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Summary

These activities deal with the physical pre-treatment requirements for woody waste. An assessment of available technologies on industrial scale was performed, adapting the selected solutions defined in the lab protocol to the specific requirements of olive tree pruning.

The technologies are evaluated from technical and economic point of view in order to define the solution to reduce as much as possible the required steps and thus obtain the best possible use of time, energy and resources.

The results of the characterization of pure olive tree pruning pellet on pilot scale are also described and discussed to verify the reliability of the lab protocol when scaled up.

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1. Introduction

In this report, the operations performed for the scaling-up of the lab protocol for producing pellets out of olive tree pruning are addressed. The Deliverable is related to the pre-treatments on the olive tree pruning as harvesting, drying and chipping.
The evaluation of certain steps under the energetic point of view has been taken into consideration.
The Deliverable gives an overview on the performed technology assessment aimed at locating technologies and sites where to conduct the pilot essays.

1.1. Background

The activities are focused on the scaling up of the lab protocol for the olive tree pruning pre-treatment for pellet production. In previous activities the technology scouting about the pre-treatments on lab scale was carried out, highlighting three main stages for the treatment of the olive tree pruning: harvesting, drying and chipping.
After, the woody biomass is ready to be mixed with olive pomace for pelletizing.
In the “Product Performance Report” two blends showed to be the most suitable for gasification among those supplied by ISAFoM. The selected blends were: ***75PR/252PH*** (75% olive tree pruning and 25% two-phase olive pomace) and ***50PR/503PH*** (50% olive tree pruning and 50% three-phase olive pomace).

2. Technology assessment on olive tree pruning pre-treatments

2.1. Harvesting [3]

Currently, the pruning residues are not an important source of income for the interested companies but they are a problem and a production cost at the same time. Nowadays, the waste cleanup provides two main solutions:

- chopping in the field and their burial;
- burning waste.

Chopping in the field and burial can be useful with vineyards and healthy crops; in these cases, the biomass from pruning is not a source of infection or spread of diseases, but rather can play feature quantity of nutrients and organic matter to the soil. However, this practice can also have a negative aspect when the residues are infected with root rot, downy mildew etc. In these cases, the burial of the waste must be avoided because the ground is a very favourable environment for the pathogen where it can overwinter and infect again buds during the following spring. Therefore, in these circumstances the burying shredded waste can be an important problem for the phytosanitary control. In many cases, instead, the pruning residues are collected by using a rake applied to a tractor and taken into perimeter areas (sideline) of the parcels where they will be burned. Now, in many regions this method is restricted or forbidden because of its negative environmental impacts, both for the air quality due to the emissions deriving from this method and for the fire prevention.

The automated collection of pruning depends on several factors and specifically by:

- **soil conditions**, and in particular by its arrangement: only the more compact tamping machine can work in the terraces being inaccessible for the other models. Instead, on the flat ground or on moderately sloped it is possible to use and work with all kinds of equipment;
- **width of headlands**: the operation of the machines at the end of sideline requires an important width of headlands. Other spaces are also necessary for the product transfer into transport vehicles or for discharge into the ground;
- **pruning characteristics**: the maximum size of pruning affects the type of technology that it can be used, because the machines have different diametric capacity. The small shredder loader can work with a maximum diameter of about 5 cm, while the industrial machine can also work with a major diameter. The pruning amount per unit area is another important parameter which influences the type of machine to be used and then the productivity.

Harvesting of olive tree pruning, usually, takes place twice a year, once, the main, after

olive harvesting in the winter time and the second one, in the summer (green pruning). Most of the biomass is burned in the field just after harvesting. Usually, only high diameter branches are collected and used by inhabitants for domestic heating [1].
The larger amount of pruning is collected from January to April in correspondence of the maintenance cut; the amount of pruning and the percentage of leaves and wood are showed in Table 1.
The measures have been taken for three consecutive years in a five-year-old semi-intensive olive orchard cultivated monocone (555 plants/ha) located in Perugia. The trees had an average height of 2.5 m [2].

Table 1 - Amount of pruning per olive tree and corresponding percentage of leaves and wood

	Kg/tree	Leaves (wb %)	Wood (wb %)
Average	6.2	40	60
Standard deviation	3.5	5.7	5.7

Three different techniques of mechanized collection of pruning can be used:

- baling on field (or wrapping field);
- chopping in the field;
- grinding or chipping at the headlands.

Baling on field

The baling is a processing technique suitable to residual woody thin, otherwise difficult to manipulate. It allows to organize the residual in homogeneous units, facilitating the handling and storage. From years, the market offers several efficiency and tested models developed from normal pressed feed. The existing balers can be divided in three groups:

- small parallelepiped balers;
- light round balers;
- industrial round balers.

The small parallelepiped balers are a modified press fodders, which pack parallelepiped bales through piston device with reciprocating rectilinear motion. They are light machines applied to farm tractor of about 40-60 kW and they are able to work on an

area of about 1x1.5 meters. The bales can have different size, however very close to standard values of 45 x 35 x 70 cm. Their weight can vary from 20 to 40 kg as a functions of collected material type and of its humidity. The real productivity of these machines depends on the model, on the treated crop type, and on operative condition. Two workers - one for leading the tractor and the other one for facilitating the collection with a pitchfork - can produce from 600 to 1000 bales per day. The hourly productivity is about 10 q/hour with an hourly cost of about 50 €. The price of this kind of equipment depends on the model and it varies between 8.000-15.000 €.

The operating principle of the light round balers is the same of the standard model, but they allow to solve the encumbrance problems through a general miniaturization: the weight of the machine is reduced to one-fifth and the starter is given by a small orchard tractor able to supply 25-30 kW. The packed bales weigh about 30-40 kg depend on material type. This kind of baler needs of only one worker and it reaches an hourly productivity of 1.6 t/hour with an hourly cost of 38 €/hour. The cost of this type of machine varies between 10.000-12.000 €.

The industrial round balers also descend from modified farm equipment. The main difference is that they are big equipment and they have to be used only in modern and rational planting, because of their considerable size, they require an important maneuvering space. The bales' diameter is between 1 and 1.5 meter with a total volume of about 1-2 m^3 as a function of the models. The unit weight of the bales varies between 200-700 kg and it depends on baler type, on the regulation of the compression chamber set from tractor driver who can do all the work alone. These machines can be started from one tractor of 60 kW and they can reach an hourly productivity between 35-70 q. Their price is about 35.000 € and the hourly operating cost is about 60 €/hour.

In general, the balers are very efficient but their main weakness consists in the bale handling rather than in the baling process. Now, the technologies required for the rationalization of the collection of the bales are not available, for that reason that process is carried out by hand or by tractor equipped with forks. The bales must be chipped by using all the necessary measures during the chipping phase in order to produce a material as homogeneous as possible.

Chopping in the field

This technique is very interesting because it allows to thinning the biomass simplifying the handling. The fine can be used in heat generator with high energy efficiency. The main difference of the available models is the machine derivation and the kind of the site (industrial and semi-industrial). Specifically, the models available are:

- semi-industrial chopper: with clubs with tilting container;
- industrial harvesters: only recently they have spread in Italy and in general they descend on the modified commercial flail to which a collection device of the chopped is applied.

The semi-industrial choppers are normal choppers with clubs on which a tilt container is applied in which the fine materials are accumulated. In fact, the rotor clubs produce an air flow (between 2-7 m^3) is able to push the fine to the tilt container in addition to mulch pruning. Some manufacturers substituted the container with canvas bags (big-bag), while other ones have redesigned the machine by installing a fan and launch tube for sending the fine to the cargo of flanked trailer. This last option is a site bulkier and it is suitable for the industrial installations in flat ground. Anyway, the required power varies between 40-70 kW and it depends on the model type; the maximum diameter of the treated material is about 5 cm. Some manufacturers applied to the machine a frontal pick-up able to raises the pruning before sending them to the clubs: primarily, this solution was developed for the shredding on stony in order to maintain the clubs raised from the ground and avoid the contact between stone and clubs which can damage the equipment or compromise the rotor balance. With the biomass recovering, the elevated processing allows to avoid the timber contamination with grass and soil and it allows to obtain a better woodchips quality. The construction site are always semi-industrial sites and they are led by only one worker, the hourly productivity varies between 10-15 q of fresh chopped and the hourly operating cost is about 45 €/hour. The equipment cost can be varied between 10.000 and 20.000 €.

Industrial harvesters are particular machine built for the pruning residues treatment. They can be self-propelled or applied to a farm tractor, but they always require high power of about 150 kW. The high available power and pick-up dimensions allow to treat also the thicker branches (8 cm of diameter) and to reach very high hourly productivity between 20-40 q of fresh chopped, therefore 2 times higher than the one obtain with the semi-industrial sites at least. The cost of the operative machine is about 20.000 € while

the hourly operating cost is about 100 €/hour including the tractor and tractor driver. Industrial harvesters are very efficient machine, especially for intensive lowland facilities which have the maneuvering space and the extension needed for rational use of them.

Shredding or chipping at the headlands

The shredding or chipping at the headlands is a modification of the old system used in the past to dispose of the pruning which consists in the concentration of the materials in the board and then in burn. Specifically, the burn is replaced with shredding process, achieving the disposal of the residue and its commercial exploitation. The system advantage consists in a considerable flexibility because the owner can perform the operation when it is free from other work. Moreover, the owner has the full control in all the operations carried out in his installation, so he hasn't to worry that others may damage his property due to hasty maneuvering or rough. The obtained productivity in this stage can be 9-12 q of fresh biomass per hour, depending on the length of the rows and the quantity of pruning on the ground. If the work isn't carried out with marginal resources, the hourly cost can vary between 35-40 €. The most important shrewdness is that the tractor driver must be careful to do not dirty the pruning residues stomping with the tractor wheels or pulling by teeth of the fork on ground. Because of possible contamination with earth or stones which is impossible despite the attention of the workers, the chopping can be carried out with a hammer mill. The mouthpiece tube models are probably the most suitable means for this work because they are also able to handle quite easily the material arranged in a disorderly manner. Anyway, the machine has to be powered by a hydraulic crane which it can be inside to the shredder or mounted on another support vessel. Due to the limited size of the headlands, it is better to use the relatively compact shredders, which they can be started from a tractor with a power of about 100 to 120 kW. A machine so light can reach an hourly productivity of 35-50 q of fine with an hourly cost of about 80 €. These kind of machines are commercially available at a cost of 80.000 € including the independent engine and the crane. The light shredder is a very versatile machine which can be used on only for working pruning but also to grid a wide variety of green or wood waste available in the company or at nearby companies.

Transportation costs to pelletizing facilities vary widely based on the different means and parameters used, such as a small truck per distances up to 20 km has a cost of

about 18 €/t, per distances below 10 km € 10/t; a tractor with a trailer up to 10 km has a cost of € 4/ton [4].

2.2. Drying and chipping

The drying of the wood residues can be resolved with two different approaches:

- drying with mechanical ventilation;
- natural drying in greenhouse or storage silos covered and suitably ventilated, for avoid triggering processes of deterioration caused by fungi or bacteria.

The drying with mechanical ventilation is the technically more efficient for obtain the desired moisture content of the biomass. The second scenario presents problems due to an increase of the moisture content of approximately 15% but is economically profitable.

The chipping is required to obtain a raw material compatible with the equipment for the energy conversion; if an industrial harvester is employed for the collection of pruning appear to be necessary a subsequent step of chipping to obtain a biofuel with suitable characteristics (homogeneous size and dimensions of between 3 and 5 cm), because of the chipped wood has a poor quality in terms of dimensional homogeneity.

To reduce the bale of pruning, generally a chipper machine is used; there are various models and various brands, but the general features are similar.

In relation to the entire phase of chipping it is necessary to emphasize that the bales have dimensions not compatible with the mouth of the chipper and thus to automate the process should use a chipper with the loading mouth or greater. This would involve the purchase of a car in the section of the market of large shredders (the difference from the chipper consists in the different orientation of the axis of the toothed rollers, shredders for horizontal, vertical for chippers) which, translated into economic evaluations would mean an investment of around € 300.000.

3. Olive tree pruning pre-treatment at pilot scale and pure PR pellet production

The mapping performed in the D2.2 underlines that the raw materials of interests are mostly localized in Southern Italy while technologies are produced in Northern Italy. According to this, it has been decided to conduct the pilot tests on a company localized nearby Benevento (Southern Italy). The site represents a good compromise in terms of raw material availability and presence of necessary equipment.

The pilot essays for the scaling up of the lab protocol were performed using olive tree pruning with initial moisture content of about 50%.

Pruning is naturally dried. Cost for handling of raw materials can be considered negligible.

Following lab scale protocol, PR was first chipped using an industrial facility and immediately grinded obtaining a mean size of 1.5 mm and a residual moisture content of about 30%: the related costs are close to those necessary for the grinding process and also the CO_2 emissions are almost the same amounts.

Table 2 shows the main characterization parameters for grinded 100PR pellets at pilot scale compared to lab scale.

Table 2 - Lab and pilot scale 100PR pellets characterization

	100PR pellets ***Lab scale***	**100PR pellets** ***Pilot scale***
Net calorific value (wb)	17.8	18.8
Ash (% db)	2.9	3.5
Ultimate analysis (% db)		
Carbon	49.8	49.3
Hydrogen	6.5	6.3
Nitrogen	1.0	0.95
Sulfur	0.15	0.12
Lignin	34.1	34.6

As pruning shows to be stable at ambient condition even at its natural moisture

content, we decided to perform chipping and grinding of pruning immediately before mixing it with grinded pomace.

Consequently, the optimized operations for pruning production, before mixing to dried pomace, can be summarized in the Figure 1:

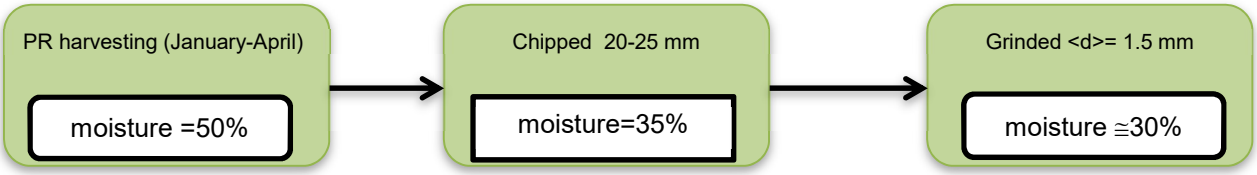

Figure 1 - Pilot scale procedure process for pruning pre-treatment before pelletizing

In Table 3 an indicative economic cost plan is reported, related to different stages of olive tree pruning pretreatments.

Table 3: Economic plan of pilot scale olive tree pruning pre-treatments

Stage	Equipment	Cost
Pruning harvesting	Industrial harvester	35 €/ton
Pruning transportation	Tractor with trailer (1.6 ton)+lorry (32 ton)	23 €/ton (depending on the distance from the pelletizing facilities)
Pruning chipping	Industrial chipper	6 €/ton
Pruning grinding	Grinder	8 €/ton
Pelletizing	Pelletizer	11 €/ton pellet

4. Conclusions

The following activities and results have been achieved:

- technology assessment of pre-treatments of olive tree pruning, aimed at locating suitable sites were to conduce the pilot essays for the scaling-up of the pellets production protocol;
- optimal moisture level for pruning to be mixed to pomace before pelletizing;
- optimal chipping and grinding procedures for pruning after harvesting;
- selection of the most suitable equipment to obtain material with the

desired characteristics;

- definition of the average cost of single unit operations for pruning pre-treatments and pelletizing.

5. References

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