil, fatally affecting the microorganisms and thus reducing soil fertility and harming the crop (PROSODOL 2013).

2.9.2 Energy-production

Energy production is one of the more interesting alternatives in the department of sustainable management of waste and by-products of the olive oil industry. The latter produces two essential types of by-products, which are considered appropriate for usage in energy production. The first group includes the residues that occur in the primary process of growth of the olive tree, i.e. branches and leaves. The second group, on the other hand, consists of different residues occurring at different stages during the production of olive oil. The energy potential of these by-products also depends on the system of oil-extraction used. For example, olive residues obtained after extraction with hexane and those obtained after the two-phase-treatment system are both characterized by the average energy value of 14,000 kJ/kg.

Both groups of by-products may be suitable for use in energy production – under conditions of stable annual by-product generation, greater concentration of residues in a relatively small area, suitably low moisture-percentage, low levels of sulphur and other harmful emissions, etc.

There are some essential thermo-chemical methods, which are used for obtaining energy from pomace, namely gasification, briquetting, combustion (direct ignition) – incineration. The gasification process includes the formation of biogas (methane), by using anaerobic degradation of residues resulting from the treatment of olives (MORE 2008).

2.9.3 Gasification

Gasification is a thermochemical process that converts biomass into gas suitable for use. This gas contains carbon monoxide, hydrogen, water vapour, carbon dioxide and steam.

2.9.4 Briquetting

The briquetting technique is an inexpensive heat-production method from by-products of the olive oil industry. For the purpose of briquetting, various products of biomass are used, including solid residues resulting from the processing of olives. The latter are moderately more resistant to humidity and moisture compared to other biomass resources. Briquettes are also significantly better than coal as an alternative source for energy production and are thus subject to massive increase in demand (MORE 2008).

2.9.5. Drying and pomace incineration

The principle on which pomace incineration is based is relatively simple. The combustion of dried pomace generates heat which may be used as an indoor heating solution. The greatest obstacle to pomace incineration, however, lies in the its moisture content, which varies depending on the processing mode for olives (approximately 27% in the traditional system, 55% in the three-phase system and 65% in the two-phase system). Minimally required moisture levels for effectively utilizing the energy capabilities of olives are approximately 5–8% (Niaounakis and Halvadakis 2006).

In practice, two methods of pomace usage have been established. Firstly, there is the dried-pomace incineration. Secondly, a method of separating the pulp and the seed takes place beforehand. The seed alone contains about 20% of moisture and thus requires less energy input to dry when compared to the pomace. The average size of the seed is approximately 3 mm, making the aeration more effective. The seed separation efficiency is around 18–30% (Analysis of Local Situations 2008).

Pomace drying is a highly energy-consuming process. Furthermore, usage of advanced systems for individual pomace drying in connection to small quantities of olive oil extraction is by no definition an economically reasonable investment, especially due to high investment and operating costs.

2.9.6. Anaerobic biogas production

Anaerobic biogas production is a process of efficient conversion of various sources of biomass into methane. Approximately 60–80 kWh of energy can be obtained from biogas produced by anaerobic treatment of 1 m^3 wastewater.

Knowing the possibilities of efficient use of olive pomace to produce energy, effectively addresses two essential problems at the same time. Namely, it gives us the option of producing cleaner energy, and helps solve the environmental and ecological problem of residues and by-products generated in the process of olive processing (MORE 2008).

2.10 AMOUNTS AND TYPES OF BY-PRODUCTS AROUND THE WORLD

Olive fruit processing produces large number of by-products, including liquid and solid wastes deriving from olive oil extraction. Types of by-products are depending on by the type of technology of olive oil production. The main difference is in the composition of olive pomace, the amount of olive mill wastewater and in the types and quantities of bio phenolic compounds and other substances present either in olive pomace or in vegetation water.

Determining the quantity of by-products in the olive oil industry is even more difficult than determining the quantities of olives produced. The main reasons are similar – the documentation in the field is practically non-existent, because olive oil producers often do not report the total quantity of by-products produced during olive oil production (Boštjančič 2012).

2.10.1 Solid residues in Liguria Region (Italy)

It was not possible to find the actual data for virgin pomace produced in the region of Liguria because no regional authority is keeping these kinds of figures on file. For the estimation it was used the assumption given by the local olive millers that from 1 kg of olives 0,450 kg virgin pomace is produced and from this amount 0,100 kg is the final product that could be used as a fuel and is called exhausted pomace.

The table below (Table 3) shows the estimated solid olive pomace residues produced between 1995 and 2007 in the Liguria Region.

Table 3: Estimated Solid Olive Pomace Residues Produced between 1995 and 2007 in the Liguria Region (MORE 2008)

SOLID POMACE RESIDUES (tonnes)													
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Virgin pomace	14,411	10,055	13,871	5,415	6,314	12,902	4,749	18,849	9,712	13,605	10,620	9,774	7,151
Exhausted pomace	1,441	1,006	1,387	542	631	1,290	475	1,885	971	1,361	1,062	977	715

2.10.2 Solid residues in the Jaén Region (Spain)

Jaén Region is one of the larger producers of olive oil in the world (amounts to around 60% of all Spanish production). Because of this, the elimination of waste is very important here. Olive-mills use a 2-phase process, which does not generate any water. Thus, the by-product designated “virgin pomace” is obtained (humidity 62–70%) that goes through a pitting machine – the pit is mainly used as fuel to produce heat for thermal use. Afterwards, the virgin pomace goes through a process of drying and extraction, and new by-product results, designated “dry pomace” (humidity 10%). This by-product is mainly used as fuel to produce electricity (MORE 2008).

The tables below (Table 4 and Table 5) show estimated solid olive pomace residues produced between the 1995 and 2007) in the Jaén Region.

Table 4: Estimated Solid Olive Pomace Residues Produced between 1995 and 2000 in the Jaén Region (MORE 2008)

SOLID POMACE RESIDUES (tonnes)						
Year	1995	1996	1997	1998	1999	2000
Virgin pomace	2,861,512	3,485,600	3,522,407	2,694,089	3,419,902	3,419,902
Exhausted pomace	492,227	522,840	563,585	431,054	547,184	547,184

Table 5: Estimated Solid Olive Pomace Residues Produced between 2001 and 2007 in the Jaén Region (MORE 2008)

SOLID POMACE RESIDUES (tonnes)							
Year	2001	2002	2003	2004	2005	2006	2007
Virgin pomace	4,680,542	2,843,173	4,686,853	3,344,862	2,533,713	3,765,956	3,961,565
Exhausted pomace	748,887	454,908	749,896	535,178	408,594	602,554	633,850

2.10.3 Solid residues in the Chania Region (Greece)

Virgin pomace derived after olive oil extraction is delivered to pomace oil refineries, usually as an exchange of the exhausted pomace that they use in their boilers for heating process water. Pomace oil refineries collect most of the virgin pomace produced in the region, about 95–99%, and they dry it in order to extract the pomace oil. The final product has humidity of around 13% as well as pits and pulp, and it is called exhausted pomace. It was not possible to find the actual data for virgin and exhausted pomace produced in the Chania Region. The presented estimate is based on the assumptions provided by local olive millers: 0.4 kg virgin pomace is produced form 1 kg of olives (MORE 2008).

The tables below (Table 6 and Table 7) show estimated olive solid pomace residues produced between 1994 and 2006) in the Chania Region.

Table 6: Estimated Solid Olive Pomace Residues Produced between 1994 and 1999 in the Chania Region (MORE 2008)

SOLID POMACE RESIDUES (tonnes)						
Year	1994	1995	1996	1997	1998	1999
Virgin pomace	56,758	59,523	79,024	73,122	77,890	81,889
Exhausted pomace	28,379	29,762	39,512	36,561	38,945	40,945

Table 7: Estimated Solid Olive Pomace Residues Produced between 2000 and 2006 in the Chania Region (MORE 2008)

SOLID POMACE RESIDUES (tonnes)							
Year	2000	2001	2002	2003	2004	2005	2006
Virgin pomace	72,728	70,396	72,033	71,998	65,381	76,177	75,298
Exhausted pomace	36,364	35,198	36,016	35,999	32,690	38,088	37,649

2.11 AMOUNTS AND TYPES OF BY-PRODUCTS IN SLOVENIA

Types of by-products are conditioned by the type of technology of olive oil production. The main difference is in the olive pomace content, the amount of olive mill wastewater and in types and quantities of phenols and other substances present either in olive pomace or in vegetation water (Boštjančič 2012). In Slovenia, it is very hard to estimate the amounts of by-products produced during olive oil production. The main problems regarding documentation stem from unreported and improvised olive oil mills. According to Mavsar et al. (2008) there approximately 31 olive oil mills in Slovenian Istria in 2008, 18 of those olive mills were registered, while there were still around 13 unregistered mills in 2012.

It was not possible to find the actual data for virgin pomace produced in the region of Istria, since no regional authority is keeping files on such figures. The presented estimate is based on the assumptions provided by local olive millers: 0.7 kg virgin pomace is produced from 1 kg of olives (MORE 2008). The quantity of by-products in olive oil production is also dependent on annual harvests, types of olives and efficiency of the process. According to Wang et al., 2010 said that, 400 kg solid by-products and 600 litres of liquid fractions per tonne of olives were produced during the traditional process, while during the three-phase extraction, approximately 550 kg of solid by-products and 1100 litres of liquid fractions per tonne of olives were produced. During the two-phase extraction, about 825 kg of water pomace per tonne of olives were produced (Boštjančič, 2012).

The table below (Table 8) shows estimated solid olive pomace residues produced between 1995 and 2007) in Slovenia.

Table 8: Estimated Solid Olive Pomace Residues Produced between 1995 and 2007 in Slovenia (MORE 2008)

SOLID POMACE RESIDUES (tonnes)													
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Virgin pomace	915	930	169	747	1,055	871	615	1,751	603	1,502	718	815	739

2.12 TREATMENT OF BY-PRODUCTS APPLIED BY SLOVENIAN COMPANIES

Olive oil production results in large amounts of by-products, in many ways considered as waste, although olive mill residues are valuable by-products. Many of the by-products occurring during olive oil production can be used further in various ways. Above that, uncontrolled disposal of olive residues without any treatment can cause serious environmental problems. Waste treatment technologies aimed at energy recovery may represent an alternative for sustainable disposal of by-products from olive oil production, able to generate energy and reduce the negative impact on the environment.

In Slovenian Istria, olive oil by-products from olive oil production are treated as waste and not as secondary products. They are usually (95.4% of by-products) composted and returned to olive groves as fertilizer. The composting of by-products is integrated in the processing cycle of each oil mill. After the composting period of 3–6 month, by-products are spread on the surface as fertilizer. With fertilization, nutrients are returned to the soil. Only 4.6% of by-products are used for energy purposes, to generate heat. This number of by-products produces enough green energy for heating two households.

Some olive millers have already bought special stoves for heating with olive oil by-products. The barriers are the lack of proper technologies, ecological consciousness, knowledge and (now) too expensive infrastructure for broader use of olive residues as a renewable energy source. In Slovenia, pit separators separating olive pits from olive pomace are not used. There are also no drying facilities and refineries to dry wet pomace in order to make them more appropriate for burning or further processing. Planned development of electricity generation from renewables does not include the energy exploitation of olive residues due of their small quantities.

The end users of olive residues are now mainly olive millers using residues mainly for composting or uses like fertilizing their olive groves. Some millers use olive oil by-products for their private energy-producing purposes (heating) and sanitary water heating (MORE 2008).

2.13 BEST PRACTICES OF BY-PRODUCT USAGE IN THE WORLD'S OLIVE OIL INDUSTRY

2.13.1 Examples of good practices in Croatia

The researched area covered the whole of Istria. Only two olive mills used olive residues for energy-production purposes (case 1, case 2).

Figure 1: location of mills with good practice in Croatia (MORE 2008)

Case 1: Pašutići Mill, where olive pomace was used to produce heat for indoor heating.

Case 2: OLEA D'ORO Mill, where olive pomace was used for heating the house and for composting.

2.13.1.1 Olive Mill Pašutići

The Pašutići Mill uses olive residues mostly for heating living areas and for procuring hot water. After the process, by-products that are left are squeezed in the press, and they are left to dry in the boxes with the help of the wind and the sun. After that, dried by-products which occur during olive oil production are used directly for incineration in the furnace (MORE 2008).

2.13.1.2 Olive Mill OLEA D'ORO

The OLEA D'ORO Mill uses olive residues mostly for heating living areas and for procuring hot water. After the olive oil extraction, by-products are left in a filed 10 km away from the mill to dry up (MORE 2008).

2.13.2 Examples of good practices in Spain

In Spain, examples of good practices can be found in the Cordoba and Jaén Provinces in the Andalusia Region, in southern Spain (case 1 – case 5).

Figure 2: Location of Mills Utilizing Good Practices in Spain (MORE 2008)

Case 1: GEOLIT CLIMATIZACIÓN S.L. public central heating and cooling system using biomass, Jàen (marked with “2” in the figure)

Case 2: ENERGIA LA LOMA S.A., Jàen (2)

Case 3: BIOMASA PUENTE GENIL, Córdoba (1)

Case 4: HOTEL & SPA SIERRA CAZORLA, Jàen (2)

Case 5: Furnace utilizing biomass for heating public buildings (schools), Jàen (2)

2.13.2.1 GEOLIT CLIMATIZACIÓN S.L.

GEOLIT is the name of the science and technology park dedicated to olive oil industry in Jaén. This park uses a network for heating and air conditioning of facilities in the park. The heating is provided by two biomass boilers with a total capacity of 6,000 khW. As a source of fuel, they use biomass from olive pomace (MORE 2008).

2.13.2.2 ENERGIA LA LOMA S.A., Jàen

Endesa Cogeneracíon y Renovables incentive built a plant for energy production from combustion of dried olive pomace, without remaining olive oil (MORE 2008).

2.13.2.3 BIOMASA PUENTE GENIL, Córdoba

Plant for biomass processing, which produces electricity from olive pomace, uses energy-generating technology with a steam circuit. The annual consumption of biomass is 71,000 tonnes (MORE 2008).

2.13.2.4 HOTEL & SPA SIERRA CAZORLA, Jàen

This hotel uses by – products of olive oil production for heating the hotel and pool complex and for heating a total of 8000 litres of sanitary water. It is a unique facility in Andalusia (Spain) (MORE 2008).

2.13.2.5 Furnace utilizing biomass in public buildings (schools), Jàen

In Andalusia, olive pomace is used to generate heat for heating private buildings and public institutions (MORE 2008).

2.13.3 Examples of good practices in Greece

The selected best practices for Greece can be found on the island of Crete (Figure 8). Most producers use olive pomace first for oil extraction, while dried pomace and olive pits are used for heating buildings (case 1 – case 3).

Figure 3: Location where Good Practices Are Being Utilized in Greece (Crete) (MORE 2008)

Case 1: ABEA. Olive pomace is used as the source of energy for heating buildings as well as for olive oil extraction and for drying olive pomace.

Case 2: BIOMEL is an olive oil extraction plant. The remaining olive pomace is sold to the United Kingdom.

Case 3: Giannoulis Plant is a public central heating system using olive pits (MORE 2008).

2.13.3.1 ABEA

ABEA deals with filling extra virgin oil, extracting olive oil from olive pomace, producing dried olive pomace for heating during the process of extraction of olive oil, selling dried olive pomace for heating, and with producing soups from extracted olive oil (MORE 2008).

2.13.3.2 BIOMEL

BIOMEL is a company that uses pits for heating and exports them to the United Kingdom. The company supplies 80,000 tonnes of olive pomace per year from millers and produces, approximately 35,000–50,000 tonnes of olive pits per year, which are used for heating the factory and a part of them is exported to the Great Britain (MORE 2008).

2.13.3.3 Giannoulis Plant

The company deals with refining olive oil and with extraction of olive oil from olive pomace. At the beginning of the 1990s, they focused on packaging, producing different products from olive oil and preparing and packaging olive pits for heating. In their production plant, they have a central heating system for the building and for hot water. They also have a system for drying olive pomace (MORE 2008).

2.13.2 Examples of good practices in Italy

During this research, all olive oil mills in Italy were contacted.

Figure 4: Location where Good Practices Are Being Utilized in Italy (MORE 2008)

Case 1: Arnasco Public Heating (marked with BP1 in the figure)

Case 2: Olive Mill Lucchi & Guastalli (BP2)

Case 3: Association of Producers of Olive Oil of the Lazio Region (BP3)

Case 4: Olive Mill Matraia (BP4)

2.13.2.1 Arnasco Public Heating

Arnasco Public Heating is a small plant for public heating using pits, which remain after olive oil processing in local mills, as a fuel (MORE 2008).

2.13.2.2 Olive Mill Lucchi & Guastalli

In Olive Mill Lucchi & Guastalli, the olive pomace, which remains after a 2-phase system of pressing olives, is dried with the help of an innovative system of adding calcium oxide. Such olive pomace can be used as compost or as fuel in a biomass processing plant. In that way, they can also solve the problem of vegetation water which remains after olive oil production (MORE 2008).

2.13.2.3 Association of Producers of Olive Oil of the Lazio Region

Their plant incorporates a system for drying olive pomace, a gasification system for olive pomace and a plant for producing electricity. Dried olive pomace (15% moisture) from the drying system is stored in a suitable storehouse for 2 months: the smaller part is used for heating in the system for drying (self-use), while the rest is used as fuel for gasification (MORE 2008).

2.13.2.4 Olive Mill Matraia

Olive mill Matraia produces pellets from olive pomace, which is certainly one of the most interesting solutions for use in pellet stoves (MORE 2008).

2.14 BEST PRACTICES OF BY-PRODUCT USAGE IN THE SLOVENIAN OLIVE OIL INDUSTRY

In the next phase of writing my master's thesis, I researched literature on the MORE project (2008), where two cases of good practices of by-product usage in the Slovenian olive oil industry were described.

The MORE project – Market of Olive Residues for Energy (2008) took under scrutiny and made a closer look at two olive mills in Slovenian Istria, where olive residues were used for energy-production purposes. Both cases involved a mill, where olive pomace was dried in open air and then used for heating.

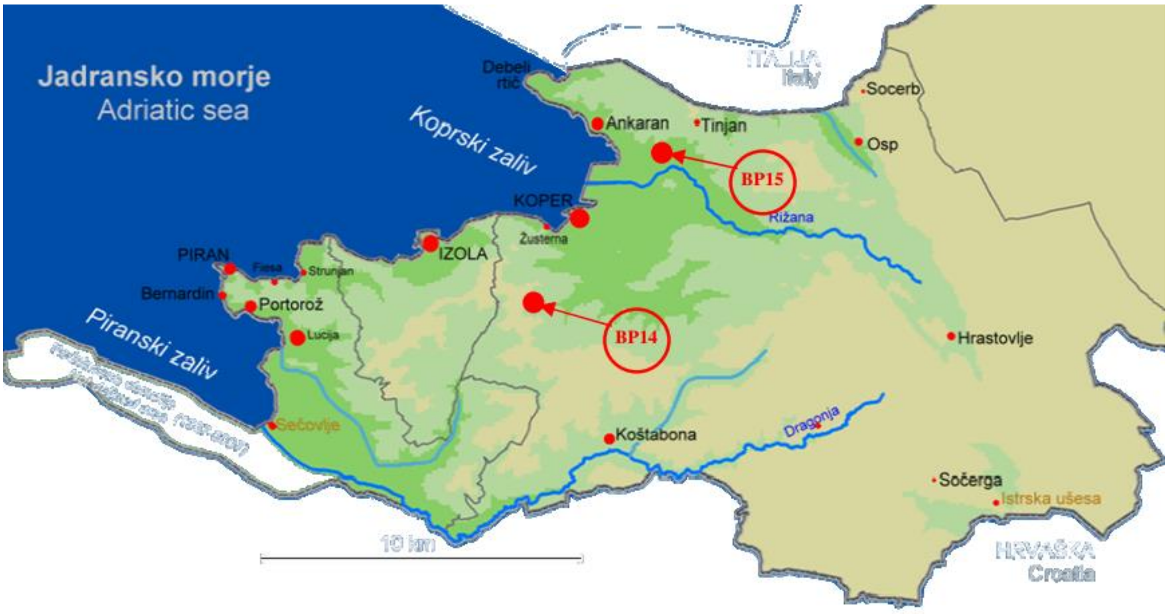

Figure 5: Location of Mills Utilizing Good Practices in Slovenia (MORE 2008)

Case 1: Krožera Mill, where olive pomace was used to produce heat for indoor heating and water heating (marked with BP14 on the figure)

Case 2: Agapito Mill, where olive pomace was used for heating the mill house and for water-heating (BP15)

2.14.1 Krožera Mill

The Krožera Mill uses olive residues mostly for heating living areas to reach the temperature of 23 °C and for procuring hot water (300-litre tank).

This Mill has adopted a 3-phase system of olive processing and annually produces 60 tonnes of by-product. Olive pomace is air dried and often stirred to speed up the drying process. When sufficiently dry, the pomace is collected and stored in wooden containers, and then it is finally used for direct combustion in the furnace or as a fertilizer for the olive grove. Annual consumption of olive pomace reaches values from 10 to 11 m^3, which is sufficient for the purpose of interior heating of a 140-m^2 apartment and heating 300 l of water. According to official records of the Mill, the investment costs of installation of the specialized furnace amounted to approximately €3000. Considering the fact that the costs of annual consumption of fuel oil for heating amount to about €1,200 per year, an investment in the purchase and installation of a biomass furnace will be reimbursed within 3 years (MORE 2008)

2.14.2 Agapito Mill

The Agapito Mill uses olive residue to produce heat for heating the mill house and water.

This mill has adopted the traditional method for the production of olive oil and produces 60 tonnes of by-product yearly. In the past, pomace found its use solely as a fertilizer of the olive grove. Now, the mill has implemented the method of air-drying the olive pomace in wooden containers under the roof and using the pomace exclusively for energy purposes – heating private and mill facilities. The annual consumption of olive pomace amounts to approximately 18 m^3 per heating season (October to end of April) which suffices for heating of the 250-m^2 mill, residential premises as well as for heating water for domestic consumption (MORE 2008).

3 METHODOLOGY

3.1 SAMPLE

For the purpose of this study, I decided to use two methods to gain insight into the situation. The first method incorporated a simple questionnaire survey sent to a list of 40 potential respondent olive oil mills in Slovenian Istria. The list of all olive oil mills, and their contact information were acquired from the Internet, where I found a list of all olive oil mills registered in Slovenian Istria. I sent an e-mail questionnaire to all the olive oil mills, which I found on the list.

The second method I choose was a telephone conversation with producers of olive oil. I tried this one, because I thought that I would get better response and more information about olive oil production in Slovenia, but I was wrong. Overall, in the end, I received 13 returned questionnaires from the 40 sent, which is a typical response rate.

In the end, I made an analysis from the 13 returned questionnaires. With all the data that I collected from the 13 returned questionnaires; I was able to make a simple analysis of the situation by using some tables.

Because most of the responders answered certain questions in the same way, and I got a larger number of the same answers, the analysis includes only one chart and some more tables.

4 RESULTS AND DISCUSSION

4.1. RESULTS OF THE QUESTIONNAIRE

The research methods included a written questionnaire, sent to producers of olive oil in Slovenian Istria. The questionnaire begins with basic questions about olive oil production in Slovenia. Next, there are questions regarding waste and by-products in olive oil production, what the main by-products from production of olive oil are, the quantity produced, and what effects the by-products can have on the environment.

For the research part, I sent questionnaires to 40 small olive mills in Slovenian Istria. My selection of questions, which I include in the questionnaire, is based on the main theme of my master's thesis and some other segments of production of olive oil. As it can be seen from the questionnaire, I focused mainly on the questions about by-products in the olive oil industry and what actions could be taken to use them in further processes.

I also made phone calls to some of them, but I got no answers. I received 13 returned questionnaires. In my opinion, the problem is that there is no central authority in Slovenian Istria to deal with by-products from olive oil industry. In addition, documentation about these by-products is inadequate, because in many cases, many olive oil producers do not report total amounts of by-products.

1. **Which year marks the start of your beginnings with the growing and production of olive oil?**

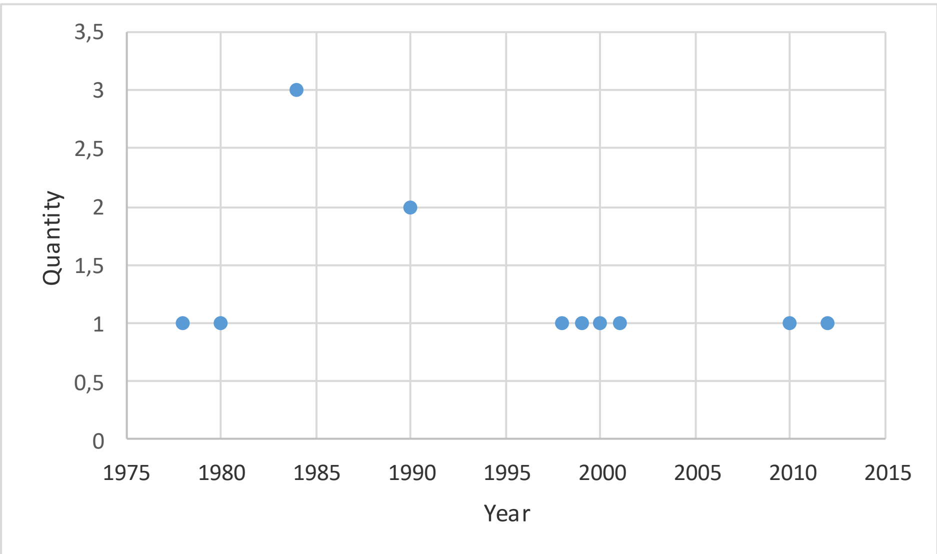

Figure 6: Starting Year for Olive Growing and Olive Oil Production

The chart above shows the years in which my responders started with growing olives and producing olive oil. As it can be seen, the first of the responders to start producing olive oil has done so in 1977. The majority of responders answered the question that their beginnings with production of olive oil were somewhere between 2000 and 2002.

2. What are the capacities of your olive oil groves (kg of olives per hectare annually)?

Table 9: Capacities of Olive Groves (kg of olives per hectare – annually)

Capacity of olive grove **(kg of olives per hectare – annually)**	**Number of answers**
80	1
300	2
350	1
400	1
600	2
1000	2
3000	2
10000	2

From the table above, we can see that the annual capacities of olive groves (kg of olives per hectare – annually) of the responders vary greatly – from 80 kg of olives per hectare to 10,000 kg of olives per hectare. Small capacities designated for olive groves are very frequent in Slovenia. Only two of the responders answered that their annual capacities of olive groves are 10,000 kg of olives per hectare, thus, it can be said that two of the responders have larger mills.

3. Which is your main method for olive processing?

All responders answered that their main method of olive oil processing is a 2-phase method. This method is also the most commonly used method for olive oil production in Slovenia.

4. Which type of olive oil do you produce (you can circle multiple answers)?

All responders answered that the type of olive oil they produce is extra virgin olive oil, which is the type of oil with the highest quality, and which is also reaching the highest prices.

5. What is the annual volume of production of certain types of olive oil in the last 10 years?

Table 10: Production of Extra Virgin Olive Oil in the Last 10 Years (litres)

Type of olive oil	Number of answers	Production in last 10 years (litres)	Number of answers
Extra virgin olive oil	13	400	1
		1000	4
		1500	1
		1750	1
		2250	1
		3000	2
		5000	2
		15000	1

As we can see from the table above, the smallest amount of olive oil produced in the last 10 years was 400 litres of olive oil in one olive mill. The most frequent response was 1000 litres of olive oil production in the last 10 years (in four mills) and the highest amount of olive oil produced in the last 10 years was 15,000 litres in one olive oil mill.

6. Which side products have you noticed to be forming during your production (for example: olive mill wastewater, pomace, olive pits, leaves, branches…)?

Table 11: Approximate Proportion (%) and Annual Volume (litres) of Pomace in Olive Oil Production

Side product of olive oil production	Approximate proportion (%)	Number of answers	Annual volume (litres)	Number of answers
Pomace	80	10	200	1
	85	2	2000	3
	90	1	2500	1
			3000	1
			4000	2
			6000	2
			15000	2
			20000	1

Table 12: Approximate Proportion (%) and Annual Volume (litres) of Olive Mill Wastewater in Olive Oil Production

Side product of olive oil production	Approximate proportion (%)	Number of answers	Annual volume (litres)	Number of answers
Olive mill wastewater	8	1	60	1
	12	1	480	1
	13	1	500	3
	15	1	550	1
	18	1	800	1
	20	8	1000	3
			1200	1
			1500	1
			5000	1

Table 13: Approximate Proportion (%) and Annual Volume (m³) of Branches in Olive Oil Production

Side product of olive oil production	Approximate proportion (%)	Number of answers	Annual volume (m³)	Number of answers
Branches	2	3	3	1
	12	1	6	3
	15	1	63	1

Table 14: Approximate Proportion (%) and Annual Volume (m³) of Leaves in Olive Oil Production

Side product of olive oil production	Approximate proportion (%)	Number of answers	Annual volume (m³)	Number of answers
Leaves	5	1	4	1

It is known that during olive oil production, a lot of by-products are formed. My responders answered that for them, the main by-products, which appear during the process of olive oil production, are pomace and olive mill wastewater, next there are branches, while just one of the responders answered that leaves are also one of the by-products in their mill.

7. **Do you discard the side products, which appear during olive oil production or do you use them in other manufacturing processes (if so, which product and in which processes)?**

All the responders answered that they use olive oil by-products for composting, which is also the most widely used way of using by-products, and is mentioned as such in literature. With composting, nutrients are returned to the soil.

7 a. If you may be using side products in other manufacturing processes, I would like to know why did you choose to do that? Are you generate revenue this way?

All responders answered that they use olive oil by-products as a fertilizer in process composting.

7 b. If you discard some of the side products, I am interested to know how you discard them? Where you do that and how much money it costs?

None of the responders wanted to answer this question.

8. Do you have any other ideas for value-added uses of this material?

Just one of the responders answered that they can make briquettes for heating from branches, which is a very useful way of using by-products from olive oil production, because by making briquettes one can provide heating for their mill and also living quarters.

9. Would you classify your mill as a small mill (capacity equal or under 250 kg of olives per hectare) or as a larger mill (up to approx. 2500 kg of olives per hectare)?

All the responders answered that they classify their mill as a small mill.

10. Where are your orchards and processing facilities located?

Just two of the responders answered to this question. One answered that the name of their olive mill is Mlin Biotehniške šole Šempeter pri Novi Gorici (School for Biotechnology Šempeter pri Novi Gorici Mill), while the other answered that the name of their olive mill is Domačija Munda (Munda Homestead). All the other responders did not want their identity to be revealed in my master's thesis, thus wanting to remain anonymous.

4.2. DISSCUSION

The research methods included a written questionnaire, sent to producers of olive oil in Slovenian Istria. The questionnaire begins with basic questions about olive oil production in Slovenia. Next, there are questions regarding waste and by-products in olive oil production, what the main by-products from production of olive oil are, the quantity produced, and what effects the by-products can have on the environment.

In my research, I sent questionnaires to 40 small olive mills in Slovenian Istria. As it can be seen from the questionnaire, I focused mainly on the questions about by-products in the olive oil industry, and what actions could be taken to use them in further processes. I received 13 returned questionnaires.

In the end, I am very satisfied with my analysis of olive oil situation in Slovenia. I think that, although I got 13 returned questionnaires from olive oil producers, these responders can provide a brief insight into the current situation of olive oil production in Slovenia. From this analysis, it can also be determined how some small olive mills in Slovenia treat waste that occurs during production of olive oil.

From the questionnaire results, I found out that only a few of the olive oil mills in Slovenia are using some of the good practices (like heating houses with the energy from olive oil production and producing energy from by-products of olive oil production). I think that the main reason for that is that olive fruit processing results in large amounts of residues, also considered waste, and, without the right treatment, uncontrolled disposal of olive fruit residues can cause serious environmental problems. One of the problems also stems from very complex regulatory and legislative frameworks regarding olive oil production by-products in some countries as well as a lack of such frameworks in others.

Examples of good practices are more common in other countries around the world, as can also be seen from literature. Some good examples come from Spain, Greece and Italy.

As it can be seen from the questionnaire, first of the olive oil producers in Slovenia started to produce olive oil in early 1977. The annual capacities of olive groves of the responders vary from 80 kg of olives per hectare to 10,000 kg of olives per hectare. Since 2010, crop area has surpassed 1800 hectares, and it was forecasted to reach 1900 hectares by year 2014.

Looking at the figures for the reference year used in the IOC questionnaire (2009), it emerges that of the 1653 hectares, dedicated to olive cultivation, 1620 hectares were dry farmed, and 15 hectares were irrigated (IOC questionnaire). From the results of the questionnaire, it could be said, that in Slovenia smaller olive groves are the dominant type of olive groves.

All the responders answered that their main method of olive oil processing is the two-phase method. This method has some very important advantages. It is a continuous and automated method. By using this method, producers get the highest percentage of oil; vegetable water is less of a problem, and olive oil from the two-phase centrifugation system contains more phenols and total aromatic compounds, and such kind of olive oil is more resistant of oxidation than olive from the three-phase method.

On the other hand, there is also the three-phase method, which also has some advantages compared to the traditional method of olive oil extraction with the press. It requires less human effort, and it has higher olive oil production rates.

All the responders also answered that the type of olive oil, which they produce, is extra virgin olive oil, which is also type of olive oil with the highest quality and the highest prices. From the other olives – of poorer quality, they can produce some other types of olive oil. For example, virgin olive oil, which also comes from the first pressing and must have the acidity level of less than 2%. It has milder taste as extra virgin olive oil. Olive oil that has been refined by using agents, such as acids, alkalis, or was heated, to extract as much oil as possible from the olive pulp that remains after the first pressing, is refined olive oil. From olive skins, seeds, pulp and some other by-products of extra virgin olive oil, producers may produce the lowest grade of olive oil. One type of olive oil, which is not fit for human consumptions until it has been refined, is lamp ante oil, which is olive oil with severe defects – usually made from bad fruit or by poor processing practices.

When asked about main by-products that appear during production of olive oil, many of the responders answered that this are olive mill wastewater and pomace, and then there are also branches and a small portion of leaves from olives.

Olive mill wastewater constitutes a major environmental problem for the Mediterranean countries, because it contains large amounts of sugars, tannins, biopolyphenol, polyalcohols, pectin and lipids, and represents a serious threat to environmental degradation. Each year, millions of tonnes of this toxic waste are produced, and most of it is not properly treated, thus causing serious damage to the environment. Some countries have already taken action in establishing a legal framework for controlling olive oil production process. But there are still many countries, where such actions have not yet taken place, and because of this, the environmentally harmful practices are still present. Because of this, all of olive mill wastewater goes directly to the sewers.

I think that a better idea for treating the olive mill wastewater would be that the entire quantity of wastewater, which arises during the process of olive oil production, e.g. in Slovenia, should be collected in a special device that would work in a similar way as a “cleaning device”.

This device could clean olive mill wastewater of all hazardous substances. Purified water could be used further for irrigating cultivated surfaces, as it would now be free of all hazardous environmental substances.

All responders said that they applied this by – products main for composting, which is also the most frequently used process for using by-products from olive oil production. Compost is an easy and environmentally responsible way of disposing by-products from olive oil industry. At the end of the process, the olive pomace results in a humus-like by-product, which is biologically stable, is free of pathogens and odour free, and is very useful in agriculture. Composting is also good, because it helps to reduce the volumes of material at landfills, and it is used to improve soil structure and provide nutrients to the soil. I think that in Slovenia, composting is one of the most frequently used processes for using by-products from olive oil production, because the process is cheap. As we can see from literature, worldwide, composting is not as common a process for using by-products as it is in our country, because others rather utilize other examples of good practices (such us using some by-products for heating houses and producing electricity).

On the other hand, compost can be a breeding ground for dangerous pathogens, and also in some huge composts, a great deal of heat is created by the microbial activity, which I think in some cases may be enough to cause a fire.

In the questionnaire, I also asked about any other ideas for value-added uses of by-products, and just one of the responders answered that from the branches, they can make briquettes for heating, but that they need to produce more oil, to also have more branches. I think that the main reason that in Slovenia there are just a few examples of good practices for using by-products from olive oil industry, is because in Slovenia, there are mostly small olive oil mills, and consequently smaller amounts of waste are generated form olive oil production.

Overall, in my opinion, the main problem is that there is no central authority in Slovenian Istria to deal with olive oil industry by-products. In addition, documentation about olive oil production by-products is very flawed, because many olive oil producers in many cases do not report total amounts of by-products. I think that a very good way to encourage olive oil producers to use by-products according to good practices is by implementing incentives by the government and maybe eco-fund subsidies for using by-products from olive oil production in a ‘green way’; for example, to use olive oil production by - products for heating houses and water, and for making electricity from olive biomass.

This is a very useful way of using by-products, as we can also see from good practices in other European countries.

5 POVZETEK V SLOVENSKEM JEZIKU

Oljčno olje je iztisnjen sok iz plodu oljke (Olea europaea; family Oleaceae), tradicionalnega drevesa Mediterana. Oljarstvo je v Sloveniji omejeno predvsem na Slovensko Istro, v manjši meri pa je razširjeno tudi na del Goriških Brd ter Goriškega.

Z intenzivnim širjenjem oljarske industrije je temu neizbežno sledilo tudi onesnaževanje okolja z številnimi izpusti. Izpusti iz oljarn kljub biorazgradljivemu značaju predstavljajo resno grožnjo lokalnemu okolju. Stranski produkti, kot so vegetacijska voda in tropine, ki nastajajo pri procesu proizvodnje olivnega olja vsebujejo velike količine toksičnih snovi, ki negativno vplivajo na okolje. Posledično se s tem uničuje tudi samočistilna sposobnost okolja, ki je sama po sebi nujno potrebna, če želimo obvladovati takšne ogromne količine neposrednih izpustov.

Zaradi velike obremenjenosti ter specifike onesnažil oljarske industrije je učinkovita obdelava stranskih produktov še vedno zelo pereča ter pomembna problematika. Večinoma so stranski produkti, ki se pojavljajo v procesu proizvodnje olivnega olja neevidentirani in ravnanje z njimi je zelo nenadzorovano. Prav zaradi tega razloga stranski produkti oljčne industrije v Sloveniji predstavljajo sekundarne produkte, ki se najpogosteje zavržejo. Zaradi zgoraj naštetih razlogov se je potrebno zavedati dane problematike, ter razumeti, da so lahko ti stranski produkti in posledično snovi, ki jih ti produkti vsebujejo zelo škodljivi za okolje ter celotno biodiverziteto. Vplivajo lahko na več nivojev biodiverzitete. Negativno lahko vplivajo na zemljo in posledično povzročajo degradacijo in erozijo le – te, vplivajo tudi na onesnaževanje podtalnice. Po drugi strani pa ti produkti predstavljajo kakovostne vire, katere lahko uporabimo v drugih procesih (proizvodnja energije, kompostiranje, namakanje kmetijstvih površin…).

V Sloveniji je znano, da se večina stranskih produktov, ki nastanejo pri proizvodnji oljčnega olja zavrže ali sežgre, nekaj malega se uporabi za kompostiranje, 4 – 5% pa se jih uporabi za proizvodnjo energije za ogrevanje stanovanjskih hiš in sanitarne vode, o čemer govorita tudi predstavljena primera dobre prakse v Sloveniji. Ker je količina stranskih produktov oljčne industrije v Sloveniji zelo majhna, njihovo izkoriščanje ni primerno za večje toplarne ali elektrarne. Uporaba le – teh je najbolj primerna za ogrevanje posameznih oljarn in zasebnih gospodinjstev, ki so v bližini manjših oljarn. Na dolgi rok bi lahko bila uporaba stranskih produktov v Sloveniji alternativni vir energije, predvsem za ogrevanje oziroma proizvodnjo toplote, kasneje pa mogoče tudi za proizvodnjo električne energije.

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APPENDICES

Appendix A: QUESTIONNAIRE

Hello,

my name is Eva Racki and I am a student of Conservation biology at the University of Primorska. I'm preparing a master's thesis titled »Waste in olive oil production in Slovenia. The purpose of the master's thesis is to determine whether olive oil production is widespread in Slovenia, which side product emerge in the process of oil production and in what quantity and what the manufacturers currently do with the side products. Finally, I would like to research how this side product affect the environment.

This questionnaire is short, and you will need approximately 3 minutes to finish it. The data collected will be used exclusively for the purposes of the preparation of the master's thesis.

I sincerely thank you for your participation.

QUESTIONNAIRE

1. Which year marks the start of your beginnings with the growing and production of olive oil?

____

2. What are the capacities of your olive oil groves (kg of olives per hectare annually)?

____

3. Which is your main method for olive processing?

a) 2-phase

b) 2,5-phase

b) 3-phase

d) press

4. Which type of olive oil do you produce (you can circle multiple answers)?

a) extra virgin olive oil

b) virgin olive oil

c) lampante olive oil (lighting oil)

d) refined olive oil

e) a blend of refined and virgin olive oil

f) olive skins oil

5. What is the annual volume of production of certain types of olive oil in the last 10 years?

Type of olive oil	**Production in last 10 years**
extra virgin olive oil	
virgin olive oil	
lampante olive oil (lighting oil)	
refined olive oil	
a blend of refined and virgin olive oil	
olive skins oil	

6. Which side products have you noticed to be forming during your production (for example: olive mill wastewater, pomace, olive pits, leaves, branches…)?

In the following question (6a) please fulfil the table with an estimated percent and annual volume of the side products (%, litres)?

____

____

____

6a.

Side products of production	**Approximate proportion (%)**	**Annual volume (litres)**

7. Do you discard the side products, which appear during olive oil production or do you use them in other manufacturing processes (if so, which product and in which processes)?

YES, used in other manufacturing processes:

____

DISCARD____

7a. If you use side products in other manufacturing processes, did you choose to do that? Are you generating revenue this way?

____

____

7b. If you discard some of the side's products, I am interesting how you discard them? Where you do that and how much money it costs?

____

____

____

____

8. Do you have any other ideas for value-added uses of this material?

____

____

9. Would you classify your mill as a small mill (capacity equal or under 250 kg of olives per hectare) or as a larger mill (up to approx. 2500 kg of olives per hectare)?

SMALL MILL

LARGER MILL

10. The name of your mill:

____

11. Where are your orchards and processing facilities located?

____

Demographics:

Age: 18-35 35-5 45-55 55-65 65 forwards

Sex: M F

Highest level of education completed: __________________________

Area where you live: _________________________