ASSESSMENT OF BIOMASS RESOURCES FOR AN INTEGRATED BIOMASS LOGISTICS CENTER (IBLC) OPERATING IN THE OLIVE OIL SECTOR

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ABSTRACT: An IBLC (Integrated Biomass Logistic Centre) is defined as a business strategy for agro-industries to take advantage of unexploited synergies in terms of facilities, equipment and staff capacities, to diversify regular activity both on the input (biomass feedstock) and output side (biocommodities & intermediate biobased feedstocks) thereby enhancing the strength of agro-industries and increasing the added value delivered by those companies. For the olive oil sector, pomace mills are the main agro-industries that can be targeted for the implementation of an IBLC concept, since they are of sufficient large size and sophistication, they have equipment (e.g. dryers) capable of handling biomass streams, they have large idle time of inactivity and, finally, they are located in areas with large untapped biomass potential from the agricultural sector, e.g. olive tree prunings.

The aim of the present paper is to assess the biomass resources that can be mobilized by an IBLC operating in the olive oil sector in Central Greece. Two main input streams are considered: wet olive pomace, which is the standard incoming stream in a pomace mill, and olive tree prunings, which are the untapped local biomass potential. The outcome of the present paper is an increased understanding of the biomass resources that an olive oil sector IBLC can mobilize. This knowledge can be used to produce updated mass balances of an operating IBLC and to estimate the new revenue streams and economic opportunities that can be emerged by an olive oil IBLC. Moreover, the methodology developed in the paper to assess the biomass resources can be employed by other agro-industries, operating in the olive oil sector, in order to assess their possibilities for implementing the IBLC strategy.

Keywords: pomace mills, olive oil, olive tree prunings, pomace, agricultural residues, IBLC.

1 Introduction

The IBLC concept can be further specified into four separate elements:

- Integrated: refers to the integration of value adding activities towards food, feed and biobased markets.
- Biomass: refers to biomass that is available in the surrounding region of the agro-industry, that is underutilized or unexploited and that has the potential as resource with an added value.
- Logistics: refers to the role of an agro-industry using its available logistics, storage operations and pre-treatment facilities to i) collect and transport biomass residues, ii) to pre-treat and transform these residues into food, feed and biocommodities & intermediate biobased products, iii) to store them and finally iv) to distribute the biocommodities and intermediate products to industrial processing sites elsewhere.
- Centre: refers to exploiting the central position of the agro-industry in a specific region.

Becoming an IBLC increases the competitiveness of an agro-industry by opening new markets, prolonging their operational periods and retaining employees in their idle periods. Moreover, it has been estimated that applying IBLCs business in existing agro-industries gives a clear competitive strength to a wide segment of agro-industries, which can exploit this privileged situation compared to a new biomass supply business built from the beginning [1].

The IBLC concept can be implemented in several agricultural sectors such as feed and fodder, cereal industries, wineries, breweries, olive oil, sugar, vegetable oil extraction etc. Aim of the current paper is the implementation of the IBLC concept in the olive oil sector.

2. IBLC concept in olive oil sector, Central Greece

The olive oil sector is one of the most important agricultural sectors in Greece as it contributes more than 0.4% to the national GDP [2] with a total annual sales of 832.7 M€ (2014) [3]. Greece is the third olive oil country in terms of olive oil productivity worldwide. Several areas in Greece dedicate their crops to olive tree cultivations. One of the most important areas in Greece in olive production is Fthiotida region (NUTS 3), located in Central Greece. Fthiotida region possess 39,000 ha of olive groves with over 33 olive mills [4]. The aim of the current paper is to address the biomass resources, regarding the olive oil sector, that can be exploited by an olive oil agro-industry located in Agios Konstantinos (NUTS 4). Agios Konstantinos' agriculture depends mainly on olive tree production. Agios Konstantinos has around 750 ha of olive groves producing two main edible olive varieties (Kalamon and Amfissis). Thus, the IBLC concept on an olive oil agroindustry located in Agios Konstantinos is considered for investigation as a case study, in terms of amount of agroresidues available to be exploited. Two agroresidues derived from the olive sector are considered, olive prunings and wet pomace.

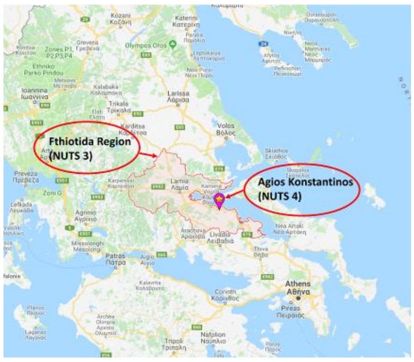

Figure 1: Greek study on implementation of IBLC concept in olive oil sector, located in Agios Konstantinos, Fthiotida region.

3 Olive prunings potential in IBLC area

Pruning is performed in most cases annually or biennially. Prunings are an untapped biomass resource that are mostly dealt with two methods: i) burned in open fires or ii) mulched and left on soil. However, the high amount of prunings can be exploited in different ways instead of burning. Prunings can be used as solid biofuels in chip or pellet form for heating applications or as feedstock in power plants. In addition, they can also be feedstock for particle board manufacture by replacing wood.

3.1 On-field Measurements of pruning productivity in local olive groves

Pruning productivity depends on various factors such as weather climate, structure of olive grove, variety of crop, age of trees, irrigation system etc. There are several values (Residue per Product/ RPR or Residue per surface/ RSR ratios) in literature to estimate olive pruning productivity. However, the actual pruning productivity varies depending the area and the local conditions of the olive groves. Thus, for the current paper, on-field measurements were performed in olive groves of Agios Konstantinos in order to accurately estimate the local olive pruning productivity.

The methodologies used to perform on-field measurements were developed in uP_running project [5]. Firstly, the trees to be measured in the olive grove have to be chosen. Several trees must be selected (>10) where the selection of trees must be a random process.

The choice of trees should be as representative as it can be. It should be avoided to choose trees that are too young or very old compared to the rest trees of the olive grove. After selecting the trees, the latter are marked with a tape or twine. Prior to weighting the prunings of the chosen trees, branches that belong to the marked tree should be identified. Continuously, the biomass (prunings) around the tree is collected and weighted (**Figure 2**).

Figure 2: On-field measurements of olive pruning productivity in Agios Konstantinos.

It should be avoided to perform the measurements if the day before was raining, as the weighing should have a significant variance. After the measurement is performed, the user should note down each measurements performed per tree. After finishing with the measurements of the first tree, the user continues with the next tree and so on. At the end, an average pruning productivity is calculated in t/ha.

3.2 Assessment of olive prunings in IBLC area

In order to assess accurately the pruning potential of Agios Konstantinos, on-field measurements were performed in the area. Two on-field measurements were held for each olive variety (Amfissis and Kalamon). The results of the pruning productivity are presented in **Table 1** along with the range of other on-field measurements performed in various olive areas of Greece (Peloponnese, Attica region, and Central Greece).

Table 1: Olive pruning productivity from on-field measurements in Agios Konstantinos compared to on-field measurements performed in different locations in Greece.

Olive Grove Characteristic	Location		
	Agios Konstantinos	Agios Konstantinos	Other Places in Greece
Variety/ Age	Amfissis/ 75	Kalamon / 60	Kalamon, Koroneiki Megaritiki/ 10- 70
Irrigation	✓	✓	✓
Planting Density (trees/ha)	85	85	53-410
Pruning Frequency	Annual	Annual	Annual/ Biennial
Production of dry biomass			
RSR (t/ha)	5.53	4.97	2.44- 5.28
Per tree (kg/tree/year)	65.0	58.5	8.0- 53.4
RPR ($t/t_{product}$)	0.55	0.5	0.26- 2.2

From the above table, it can be concluded that olive trees in Agios Konstantinos have a high biomass productivity compared to other olive areas, thus resulting to an excellent candidate for IBLC implementation.

Taking into consideration that Agios Konstantinos has over 750 ha of olive trees and by assuming a pruning productivity in the range of 5- 5.5 dry t/ha, the pruning potential in the area is more than 3.75 dry kt of prunings.

3.3 Fuel Characteristics of olive prunings

Olive prunings can be mainly used as solid biofuels for heating applications at industrial scale or for power generation in energy plants. In this sense, samples were collected from Agios Konstantinos in order to perform Fuel Analysis. The Fuel characterization was performed in CERTH/CPERI's laboratories in Ptolemaida by applying established standards (EN 14774 for moisture, EN 14775 for ash, EN 14918 for heating value, EN 15104 for ultimate analysis). **Table 2** presents the fuel characterization of the two varieties of olive prunings in Agios Konstantinos compared to a range of fuel characteristics of olive prunings from other olive areas in Greece (Peloponnese, Attica region, and Central Greece).

Table 2: Fuel characterization of olive tree prunings (OTP) from different varieties (Amfissis and Kalamon) in Agios Konstantinos.

Property	Amfissis	Kala-mon	Other OTP samples from Greece (min-max)
Moisture Content (w-% db)	12.3	13.1	9.1- 39.4
Proximate analysis (w-% db)			
Ash	4.6	5.1	3.6-5.3
Volatile Matter	80.2	80.1	76.9-79.7
Ultimate analysis (w-% db)			
Carbon, C	51.0	50.8	49.0-53.1
Hydrogen, H	7.4	7.6	6.5-7.7
Nitrogen, N	1.08	1.22	0.19-1.15
Sulphur, S	0.06	0.08	0.06-0.19
Chlorine, Cl	0.05	0.04	0.05-0.07
Heating Value			
HHV (MJ/kg db)	20.08	19.84	19.4-19.9
Major elements (w-%, in ash)			
Aluminium, Al	2.65	2.13	1.84-2.9
Calcium, Ca	11.29	8.60	6.8-13.4
Iron, Fe	0.10	0.10	0.05-0.51
Potassium, K	10.85	13.53	6.8-17.2
Magnesium, Mg	2.36	2.65	1.23-4.9
Sodium, Na	0.98	0.84	0.38-5.0
Silica, Si	11.95	12.95	9.2-14.1
Titanium, Ti	0.06	0.06	0.05-0.06
Minor elements (mg/kg db)			
Chromium, Cr	0.9	1.1	0.73-1.96
Copper, Cu	42.8	31.7	4.8-76.3
Manganese, Mn	21.9	23.5	11.1-56.7
Nickel, Ni	2.0	2.6	0.0-2.8
Zinc, Zn	6.0	11.7	7.6-15.3

The samples of olive prunings were retrieved on field without separating the leaves and free from soil contamination. Without the leaves, the ash content would be lower. During mechanized harvesting it is expected that part of the leaves will drop off if the material is left on the field for a sufficient time; this is expected to have a positive impact on the fuel properties, by lowering ash, nitrogen and chlorine contents. On the other hand, soil contamination is unavoidable in mechanized harvesting. Overall, a final ash content of 4.5 – 5 w-% d.b. is expected if mechanized harvesting is applied. Furthermore, the moisture content depends on how many days the prunnings were left on soil. In general, olive prunings have a good energy content but differ to forest biomass in terms of higher ash content. Thus, this type of biomass requires boilers with higher requirements in the systems dedicated to withdraw ashes or to clean the flue gases.

4 Wet Olive Pomace Potential in IBLC area

Another agroresidue that can be exploited by an IBLC is that of wet olive pomace. Wet olive pomace is the residue produced by olive mills including the skin, pits and flesh of the olive fruit. It is used to produce pomace oil and generates different solid by-products (olive stones, exhausted olive cake) which can be used as fuels in industrial processes and small-scale heating applications. Olive stones are much better fuel than exhausted olive cake due to lower moisture and ash content. However, in practice, the separation of olive stones by the Greek mills is rare. In most cases, all solid by-products end up in a single fraction.

4.1 Mass Balance of olive and pomace mill

In order to assess the biomass resource of wet olive pomace, several questionnaires were distributed to olive mills to record their mass balances. Taking in consideration the feedback from the questionnaires and by assuming a two-phase olive oil production technology, the following mass balance in olive and pomace mills can be considered as shown in **Table 3**.

Table 3: Mass balance of olive and pomace mill regarding the production of by-products.

	Two-Phase Production Process (% wb)	
Olive Mill	Olive Fruits Input	100.0
Olive Mill	Olive Oil Production [a]	20.0
	Olive Mill Residues	
Olive Mill	Olive Mill Waste Water [b]	-
Olive Mill	Wet Olive Pomace, sent to pomace mills [c]	80.0 [d]
	Pomace Mill Products	
Pomace Mill	Pomace Oil	1.1
Pomace Mill	Exhausted Olive Cake	29.1 [e]
Pomace Mill	Olive Stones	14.5
Pomace Mill	Exhausted Olive Cake (destoned)	14.5

[a] 20% of olive fruit is converted into olive oil; [b] No wastewater produced in two-phase olive mills; [c] 80% of olive fruit is converted into wet pomace in two-phase mills; [d] 68% wt moisture and 5% wt d.b. oil content; [e] 15% wt moisture and 1% wt d.b. oil content. Source of all values: Communication with Greek Olive and Pomace Mills

4.2 Assessment of Wet Olive Pomace in IBLC area

Fthiotida region possess 33 olive mills [6] scattered around the region (**Figure 3**). From these olive mills, wet pomace is produced that is considered as a potential feedstock for an IBLC in the olive sector.

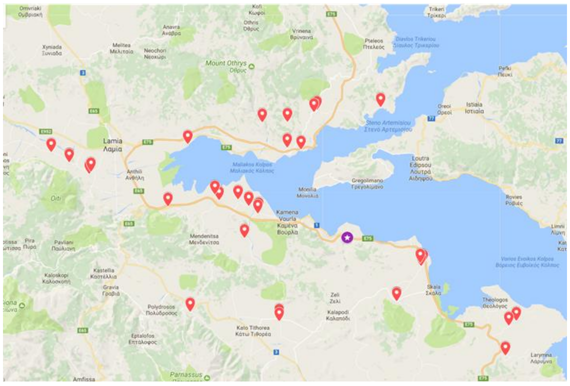

Figure 3: Olive mills in Fthiotida region.

Fthiotida region produces 75 kt olive fruits [7] for olive production. Based on the abovementioned mass balance of olive and pomace mills, an estimation of wet olive pomace in Fthiotida region can be done as presented in **Table 4**.

Table 4: Estimated Olive and Pomace mill products in Fthiotida region.

	Two-Phase Production Process	
Olive Mill	Olive Fruits Input (kt)	75
Olive Mill	Olive Oil Production (kt) [a]	15
	Olive Mill Residues	
Olive Mill	Olive Mill Waste Water (ML)[b]	-
Olive Mill	Wet Olive Pomace (kt), sent to pomace mills [c]	60.0 [d]
	Pomace Mill Products	
Pomace Mill	Pomace Oil (kt)	0.8
Pomace Mill	Exhausted Olive Cake (kt)	21.8 [e] (wb), 18.6 (db)
Pomace Mill	Olive Stones (kt)	10.9 (wb), 9.3 (db)
Pomace Mill	Exhausted Olive Cake (destoned) (kt)	10.9 (wb), 9.3 (db)

[a] 20% of olive fruit is converted into olive oil; [b] No wastewater produced in two-phase olive mills; [c] 80% of olive fruit is converted into wet pomace in two-phase mills; [d] 68% wt moisture and 5% wt d.b. oil content; [e] 15% wt moisture and 1% wt d.b. oil content. Source of all values: Communication with Greek Olive and Pomace Mills

Based on the validated mass balances, the wet pomace potential in Fthiotida region is around 60 kt (19.2 dry kt). After extracting the pomace oil from wet pomace, the exploitable solid byproducts amount to 9.3 dry kt olive stones and 9.3 dry kt exhausted olive cake, if olive stones are separated. It should be noted that part of the produced exhausted olive cake is consumed by the pomace mills for covering their own heat demands.

5 Conclusions

Aim of the current paper is the assessment of biomass resources that an IBLC in olive sector located in Agios Konstantinos, Central Greece, can mobilize. Two biomass feedstock were taken into consideration: i) olive prunings and ii) wet olive pomace (**Figure 4**).

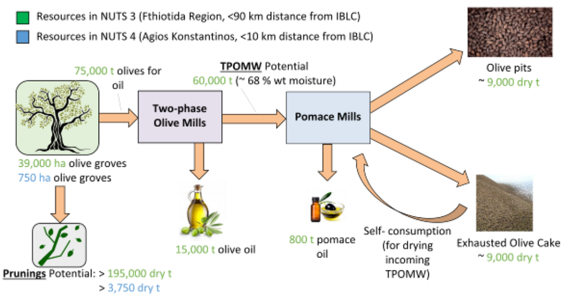

Figure 4: Assessment of biomass resources for exploitation by an IBLC in the olive oil sector

Olive prunings potential in Agios Konstantinos is estimated more than 3.7 dry kt biomass annually from local trees that currently remain unexploited. The distance for retrieving this biomass is considered less than 10km from the IBLC as the local olive groves are close to the IBLC. In comparison with other olive areas in Greece, Agios Konstantinos has olive groves with high biomass productivity based on the on-field measurements performed. The main exploitation method for olive prunings is as solid biofuels. Thus, olive pruning samples undergo fuel analysis in order to further investigate the energy exploitation of such biomass resource. From the fuel results, olive prunings have high energy content but with high ash content. For that reason, the olive prunings could find application as solid fuels at industrial level and not domestic.

Wet olive pomace potential in Fthiotida Region is estimated more than 18.6 dry kt annually that result to more than 9.3 dry kt of olive stones and 9.3 dry kt of destoned exhausted olive cake that can be exploited in heating applications. The distance for retrieving wet pomace is considered less than 90 km from the IBLC. The reason is that wet pomace is produced only in olive mills which are scattered around Fthiotida region, thus the distance to acquire this kind of biomass is greater.

Finally, the assessment of both biomass resources in Agios Konstantinos was based on several on-field measurements of pruning productivity by developed guidelines and from validated mass balances of olive and pomace mills. Thus, the methodology developed in the current paper can be employed by other agro-industries, operating in the olive-oil sector, in order to assess their possibilities for implementing the IBLC strategy. In this light, the current paper can be used as a roadmap to define the amount of biomass that can be mobilized by an IBLC in order to estimate the new revenue streams and economic opportunities that can be emerged.

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8 LOGO SPACE

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