

Communication

# Innovative Olive Tree Leaves Shredder Prototype for the Valorization of Wasted Leaves: An Application to High-Quality Compost Production

Alessio Cappelli , Nicola Menditto and Enrico Cini 

Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Piazzale delle Cascine 16, 50144 Florence, Italy; nicola.menditto@villamontepaldi.it (N.M.); enrico.cini@unifi.it (E.C.)

\* Correspondence: alessio.cappelli@unifi.it

**Abstract:** Extra virgin olive oil is considered worldwide as one of the most important products, a standard bearer of the Mediterranean diet. Despite this, the production chain of extra virgin olive oil generates four times more waste than quantity of oil. For this reason, the disposal of olive mill wastes represents a significant environmental problem in all the Mediterranean countries. In this direction, several innovations and improvement strategies were proposed in the literature to correctly manage these by-products and, in some cases, to valorize them by the recovery of polyphenols and other interesting substances. However, innovations and improvement strategies for the valorization of olive tree leaves are definitely neglected in the literature, thus motivating this work. The aims of this work are as follow: firstly, to develop and test an innovative olive tree leaves shredder prototype to help olive oil millers in the management of waste leaves deriving from pruning and olive oil production; secondly, to test the combination of the minced olive tree leaves with other by-products in the production of high-quality compost. The results showed the effectiveness of the tested olive tree leaves shredder in significantly reducing the volume occupied by the leaves by 40%. Moreover, the mixing of the minced olive tree leaves with other by-products lead to a high-quality compost which, in accordance with Italian legislation, could even be certified and labeled with this denomination. Future research will investigate the quantification of the benefits in terms of environmental impacts using life cycle assessment.

**Keywords:** olive mill waste; by-product valorization; organic carbon; nitrogen fertilization; polyphenol extraction; waste management



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## 1. Introduction

Extra virgin olive oil, a standard bearer of the Mediterranean diet, is constantly gaining interest. Its production continues to increase from levels seen in 2006 [1]. According to a European Commission report, 3 million tons of olive oil are approximately produced each year in the world [2]. Two million tons of this production takes place in the EU [2]. The main member states involved are Spain (66% of EU production); Italy (15%); Greece (13%); and Portugal (5%) [2]. The European Union is the main producer, consumer, and exporter of olive oil; it produces about 67% of the world's olive oil [2].

However, as highlighted by Espadas-Aldana et al. (2019) [3], approximately eighty percent of olive mass is composed of pulp, stones, and water; the production process of extra virgin olive oil therefore generates four times more waste than quantity of oil [3]. Consequently, disposal of olive mill wastes (mainly olive washing water, wastewater, olive pits, and pomace) represents a significant environmental problem in all the Mediterranean countries. In particular, these olive oil mill wastes are very harmful for the environment due to the high organic load (mainly polyphenols, short- and long-chain fatty acids), which contributes to the phytotoxic nature and antimicrobial effect of the olive wastes [1]. For this

reason, several innovations and improvement strategies were proposed in the literature to recover these important polyphenols, reducing the environmental impacts.

Starting from the harvesting phase, Masella et al. (2021) [4], Beghi et al. (2021) [5], and Tugnolo et al. (2021) [6] suggested very interesting strategies to optimize the olive harvesting phase using an artificial neural network model and visible/near infrared tools. Moreover, with respect to saving water in the olive washing phase, Cappelli et al. (2019) [7] developed an innovative washing machine able to significantly reduce water consumption (i.e., 60 L per hour), which additionally proved to be able to improve olive washing. Proceeding further in olive oil mill by-product management, Russo (2007) [8] suggested the most interesting strategy to manage olive oil mill wastewater. This involves a novel treatment approach based on tangential flow membrane filtrations for the selective separation and total recovery of oleuropein, hydroxytyrosol, water, and organic substances [8].

Despite the fact that several innovations and improvement strategies aiming to valorize the most impactful olive oil mill by-products are available in the literature, suggestions regarding the correct management of another critical by-product, namely olive tree leaves, are definitely neglected. In several countries of the Mediterranean area, there is, unfortunately, the common illegal practice of burning olive tree leaves (with other by-products such as olive tree branches and twigs), significantly increasing fire risks and environmental pollution. As suggested by a few authors in the literature, to valorize this important waste, one interesting strategy could be related to the extraction of polyphenols from the olive tree leaves [9,10]. This allows the removal of pollutant elements, obtaining products rich in polyphenols with high commercial value. However, polyphenol extraction from olive tree leaves requires major economic investments, not affordable for the majority of olive oil mills.

Therefore, another interesting approach found in the literature aims to transform the olive mill wastes into a non-toxic organic medium. This strategy has received increasing attention in modern sustainable agriculture [1]. Many beneficial effects of applying olive oil polyphenols to soil have been reported by several authors [1,11], in particular for the combined use of olive oil mill by-products with wastes from other production chains (e.g., vine, cotton, etc.) in the production of high-quality compost, thus motivating this work. The aims of this work are as follows: Firstly, to develop and test an innovative olive tree leaves shredder prototype to help olive oil millers in the management of waste leaves deriving from pruning and olive oil production, reducing the space occupied by this by-product. Secondly, to test the combination of the minced olive tree leaves with other by-products in the production of high-quality compost.

## 2. Materials and Methods

### 2.1. Prototype Description

The olive tree leaves shredder prototype is shown in Figure 1.

The machine has been developed according to the Deming approach (i.e., plan, do, check, and act), consistently with earlier work [7]. The machine, built using stainless steel, presents the input section for the olive tree leaves at the top. This allows the machine to be directly connected with the olive oil mill defoliator or to be fed independently. Once the leaves are feed into the machine, a rotating shaft with several cutting elements (knives) break down the leaves into small pieces, creating an air vortex which allows the discharge of the minced leaves in the lower part of the machine. The minced olive tree leaves could be successively collected and used in several applications (i.e., high-quality compost production, polyphenol extraction, etc.). In particular, to highlight the potential application of this olive tree leaves shredder machine in polyphenol extraction, a patent application regarding a complete extraction process has been submitted to the Italian Patent and Trademark Office, and for international patenting to the PCT (Patent Cooperation Treaty). The effectiveness of the olive tree leaves shredder prototype in reducing the volume occupied by the olive tree leaves was evaluated by measuring the apparent volume occupied by 100 g of fresh olive tree leaves and, successively, by the volume of the minced

leaves. This was carried out using a plastic graduated cylinder. The results were expressed as volume reduction in % using the following formula:

- $$\frac{(\text{volume of fresh olive tree leaves} - \text{volume of minced olive tree leaves})}{\text{volume of fresh olive tree leaves}} \times 100$$



**Figure 1.** Pictures of the olive tree leaves shredder prototype.

## 2.2. Compost Formulation

The study was carried out in Montepaldi Farm (Florence, Italy) using the cement tank located in the composting area of the farm. The cement tank dimensions were 9.10 m × 2.20 m × 0.20 m. Using the olive tree leaves shredder prototype, 400 kg of minced olive tree leaves were produced and mixed with 400 kg of green stalks, 400 kg of minced walnut hull, 400 kg of unfermented white marc, 1400 kg of wet olive pomace, and 400 kg of vine residuals to produce the tested compost. The compost mass was mixed every two months to allow aerobic fermentation and microorganism activities. The volume occupied by the mass was 4.004 m<sup>3</sup>.

## 2.3. Sampling and Compost Analyses

Compost sampling and analysis had the aim of assessing the evolution of the compost composition every three months (for a total of six months). For this reason, samples (in three replicates) were collected in December 2017, March 2018, and June 2018. Sampling was carried out at 10 cm depth in randomly selected points. According to UNI EN ISO 5667-13 [12], every sample was homogenized and processed to obtain 1.5 kg of representative sample. Finally, samples were stored in plastic bags and refrigerated during transport (0–4 °C). The analyses were carried out by the StudioAmbiente laboratory (Grosseto, Italy) following approved, official methods [13]. In particular, pH, dry matter content, humification index, ashes, organic carbon, total nitrogen content, total phosphorus content, and Pb, Cu, Cd, Hg, Ni, and Zn levels were analyzed.

## 3. Results and Discussion

The tested olive tree leaves shredder was able to reduce the volume occupied by the leaves by 40%. This marked decrease of the volume occupied by the olive tree leaves could significantly help olive oil mills and farms to optimize the management of this bulky

by-product. Moreover, the inclusion of the minced olive tree leaves showed interesting results in the production of high-quality compost. Table 1 shows the results of compost characterization and analysis.

**Table 1.** Compost characterization and analysis. Results are expressed as the mean of three replicates  $\pm$  SD. Sample 1 (December 2017); Sample 2 (March 2018); and Sample 3 (June 2018).

Parameters	Sample 1	Sample 2	Sample 3
pH	4.71 $\pm$ 0.10	6.96 $\pm$ 0.55	9.69 $\pm$ 0.25
Dry matter (g/100 g)	41.50 $\pm$ 0.28	45.55 $\pm$ 3.75	43.95 $\pm$ 4.45
Ashes (g/100 g)	2.25 $\pm$ 0.21	2.55 $\pm$ 0.07	4.85 $\pm$ 0.78
Humification index (HI)	0.54 $\pm$ 0.02	0.51 $\pm$ 0.01	0.50 $\pm$ 0.01
Organic carbon (%)	29.65 $\pm$ 4.60	31.10 $\pm$ 3.54	31.82 $\pm$ 1.95
Total nitrogen (%)	10.40 $\pm$ 0.01	10.95 $\pm$ 0.35	4.65 $\pm$ 0.07
Total phosphorus (%)	3.67 $\pm$ 0.52	3.98 $\pm$ 0.39	3.93 $\pm$ 0.32
Pb (mg/kg)	8.45 $\pm$ 1.77	5.85 $\pm$ 0.49	7.55 $\pm$ 1.34
Cu (mg/kg)	12.05 $\pm$ 3.32	10.35 $\pm$ 0.07	13.75 $\pm$ 6.86
Cd (mg/kg)	<1	<1	<1
Hg (mg/kg)	<0.5	<0.5	<0.5
Ni (mg/kg)	12.05 $\pm$ 3.32	7.45 $\pm$ 1.63	7.11 $\pm$ 1.06
Zn (mg/kg)	14.45 $\pm$ 0.07	10.60 $\pm$ 0.28	14.05 $\pm$ 3.58

According to Chiumenti et al. (2007) [14], a humidity between 40% and 60% is optimal for compost. Despite this, Italian law has set this limit between 50% and 55% for high-quality compost (D.lgs n 152/2006; D.M. n 21/2000). As a result, according to Table 1 and the humification index (HI) figures, optimal results were obtained for the tested compost. Moreover, Table 1 shows that the pH initially tended toward acidity due to CO<sub>2</sub> and organic acid formation; successively, it tended toward neutrality thanks to aeration (CO<sub>2</sub> expulsion) and ammonia production from denatured proteins; and finally, an alkaline pH values was reached, highlighting the production of high-quality compost (Table 1).

Results for organic carbon met the standards for high-quality compost and, moreover, showed a good carbon/nitrogen balance (Table 1). The carbon/nitrogen ratio is a key parameter since a carbon excess could slow down microbial activities and the contrary could instead cause a rapid breakdown. Moreover, according to Italian Legislative Decree 75/2010, high-quality compost is: “a product obtained from the composting of individually collected organic wastes that meets the requirements and characteristics established by Annex 2 of Legislative Decree 75/2010 and subsequent amendments”. The following limits were reported in Annex 2 of Legislative Decree 75/2010: Pb 140 mg/kg; Cd 1.5 mg/kg; Ni 100 mg/kg; Zn 500 mg/kg; Cu 230 mg/kg; and Hg 1.5 mg/kg. The results presented in Table 1 show that all the tested metals were significantly below the legal limits, highlighting the achievement of a high-quality compost which could gain this label.

As highlighted by Charisiou and Goula (2014) [15], the composting of olive tree leaves and other by-products can eliminate pathogens, convert nitrogen from unstable ammonia to stable inorganic forms, reduce the volume of waste, and satisfy the needs for fertilizer in agriculture. Composting olive tree leaves (alone or in a mixture) was studied by several authors [16,17]. Moreover, phytotoxicity of olive tree leaves was evaluated by Manios et al. (1989) [17] in relation to the compost maturity by measuring the germination index of lettuce seeds. This could be a useful approach for further studies. However, the results are encouraging, in particular because they meet the standards for high-quality compost reported in Annex 2 of Legislative Decree 75/2010. However, this does not mean that

the long-term effects of heavy metals on the soil should not be monitored. In particular, accumulation phenomena must be carefully evaluated.

#### 4. Conclusions

The results presented in this paper showed the effectiveness of the tested olive tree leaves shredder in significantly reducing the volume occupied by the leaves by 40%. Moreover, the mixing of the minced olive tree leaves with other by-products led to a high-quality compost which, consistent with the results of the analysis reported in Table 1 and in accordance with Italian legislation, could even be certified and labeled. This preliminary study highlighted the interesting opportunity to correctly manage farms' by-products for the production of high-quality compost by applying circular economy approaches capable of reducing environmental impacts, energy consumption, and costs. As a result, eco-friendly waste management could allow, in small- and medium-sized companies, for 100% of raw materials to be reused, closing the nutrient circle directly in the production area with huge economic and environmental advantages. Moreover, this eco-friendly waste management approach could be used in mushrooms production, leading to an additional source of profit for farms. For these reasons, we believe that the suggested approach and the use of the olive tree leaves shredder might be of interest in small- and medium-sized farms. Moreover, the suggested approach could be extended to different contexts of the agro-food industry. In conclusion, with respect to future research, the quantification of the benefits related to self-made high-quality compost in terms of environmental impacts will be investigated using life cycle assessment.

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