

Analysis of the Management Mechanisms for Vegetable Oil and Fat Flow in Portugal

Joana H. G. Veloso and Paulo C. Ferrão

Department of Mechanic Engineering, Instituto Superior Técnico, Av. Rovisco Pais, 1409-001 Lisboa, Portugal

Abstract

The consumption of vegetable oils and fats produces high amounts of waste that, when disposed in inadequate final destinations, produces negative impacts on the environment. In Portugal there isn't an adequate management system for flows of vegetable oil and fats (commonly referred to as used frying oils). However, the nature of this waste flow represents a source of raw material for the production of biodiesel, making the collection of the former an important step for the production of the later, with important economic and environmental effects – whether in terms of lowering the consumption of non renewable resources (e.g. fossil fuels), but also in creating a new source of revenue.

This paper reports on the analysis of European (EU) initiatives in this area, as well as the current national market potential in terms of oil consumption and consequent waste oil generation.

It is concluded that national and international initiatives occur most often in the context of projects for Sustainable Mobility or for the use of Renewable Energies, and not under the scope of waste management. This result may suggest that it is not the environmental problem associated with improper disposal that drives the management of this waste stream.

For the Portuguese case, it was estimated that total oil waste production in the industry, catering and domestic sectors is between 117.000 and 146.000 tons of used vegetable oils and fats per year. Of these, only a fraction is effectively collected and value-added. It was verified that, currently, the most attractive destination for this waste flow, from an environmental and economic point of view, is indeed biodiesel, as seen in several case studies analysed.

It is also suggested that the implementation of regional campaigns in Portugal to quantify the consumption habits for each region, as well as the attainment of more conclusive data on the life cycle of these oils, is of utmost importance. This way, it will be possible to design and implement an integrated model for this waste material flow, suggesting the given example that currently exists for the Portuguese end-of-life vehicles management system - Valorcar.

The present work and proposals prescribed are intended to give decision-making actors tools to define waste policies and adequate integrated management models for the vegetable oil and fat flow.

Keywords: Used Frying Oils; Waste; Biodiesel; Management system.

1. Introduction

Vegetable oils and fats (VOF) represent a product category largely consumed in all sectors of the present society: whether in catering, industrial or domestic applications. However, like most of consumer products, vegetable oils and fats also produce waste.

In 2003, the Portuguese nongovernmental organization for the environment QUERCUS, quoted an estimate that pointed to a production of about 125.000 tons per year of waste frying oils (WFO) in Portugal. Of this quantity only around 3.000 tons were collected [1].

These wastes are classified by the European Waste List with the code 20 01 25 (as transposed to the Portuguese Law by Decree Order n. °209/2004, March 3rd). Although this flow management does not obey to any specific legislation, it must comply with the present Portuguese Decree-Law n. °178/2006, September 5th, which establishes the general rules for waste management.

In this context, the Portuguese scenario for this waste flow is still relatively unknown, whether in terms of consumed and generated quantities, or producers and operators, licensed or not. Hence, the management of this particular waste is not actually controlled and audited. Being a material of transversal use, it should be object of global management, independently of the source.

The questions related to the production of WFO as assumed a growing importance in our society, mainly due to the negative environmental impacts associated to its deficient management. In Portugal, the major part of WFO produced has the sewer as its final destination: a bad practice that causes corrosion and blockage of wastewater drains and the increase of oils and fats concentration in the affluent to wastewater treatment plants, causing the degreasing treatment to be more expensive. The presence of these used frying oils and fats in wastewater also contributes to a significant increase in levels of BOD (Biochemistry Oxygen Demand), COD (Chemical Oxygen Demand) and TSS (Total Suspended Solids), hindering the proper performance/operation of the treatment systems. The increased concentration of these parameters requires a significant increase in energy consumption and frequency of maintenance operations for oils and fats separation equipments (those being very expensive) [2]The Decree-Law n. °152/2002, of May 23rd (that transposes Directive 1999/31/EC, of April 26th regarding waste landfill), establishes the need to define a national strategy for the reduction of biodegradable municipal waste sent to landfills, strategy already undergoing. The WFO, as biodegradable wastes, have to be in compliance with this strategy: its disposal should be reduced to minimum, while its recovery should be promoted to a maximum.

Some important initiatives to address this waste management challenge have emerged in recent years. The WFO are now seen, not as a problem, but as an opportunity, as it can be converted into various types of raw materials such as, pharmaceutical glycerine, soap and particularly, biodiesel.

The alternative of transforming WFO into biodiesel seems to be, so far, the most consensual, since it can help to meet the targets set out in Directive 2003/30/EC of the European Parliament and Council, May 8th 2003, on the promotion of biofuels or other renewable fuels on transportation.

The use of WFO has obvious advantages when nowadays the use of oilseed crops in biodiesel production is already generating controversy. These crops used to be developed and typically traded for human consumption, but energy markets' demand is diverting this tendency with considerable impact. Consequently, the price of basic goods such as bread suffer an inflating increase, which has led the international community to reveal that the world reserves of wheat are currently in the lowest levels of the recent years, reaching a historical minimum. This raw material is being used on a large scale in the EU (European Union) for the production of biodiesel and in United States of America to the production of ethanol [3].

This represents and an opportunity for WFO, since today is already evidenced by several studies [4], articles [5] [6] and projects, that we can successfully use this waste material as an alternative for fuel production. The biodiesel has several physical-chemical properties and advantages compared to diesel: for instance, the fact that it is non-flammable, non-explosive has a temperature of inflammation equal to 150 °C (very high), is biodegradable and non-toxic.

Therefore, it is important to disclose all these aspects related to the production and use of used vegetable oils and fats contributing to an integrated management, this being the objective of this paper.

2. State-of-Art on management mechanisms and initiatives for vegetable oils and fats flow

In order to know the legal mechanisms and initiatives that have been developed for this particular waste stream, it's important to review the legal framework, and which projects were developed so far, both at European and National level (their methodologies, sectors targeted and actors involved).

It was verified that at international or national level, most projects on collection and processing of WFO arise from partnerships or co-financings from European Commission programs. However, contrary to what was expected, these initiatives occur most often in the context of initiatives for Sustainable Mobility or for the use of Renewable Energies, and not under the scope of waste management. This result may suggest that it is not the environmental problem associated with improper disposal that drives the management of this waste stream.

However, it's important to refer that, from north to south of Portugal, there are many initiatives being implemented at the municipal or regional level, covering transversal sectors of the economy (Table 1).

Table 1 – Summary of initiatives and projects implemented in Portugal for managing waste frying oils.

Country / Name of the Project	Date	Covered Sectors / Operation Mode	Collected Quantities / Final Destination
Projects developed by the Municipal Solid Waste (MSW) Management Systems			
LIPOR (region of Porto), Project of WFO collection [7]	Since 2005	Domestic Sector: available containers for WFO deposition in eco deposition centres.	In 2005, sent around 4.630 liters of WFO to production of natural soap and biodiesel.
Resíduos do Nordeste (region of Trás-os-Montes), WFO Valorisation Protocol [8]	Since 2005	Domestic and Catering Sector: collection of WFO in 14 eco deposition centres	Agreement made with the company RECIOL for the recovery of these wastes. (No data was disseminated yet)
BRAVAL (North region) Project of WFO collection [9]	Beginning planned for the end of 2007	Domestic Sector: distribution of 5 thousand containers collected door-to-door that are replaced for new empty ones.	In a first phase it will be produced around 750.000 litre of biodiesel, to be consumed in the municipal fleet, and it will be constructed a biodiesel transformation unit.
VALNOR (region of Alentejo), Project of WFO collection [10]	Since 2005	Domestic Sector: containers putted in collection points in public places, ex: municipal markets, eco depositions centres, etc., monthly calendar collection. Catering Sector: distribution of containers for WFO collection.	In 2005, collected and recovered 21 tons of WFO. In 2006, collected and recovered 70 tons of WFO. In the end of 2007, it is expected to be on function a biodiesel production unit.
AMALGA (region of Alentejo), Project "Biodiesel" [11] Note: partnership with the other MSW management systems of the region of Alentejo (AMCAL e AMDE).	Beginning planned for the end of 2007	Domestic Sector: collection done in schools with specific containers that are placed for deposition.	Biodiesel production to be consumed in municipal fleet. It will be constructed a biodiesel transformation unit, with a diary capacity of producing 500 liters of biodiesel.
Projects developed by Municipal Energy Agencies, Environmental Associations and Portuguese Environmental Agency			
Municipal Energy Agency of Sintra, WFO Valorisation Plan [12]	Since 2003	Domestic and Catering Sectors: collection in restaurants and in schools (containers for canteen waste and for WFO that students bring from home). More recently containers near the other public selective eco points.	The estimated quantities of WFO produced in Sintra are of 600 tons per year. In 2005, it was created in Sintra the first biodiesel transaction post in Portugal (to serve the municipal fleet).
Municipal Environmental and Energy Agency of Oeiras, Project "Óleo Valor" e "OILPRODIESEL" (co-financed by the LIFE Program – Environment 2005 of the European Commission) [13]	Since 2005	Domestic Sector: production of new containers of 500 liters with level regulator by GPS. Catering Sector: free collection made in the acceding establishments.	Domestic Sector: pilot-neighbourhood with around 200 families, in the 1º e 2º month it were collected 140 liters of WFO. Catering Sector: acceding of 200 establishments and collection made by the company Óleotorres. It will be constructed a biodiesel transformation unit, with a diary capacity of producing 250 liters of biodiesel, to be used in the municipal fleet.
Environmental Association ALMARGEM (all South region), Project "Biodiesalgarve" [14]	Beginning planned for the end of 2007	Domestic, Catering and Industrial Sectors: containers placed near the other public selective eco points.	The estimated quantities of WFO produced in the Algarve region are of 2.400 tons per year. Biodiesel Production.
Portuguese Environmental Agency, Voluntary WFO Management System [15]	Since 2005	Catering and Industrial Sectors: Voluntary Agreement between associations of: new vegetable oils and fats producers, catering industry, marketing and distribution of vegetable oils, WFO collectors and biodiesel producers. Fixed goals for increasing of collection and recovery quantities. Developed a registration system for the several intervenient in WFO life cycle and registration of managed quantities. Attributed identification sign of accession to the system (environmental marketing).	At the end of 2007, 63 registry certificates were emitted. This voluntary approach was divulgated at several expositions related to the environment. In terms of effective results, this wasn't a successful agreement because the quantities managed in this life cycle product/waste are still not well known. So this approach will be changed, being study alternatives based on the concept of an integrated management system (not voluntary) for this specific flow. It is also being prepared specific legislation and ongoing an economical and technical viability study. It is expected in the end of 2007 that with the new Waste Electronic Registration Integrated System the quantities of WFO managed in Portugal will be more updated.

One can notice that, in similarity of what is occurring in other European countries, access to these embryonic management systems is always voluntary and does not work together nationally.

It was also verified that WFO collection is free of charge, and that in countries where there are no collection projects, but companies acting in the market (like Sweden and United Kingdom), the targeted sectors of collection are catering and industry.

Once again confirming the idea that this waste can be considered as raw material for fulfilling the targets of biofuel consumption, all projects or companies studied use the WFO for biodiesel production. All over Europe the Municipal Energy Agencies have therefore taken a leading role in implementing these projects, developing a very important job.

But there is still very little data available on these projects, especially in terms of amounts collected and processed. This would be of extreme importance for a better understanding of the path dependency of WFO materials. So, these initiatives should be disclosed on a more focused manner, through publicly available information on new oils consumed, quantities of used oils generation, collection and recovery.

3. Characterization of vegetable oils and fats flow – Review of National Situation

To better quantify managed vegetable oils and fats in Portugal, considering its entire life cycle, and its position relatively to European average, an assessment study was conducted through data compilation from various sources and evaluation on oil production, use and disposal. It was depicted the values of new VOF consumption, the consequent production of WFO and the operators currently licensed to the collection, transport, storage and recovery of these oils, as well as the typical recycling destinations. In this context, this analysis also intended to identify the relative contribution of the different activity sectors to the WFO flow.

This analysis considered different kinds of edible oils, not only soy, sunflower or peanuts oils, but also other VOF. This broader sample was chosen after contact with one of the largest WFO collection and recovery companies operating in Portugal. As it was previously mentioned, collection and treatment operators acting in the Portuguese market do not have control on the type of WFO that is dumped in the distributed containers. Clients can discharge frying oils, olive oils, but also waste of other vegetable fats. It was also pointed out that, so far, there was no decline in biodiesel quality attributed to using this mixed WFO, since after collection the mix undergoes a pre-treatment for impurities and particulate matter removal.

Data availability covers the time period from 2000 to 2005, making this the analysis time frame.

3.1. Consumption of new vegetable oils and fats

In order to quantify the amounts of new VOF consumed at European and National level, data compilation was conducted from the following information sources: European Union Oil and Protein Meal Industry, International Olive Council, National Institute of Statistics and Restaurants and Similar Portuguese Association (ARESP).

Olive oil and other vegetable oils and fats consumption in the European Union in the last six years are depicted in Table 2 and Figure 1.

Table 2 – Total vegetable oils and fats consumption evolution in European Union between 2000 and 2005.

Year	European Union Consumption		
	Vegetable oils and fats (t)	Olive oil (t)	Total (t)
2000	11.068.000	1.834.400	12.902.400
2001	11.761.000	1.893.700	13.654.700
2002	11.968.000	1.917.900	13.885.900
2003	12.528.000	1.979.000	14.507.000
2004	14.306.000	2.078.000	16.384.000
2005	16.572.000	1.884.300	18.456.300

Source: Vegetable oil and fat consumption [16] and olive oil consumption [17].

Note 1: Data from 2000 to 2003 include EU-14 e data from 2004 to 2005 include EU-24 (it doesn't count with Luxemburg data).

Note 2: Olive oil consumption data for 2005 are still provisional.

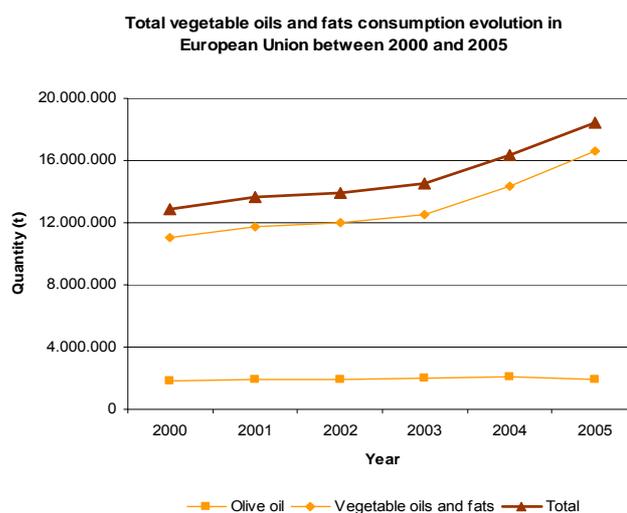


Figure 1 - Total vegetable oils and fats consumption evolution in European Union between 2000 and 2005

As it can be observed, there has been a growth in the total consumption of oils and fats by approximately 12% between 2000-2003 (UE-14) and 13% between 2004-2005 (UE-24). It's plausible to assume that this increase is attributed to the increase in oils and fats consumption other than olive oil, because the later presents a stable consumption during the same period. Average consumption for the last two years was 17.420.150 tons per year.

Through the available data of total consumption of VOF for the year 2005, broken down by EU country and based on its estimated population, it was possible to calculate the total oil and fats consumption *per capita* (t/hab), in order to understand the tendencies of consumption in EU countries, relatively to EU average.

It was observed that Portuguese consumption of VOF in 2005 (provisional) was 310.000 tons, thus below the EU average, of which 240.000 tons are of oils and fats and 70.000 tons of olive oils. The Portuguese *per capita* consumption approached 0,029 tons/hab, also below the European average of 0,040 t/hab.

According to what would be expected, Mediterranean countries, with a diet rich in vegetable fats, have higher per capita consumptions of olive oil (only considering the olive oil fraction of VOF): Portugal (0,007 t/hab), Spain, Italy, Greece and Cyprus, all well above EU average per capita consumption of olive oil (0,004t/hab).

It was also possible to compile more detailed information on the evolution of the total VOF consumption in Portugal, between 2000 and 2005. The data showed a growth tendency, when in comparison with EU values, in total consumption of VOF - about 13% since 2000. As we have seen, this development is similar to the evolution observed in the European Union and, once again, the consumption of olive oil almost stabilized. The average consumption for the period, 2000 to 2005, was around 285.230 tons per year.

In an effort to confirm and validate the values for Portugal, the same type of information was collected from the Portuguese statistical source, the National Statistics Institute (INE).

From the national tables of Raw Vegetable Oils and Fats Balance Supply, it was possible to collect the data total oils and fats usage for human consumption and industrial processing.

The definitions of industrial processing and human consumption provided by the Metadata didn't allow discerning which activity sectors were covered in those categories. It was also found that the total amount of internal usage didn't correspond to the sum of industrial processing and human consumption. In this sense, it was necessary to contact INE for clarification. It was possible to confirm that "industrial processing" refers to the consumption of edible oils done by three national companies for the production of margarine (since they have a specific balance). It was also explained that the human consumption refers not only to direct consumption by households and

restaurants, but also to the consumption of VOF made by a segment of the industry: in particular, oil consumed by agro-industries for the production of fried potatoes in package, frozen food pre-fried, among others.

The internal use in INE data includes not only industrial processing (production of margarine) and human consumption (industrial, catering and domestic), but also cooking oil used for other purposes, including animal feed, industrial use (for production of soap) and losses.

Table 3 shows the evolution in total vegetable oils and fats consumption in Portugal between 2000 and 2005, by sectors.

Table 3 – Total vegetable oils and fats consumption in Portugal between 2000 and 2005.

Years	Internal Use in Portugal			Total (t)
	Industrial processing (t)	Human consumption (t)	Other use (t)	
2000	49.000	217.000	13.000	279.000
2001	51.000	218.000	20.000	289.000
2002	44.000	212.000	27.000	283.000
2003	39.000	213.000	24.000	276.000
2004	35.000	219.000	22.000	276.000
2005	36.000	224.000	19.000	279.000

Source: 2005 to 2003 [18], 2002 [19] and 2000 to 2001 [20].

As evidenced, oils and fats consumption in recent years is practically stable, reaching a minimum of 276.000 tons in 2003 and 2004, and a maximum of 289.000 tons in 2001. The average consumption for 2000 to 2005 period was approximately 280.330 tons per year.

Results obtained from data analysis of the two international organizations earlier referred (European Union Oil and Protein

Meal Industry and International Olive Council), show that average consumption for the same period rounded the 285.230 tons per year.

According to provisional 2005 data from INE, the total consumption of VOF was approximately 279.000 tons, which is different from what was previously gathered from the international sources (310.000 tons).

However, these differences between national and international data are between 2% to 10%, being within the same order of magnitude. Thus, it seems reasonable to assume Portuguese national estimates for calculating the quantities of new vegetable oils and fats consumed by economic sectors.

The approach followed for the quantification of VOF consumption in Portugal was made for three main sectors: Industry, Catering and Households. The quantification of new vegetable oils and fats consumed in Portugal by the **industrial** sector considered the following points:

- Data from the Annual Survey of the Agro-Industrial Production assigned by INE on the consumption of edible oils in 2005 by the total of Agro-industries, 124 companies in the amount of 14.314 tons. Of this, around 5.395 are consumed by fried potatoes manufacture industry in a total of 8 companies;
- The industry of margarine consumed in 2005 about 36.000 tons of gross oils and fats in a total of 3 companies. This so high value is due to the fact that the main constituent of margarine is the liquid hydrogenated vegetable oil;
- The quantification of industrial uses for soap manufacture and animal feed wasn't considered, since INE states they are not intended for human food consumption. Also, the lack of available data doesn't make it possible to further estimate the quantities of used oil generated;
- Contacts were made with the largest industries of fried potato production operating in Portugal. Three of them responded and in the total it was pointed a consumption of 7.390 tons. This consumption of new VOF for just 3 companies is superior to that estimated by INE to 8 companies. Therefore, besides the personal contacts are not institutional sources, it is suggested that possibly the estimative presented here for the industry sector may be under-valued, and may actually be higher than the ones indicated by INE.

Despite the specified limitations, the data presented above point a value of 50.314 tons for new vegetable oils and fats consumption in the industrial sector in 2005 in Portugal.

Next it was estimated which part of the previously identified human consumption would be attributed to the catering sector. For that, were consulted data from the Catering Observatory - 2004 [21], inquiry made by ARESP and data from recent statistics published by INE on the preliminary results of the integration process of statistical information on enterprises for the year 2005 [22].

Therefore, to quantify the new vegetable oils and fats consumed by the **catering** sector the following data were considered:

- According to data from the observatory, in average each catering establishment consumed in 2004, 125 liters of cooking oils and 40 liters of olive oil per month. What represents a total of about 1.980 liters/year = 1,82 t/year per establishment (920 kg \approx 1.000 liters [23]);

- According to INE in 2005 there were about 85.561 establishments of CAE rev.2.1 Section (Code of Economic Activity, revision 2.1) H - Hotels and restaurants;

Please note that, these data relate to the different years. Thus, since the variation in the consumption of this raw materials between 2004 and 2005 specifically for the catering sector is unknown (it is only known that between 2004 and 2005 there was an overall increase in human consumption of about 2,3% and an increase in the number of establishments), this may slightly influence the estimate presented possible being the VOF consumption by the catering sector upper or under estimated.

Considering the data presented above it was estimated that the total consumption of new vegetable oils and fats in the catering sector in 2005 was approximately of 155.721 tons.

In this context, to calculate the quantities of new vegetable oils and fats consumed by new **households** was considered the following:

- The total human consumption in INE data, 224.000 tons, includes the consumption occurred in the industrial sector (only the industrial fraction industrial that regards to the agro-industries), the consumption in the catering sector and domestic consumption.

Thus, considering the previously presented estimative for the remaining sectors, the total consumption of new vegetable oils and fats (by difference) in domestic sector in 2005, were of about 53.965 tons.

In terms of representative percentages of the weight of each sector in the total consumption of new VOF in Portugal in 2005, it was found the following distribution: industrial sector 19%, catering sector 60% and domestic sector 21%. It follows then that the catering sector is the largest consumer of new vegetable oils and fats. In the next chapter it will be assessed the bigger contributor sector to the generation of waste associated with this consumption.

3.2. Production of used vegetable oils and fats

In the following section WFO estimates in Portugal will be developed, based on the calculations and values previously obtained, for the consumption of VOF. It is pretended to know the quantities generated in this waste stream that must be subsequently collected and recovered, through a proper management system.

It will be presented here the assumptions made for each sector. In the catering and domestic sectors it was felt the need to calculate new VOF consumption per capita. It was discounted for this sectors from the VOF presented earlier, the values relating to quantities of olive oil that are consumed but will not generate waste directly (for example olive oil used for seasoning salads, etc.).

The sub sector of soap manufacture, detergents and glycerin, was in 1998 constituted by 64 companies, concentrated in the Lisbon region and North region. In the Technical Guide on the sector of vegetable oils and similar derivatives of INETI [24], are detailed the waste produced by this and other sub sectors. It was found that this industry does not produce WFO (in 1998 this wastes were classified by the European Waste Catalog with the code 20 01 08).

As mentioned in the previous section, it was excluded from these calculations the fraction of the internal use of new VOF, which according to INE concerns oils used in animal feed, production of soap and losses.

The approach followed for the quantification of WFO production in Portugal was made for three main sectors: Industrial, Catering and Households and their quantification are explained below.

To calculate the quantities of WFO generated in 2005 by the **industrial** sector were taken into account the following aspects:

- The subsector of margarine and other alimentary fats and similar was already in 1998 made up by only 3 companies, concentrated in the region of Lisbon and North. After consulting the Technical Guide on the sector of vegetable oils and similar derivatives of INETI [24], it was found that this industry does not produce WFO.

As earlier referred, in margarine manufacture the main constituent of this product is the VOF, so it is considered that the quantities of WFO generated are approximately equal to zero (it is all incorporated). For the balance of WFO generated it was admitted that the only contribute only came from the Agro-industries. Remembering, these industries consume 14.314 tons per year of new VOF in a universe of 124 companies, which corresponds to consumption per capita of about 115,44 t/year;

- In contact with the company "Matutano" (fried potatoes company) this one pointed to 2005 a consumption of about 6.590 tons of new VOF and consequent generation of 230 tons of WFO, which represents approximately 3,5% of the initial consumption. The company "Dalimar" (fried potatoes company) presents a consumption of 200 tons of new oils, and indicated that each kilo of fried potato consumes about 0,32 liters of oil. With a production capacity of 250 kg of potatoes per hour and considering shifts of 10 hours, it was estimated that the resulting waste would be approximately 16,7 tons per year which corresponds to 8,4% of the initial consumption;

- In the study carried out by IPA in 2004 [25] and update in 2006 [23] is pointed an estimate prepared by the now extinct Center for Energy Conservation (estimate that could not be confirmed and that was referred to the year 2000) that suggests this sector only produces 540 tons per year of WFO. These studies refer that this value result of concrete information provided by the industrials and that it was confirmed in contacts established by the project team (although specific references to sources of information that have provided these data are not showed). It is also specified that this sector "... due to the constant improvement on the frying equipment, it is concluded that the oil consumption is optimized, resulting only a small portion of used oil" and "... of the new oils utilized, the majority is virtually consumed in its totality". In this context, it is pointed out that the waste generated is only about 10% of the initial oil consumption [25].

There are no consensus values of reference for what will be the percentage of new VOF that actually turn into waste at the end of the production processes. It was then necessary to present a likely range of variation (based on the previous points) to know what would be the possible universe of quantities to be considered in the collection of these wastes. The range considered was 5% to 10%, having been obtained quantities between 716 tons and 1.431 tons of WFO generated in 2005.

To quantify WFO generated in 2005 by the **catering** sector were taken into account the following statements:

- The frying oils and fats if too often reused represent risks to the health of consumers, so it has been necessary to monitor the quality of these products. The quality of these raw materials should be checked by a sensory analysis, identifying changes such as increasing in viscosity, darkening of the color, unpleasant smell, acidification of the flavor, etc. When noticed any indicated change the oils should be immediately replaced. The catering sector has thus increasingly being monitored, in this and other aspects.

It is therefore assumed that presently the percentage of new oil that generates waste in this sector should be fairly high, given the restrictions on reuse;

- According to the above data of the Catering Observatory - 2004 [21], in average the associated catering establishments consume 125 liters of cooking oil and 40 liters of olive oil per month. But it is also stated that of the 40 liters of olive oil consumed, about 17 liters are directly consumed by customers with the use of cruet. In

consequence these 17 liters monthly should not integrate the calculations of the quantities of WFO generated, since they are totally consumed for seasoning. Therefore, the consumption which could lead to the generation of waste oils and fats will be: 125 liters of new VOF + 23 liters of olive oil per month. What represents about 1.776 liters/year = 1,63 t/year per company (920 kg \approx 1.000 liters [23]), in a total of 85.561 companies;

- In IPA study [23], it is pointed by ARESP an estimate of 80% production of WFO of the total quantity of new VOF consumed, a value not confirmed by any national or international source.

Once again it was necessary to provide a likely range of variation (based on the previous points) to know what would be the possible universe of quantities to be considered in the collection of these wastes. The range considered was from 70% (assuming that not all establishments comply with the standards of food safety and reuse more times the VOF than would be desirable) to 80%, having been obtained quantities between 97.860 tons and 111.840 tons of WFO generated in 2005.

To calculate the quantities of WFO generated in 2005 in **domestic** sector it was first taken into account that, in similarity to what happened in the catering sector with olive oil consumption, also in this sector not all the olive oil consumed will generate waste.

As for the habits of Portuguese consumers it is known that the olive oil is usually used as seasoning, given its higher price (than other vegetable oils and fats) and in general it is not used for frying. Therefore, knowing that 68.000 tons, in a total of 224.000 tons of new VOF used in human consumption, are of olive oil, and given that this human consumption is divided into consumption by the industry, catering and domestic sectors, it were considered the following hypothesis:

- Of the 68.000 tons of olive oil consumed, 0% is consumed by the industrial sector (typically are used other vegetable oils for product preparation in the fried potatoes industry, etc.). The total consumption of olive oil by the catering sector amounts to 40 liters per month per company, then in a total of 85.561 companies in 2005 it were consumed approximately 37.784 t/year (920 kg \approx 1.000 liters [23]). It follows that the amount of oil consumed in the domestic sector rounded the 30.216 tons.

Knowing that in the catering sector of the total oils consumed only 57,5% actually counts for the calculations of the quantities of waste generated (when accounting seasoning), this percentage was also considered in the case of households. Therefore, in the total quantities of new VOF consumed in the domestic sector calculated in the previous section, 53.965 tons, it was withdrew 12.842 tons of olive oil, leaving about 41.123 tons of new VOF for calculation of WFO generated. Considering the total national population equal to 10.549.429 inhabitants (in 2005, INE), it was possible to determine new per capita consumption, approximately 0,004 t/hab in 2005;

- In IPA study [23], it is pointed an own estimate of 45% of production of waste against the total quantity of oils and fats consumed in the domestic sector, a figure not confirmed by other sources. However it is considered that this value seems to be grossly low since that would mean that about 55% of the oil would be consumed during the preparation of their dishes. Given the percentage by ARESP (which reflects a bit in this sector since the end clients of catering are in did the same as domestic consumers) and considering experiment carried out personally, it is considered that a value of 80% may not be entirely out of question.

Since once again there is no consensus values of reference for what will be the percentage of new VOF that actually turn into waste, it was necessary to present a likely range of variation (based on the previous hypothesis) to know what would be the possible universe of quantities to be considered in the collection of these wastes. The range considered was 45% to 80%, having been obtained quantities between 18.505 tons and 32.898 tons of WFO generated in 2005.

It follows that in Portugal in 2005, were generated approximately between 117.081 and 146.169 tons of waste frying oils. As evidenced the abovementioned estimate presented by QUERCUS in 2003 [1], 125.000 tons of used cooking oils generated per year, is within the final range obtained. As for the estimated quantities in the IPA study [23], 116.717 tons (counting also with the three sectors) gives a similar quantity as the present study minimum

generation.. This last value is slightly below the minimum value here estimated perhaps because of the fact that in IPA study were used quantities for years prior to 2005, and not considered the industry as being included in part of the human consumption of new oils in INE statistics.

It can be observed that the most problematic area in terms of quantities of this waste generated is the catering sector, followed by the domestic sector, being the industrial sector the least contributor due to normal mechanisms of economy of resources and use of the best available techniques.

Once again note that the estimates presented here are based on the year 2005, being currently expected that these values can be approximate because there has been a general stabilization in the consumption of new vegetable oils and fats. These quantities may be a little higher because the number of agro-industrial companies and restaurants has increased in recent years. However, quantification updates can only be done when more recent data will be assessed and disclosed by INE relating to companies incorporated in our country, as well as the currents supply balances of raw vegetable oils and fats. With specific regarding to domestic sector, it is possible that the actual generation of WFO can be higher since the Portuguese population has increased slightly in recent years.

3.3. Collection and Recovery of WFO

Despite the obstacles encountered due to lack of data and consistent studies, it was possible to clarify the more contributory stakeholders regarding the generation of waste.

However, this study could be complemented with regard to the quantities collected and treated, with the dissemination of the results of the new Waste Electronic Registration Integrated System (SIRER), Decree-Law n. °178/2006, September 5th. All operators acting in the market of waste are in Portugal obliged to report the quantitative managed and operations preformed by the end of September 2007. At the present exist about 24 operators in this waste context.

As the only estimate in a study of this kind, can be referred the one presented by IPA [23], which in Portugal only about 23.000 tons of these waste are collected. As can be seen this figure falls far short of the total generated annually.

It was also concluded that currently the two most common recovery operations, on this scope, are the use in biodiesel processing and soap, with the last one falling in disuse because of the increased environmental benefits of biodiesel use.

As environmental benefits from biodiesel use is showed Figure 2. It may be pointed the reduction of CO emissions at about 50% and emissions of benzopyrene in 71% because of its low content in Aromatic Hydrocarbons (HC). It should be noted that these values relate to the use of 100% biodiesel. It doesn't produce SO₂ emissions, since the biodiesel contains no sulfur in its composition. It still reduces particulate matter (PM) emissions by 50%.

The use of biodiesel produces, however, more NO_x than diesel, but these emissions can be reduced by using catalysts already made by the car industry.

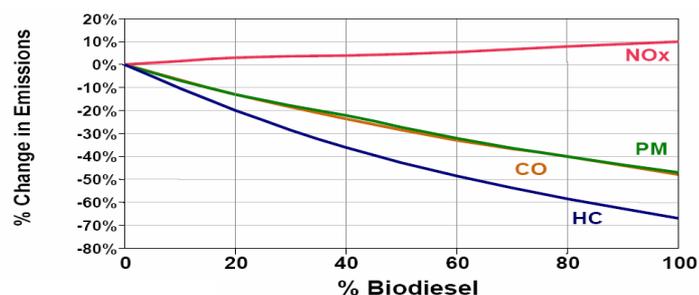


Figure 2 – Benefits of biodiesel in terms of emissions comparing to diesel. Source: [26]

4. Conclusions and Evaluation of the Used Vegetable Oils and Fats Specific Flow – Present and Future

As already seen, there is no specific national or European legislation for the management of this waste flow, it's only applicable the principle of producers responsibility.

The life cycle of a material typically comprises five phases: raw material (feature), production (product), marketing, consumption and waste management. As it as seen, in this context, arose throughout Europe and Portugal various initiatives undertaken primarily at the municipal level that intended to close this cycle in a sustainable way.

"The producer responsibility, priority aspect of any integrated policy for waste management, allows placing the burden of waste managing in the actor that could have more impact throughout the life cycle of the material, encouraging changes in the design of the product, maximizing the savings of raw materials, and minimize the production of waste "[27]. In case of the studied waste, the minimization of waste production is not considerable in a broad sense, since it is generated from an edible product which as restrictions and requirements of food safety and hygiene, and can't and should not be reused several times.

In Portugal specific waste streams usually walked through the creation of management entities of integrated systems, allowing getting together the different stakeholders in order to achieve a common objective. In Portugal, in recent years emerged management entities that regulate the flow of generic packaging (SPV), medical packaging (VALORMED), biopharmaceutical packaging (SIGERU), used tires (VALORPNEU), mineral oils (SOGILUB), wastes of electrical and electronic equipment (AMB3E and ERP), batteries and accumulators (ECOILHAS) and the end-of-life vehicles (VALORCAR).

Comparing the situation in which these entities fall, there was a certain similarity between the flow managed by VALORCAR and the reality associated with the life cycle of the WFO. As background of VALORCAR is to highlight the development of a voluntary agreement, similar to that is found today in the case of the WFO (already referred, developed by the Portuguese Environmental Agency), created in 2000 in parallel with the preparation of legislation on the scope of end-of-life vehicles (ELV) management, Directive 2000/53/EC, September 18th.

As explained in contact made with VALORCAR, the objective of this agreement was mainly to discuss and work among the various associations related to the automotive industry, preparing the necessary conditions for the transposition and implementation of the objectives that would be set at EU level, than just manage effectively and actively this flow. This initiative led also to the creation of the first licensed operators for the management of ELV.

The referred Directive was transposed into national law only in 2003, through the publication of Decree-Law n. °196/2003, August 23rd, after which began the preparation and implementation of this authority.

In the current scenario this integrated management authority doesn't have costs with the management of the waste, it has costs with information campaign's and I&D projects, management with the informatic system and staff. It presents a minimal eco value, with a variable component of 0,413€ per vehicles (charged to new vehicles producers). This is due to the positive market value of the materials resulting from dismantling an ELV that allow supporting this waste collection and treatment cycle. Here can be fund another similarity with what is happening in the WFO flow, where this waste currently have positive market value – the biodiesel production companies pay for the delivery of this used oils that for themselves become a raw-material.

It was suggested that the waste frying oils flow should follow "the footsteps" of VALORCAR being implemented a similar scheme to what this regulator has today, setting collection and recycling targets.

But once again this entity only evolved from mere voluntary agreement between the area associations to effectively flow managing entity after the publication of specific European and National legislation. So until there is such a legislative initiative to the WFO, positive voluntary agreements are welcome to be implemented. In Table 4, there is a brief comparison between the form of management linked to an integrated managing system and voluntary agreements.

Table 4 – Key Indicators of comparison Integrated Management System vs. Voluntary Agreement.

Key Indicators	Integrated Management System	Voluntary Agreement
Legal Framework	Strengthened with European legislation and consequent transpositions for the Portuguese legal law.	It has no specific legal support, applying only the principle of producer's responsibility.
Managing the Flow	Actually manage the flow through the establishment and fulfilment of collection and recovery of waste goals.	Do not serve the purpose of effectively managing the waste stream. In the forefront as only important role in dissemination and awareness of the problems associated to the bad disposal of the wastes.
Financing	Usually setting eco values on new products finances the management of the flow. These administering agencies are non-profit associations.	Without funding. The contracting precursor of the initiative is who usually sponsors the actions of disclosure and other costs associated with the management of routine activities. Each participation entity in the agreement also sponsors the awareness raising that develops among their members.

As can be concluded by the analysis of these key indicators, a management scheme based on voluntary agreements can only exist in a module prior to the implementation of an integrated management system. These agreements have their primary relevance to the level of developing the awareness of all actors involved in the area under study.

As it was verified the MSW management systems are already aware of this issue and the Municipal Halls should become one of the entities/organizations participating in the WFO Voluntary Agreement developed by the Portuguese Environmental Agency.

Note that according to 2005 data from the former Waste Institute, in Portugal were collected by the MSW management systems in eco points, door-to-door and eco centres, about 32.650 tons of packaging waste (plastic and metal). As could be saw in the chapter before, the potential production of WFO generated in the domestic sector (sector whose waste is collected by the MSW management systems mentioned above) may in 2005 have even reached the 32.900 tons, very close to the value of the packaging material collected.

It is appropriate to say that it would be of great importance to start the collection of this type of household waste, to be made in a generalised way placing oil containers near the existing selective collection eco points accessible to the general population, which has been increasingly joining the slogan of the selective collection.

Despite the estimates presented it still not known with sufficient accuracy the entire panoramic of this flow, in order to define or propose a specific management model for the used vegetable oils and fats.

It is urgent to organize national campaigns allowing the filling in of missing data (more recent years) and allowing knowing the typical consumption dietary habits for each country region. As an example it is the case of the region "Alentejo" that although present a reduced population, it is possibly one of the regions most appreciating of olive oil and therefore having a high potential of VOF consumption. By applying the calculations based on a national per capita consumption undifferentiated, these factors will be neglected.

These campaigns, if carried out by entities with jurisdiction in the matter, will permit assess actually consumed quantities of new vegetable oils and fats, subsequently quantities of waste generated, collected and valued. Thus, combined with specific legislation, targets of collection and recovery defined, etc., it would be possible to model what would be the future integrated management system for waste frying oils.

References

- [1] QUERCUS (Associação Nacional para a Conservação da Natureza) – Centro de Informação sobre Resíduos, <http://www.netresiduos.com/cir/rsurb/oleosalimentares.htm>;
- [2] Manual Prático para a Gestão de Resíduos, 2005, *Verlag Dashöfer*;

- [3] Westcott P. C., 2007. U.S. Ethanol Expansion Driving Changes throughout the Agricultural Sector, United States Department of Agriculture, <http://www.ers.usda.gov/AmberWaves/September07/Features/Ethanol.htm>;
- [4] Avellan A.V., Alfes C., 2005. Valorisation non alimentaire des huiles de friture usagées en tant que lubrifiants biodégradables. *Oléagineux, Corps Gras, Lipides* 12 (4), 290 – 294, http://www.jle.com/fr/revues/agro_biotech/ocl/e-docs/00/04/15/8B/article.md?type=text.html;
- [5] Felizardo P., Correia J. N., Raposo I., Mendes J. F., Berkemeier R., Bordalo J. M., 2006. Production of biodiesel from waste frying oils. *Waste Management* 26, 487- 494;
- [6] Buczek B., Czepirski L., Março 2004. Applicability of used rapeseed oil for production of biodiesel. *Industrial oil products* 15 (3), http://www.inl.gov/chemistry/d/inform_magazine.pdf;
- [7] LIPOR – Recolha de óleos alimentares usados, Comunicado de Imprensa de 12/04/2006, <http://www.lipor.pt/default.asp?CpContentId=1010&cor=0&back=-;>
- [8] Resíduos do Nordeste, *Newsletter* de Outubro de 2005, <http://residuosdonordeste.pt/newsletterOut05.pdf>;
- [9] Jornal de Notícias on-line, 05/09/2007, http://jn.sapo.pt/2007/09/05/norte/braval_inicia_recolha_oleos_domestic.html;
- [10] VALNOR – “O circuito da reciclagem”, <http://www.valnor.pt/conteudo.php?id=2322>;
- [11] AMALGA (Associação de Municípios Alentejanos para a Gestão do Ambiente) – Nota de Imprensa de 25/01/2005, http://www.amalga.pt/notasimprensa/nota_imprensa_Biodiesel.pdf;
- [12] AMES (Agência Municipal de Energia de Sintra), http://ames.linkare.pt/site/pagina.asp?nome=valorizacao_oau§ion=20;
- [13] OEINERGE (Agência Municipal de Energia e Ambiente de Oeiras), http://www.oeinerge.pt/saiba_mais.asp;
- [14] Jornal Público on-line, notícia de última hora – 27/08/2007, <http://ultimahora.publico.clx.pt/noticia.aspx?id=1303354&idCanal=10>;
- [15] Agência Portuguesa do Ambiente, Resíduos – Outros Fluxos – Óleos Alimentares Usados, http://www.inresiduos.pt/portal/page?_pageid=33.64036&_dad=portal&_schema=PORTAL&docs_residuos=56001911644&cboui=56001911644;
- [16] FEDIOL - European Union Oil and Protein meal Industry – Statistics (FEDIOL – Indústria de Óleos e Proteínas alimentares da União Europeia – Estatísticas), <http://www.fediol.be/6/index.php>;
- [17] International Olive Council - World Olive Oil Figures (Conselho Internacional do Azeite – Figuras sobre o consumo de azeite a nível mundial), <http://www.internationaloliveoil.org/web/aa-ingles/corp/AreasActivitie/economics/AreasActivitie.html>;
- [18] INE – Instituto Nacional de Estatística, “Estatísticas Agrícolas – 2006”, Edição 2007, http://www.ine.pt/portal/page/portal/PORTAL_INE/Publicacoes?PUBLICACOESpub_boui=6209833&PUBLICACOESmodo=2;
- [19] INE – Instituto Nacional de Estatística, “Estatísticas Agrícolas – 2005”, Edição 2006, http://www.ine.pt/portal/page/portal/PORTAL_INE/Publicacoes?PUBLICACOESpub_boui=129237&PUBLICACOESmodo=2;
- [20] INE – Instituto Nacional de Estatística, “Estatísticas Agrícolas – 2004”, Edição 2005, http://www.ine.pt/portal/page/portal/PORTAL_INE/Publicacoes?PUBLICACOESpub_boui=129211&PUBLICACOESmodo=2;
- [21] ARESP – Associação da Restauração e Similares de Portugal. “Observatório da Restauração – 2004”, Edição de Novembro de 2004, http://www.aresp.pt/default.jsp?file=ver_artigo&nivel=1&id=41&idRec=107;
- [22] INE – Instituto Nacional de Estatística, “Empresas em Portugal 2005”, Edição 2007, http://www.ine.pt/portal/page/portal/PORTAL_INE/Publicacoes?PUBLICACOESpub_boui=7075976&PUBLICACOESmodo=2;
- [23] IPA – Inovação e Projectos em Ambiente. “Actualização da Situação de Base para o Sector de Gestão e Valorização dos Óleos Alimentares Usados”. Maio de 2006;
- [24] INETI – Instituto Nacional de Engenharia e Tecnologia Industrial, Setembro 2001, Lisboa. Guia Técnico relativo ao Sector dos óleos vegetais derivados e equiparados;
- [25] IPA – Inovação e Projectos em Ambiente. “Linhas de Definição Estratégica do Sistema de Gestão dos Óleos Alimentares Usados”. Fevereiro de 2004;
- [26] Environmental Protection Agency, <http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf>;
- [27] Agência Portuguesa do Ambiente, Resíduos - Entidades Gestoras, http://www.inresiduos.pt/portal/page?_pageid=33.64040&_dad=portal&_schema=PORTAL&docs_licenciamento=56001911719&cboui=56001911719.