Biological Degradation of Olive Mill Solid Wastes Produced from Olive Oil Extraction

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Abstract
Olive mill solid waste (OMSW) has a potential to cause pollution either in land or in water. In order to reduce this problem, a study was conducted to investigate the effect of microbes on the treatment of this waste. The context of this work was to solve this environmental problem by recycling of OMSW, by a composting system that was carried out by a thermophilic process in which the microorganisms (Psychrophiles, Mesophiles and thermophiles) were responsible for the composting process. This project addresses reducing the environmental impact of Olive Mill Solid Waste, called jift, produced from olive oil extraction. A composting process was managed to solve or make progress on the problem by composting OMSW with cow manure. The method of research applied to the problem was based on the digestion of organic species available in OMSW by the microorganisms, through three stages. The results indicated that the first stage occurred at low temperature (below 20°C) where simple compounds such as saccharides and polyunsaturated fatty acids were consumed. This stage produces energy (heat) and so accelerates the decomposition of fats and polyphenols by mesophiles, at medium temperature (20-40°C). The third stage was the stabilization state, where the temperature became high (reached 65°C) due to the previous process, and so, the thermophiles started digestion of all the remaining organic matters. After the completion of the third stage, the temperature of the system decreased slowly until it became 25°C, indicating the consumption and decomposition of all the organic contents in the OMSW, by the three Kinds of microbes. The products, obtained from these processes, were carbon and nitrogen. The C/N ratio in the product was calculated which showed the complete degradation of the organic compounds. The significance of this work is that detoxification of OMSW to produces new substances that can be used in feeding animals and as natural soil conditioning, and to produce a new source for heat production. The implications for future work is to treat the OMSW by various methods because olive waste contains oil that may increase soil hydrophobicity and decrease water retention and infiltration rate.

Keywords: olive oil, olive mill solid waste, thermophilic process

INTRODUCTION
Olive oil production is an important industry in many countries. The annual production of olive fruits in Palestine is about 100,000 tons producing more than 40,000 tons of solid waste and about 25,000 tons of olive oil. OMSW can be highly beneficial to agricultural soil. The influence of OMSW on soil hydraulic properties has been studied (Majed, 2002; Albarran 2006). The OMSW has many uses such as sorbent material for heavy metals (Pagnanelli, 2009), sorption of copper (Veglio, 2003), preparation of activated carbon (Mameri, 2000), treatment of drinking water (Gharaibeh, 1998; Shar, 1999), feeding animals, fuel, natural fertilizers and charcoal industry. However, the OMSW causes an impact on the environment and so, it should be treated. Many previous efforts have been given for the treatment. The capability of the edible mushroom Pleurotus ostreatus to degrade cell wall components and soluble phenols of OMSW and improve it for ruminant nutrition has been explored (Shabty, 2009). Also, biodegradation (Borja, 2006), digestibility (Borja, 2002; Borj, 2003) and co-digestion (Boubaker, 2007) of OMSW have been investigated. The main objective of this work is to reduce the environmental impact of OMSW from olive mills by microorganisms. The specific objectives are: reducing the environmental impact of olive mill solid waste, find a process for the use of this material (OMSW), find suitable parameters for compost production and to design and construct composting bens. Among the different ways of OMSW detoxification, composting seems to be the most logical from both ecological and economical points of view. The compost application will increase soil fertility and will also lead to
increased carbon sequestration by soils (Franzluebbers, 2005). The most potential uses of compost are soil amendment and as an ingredient in growing media. Normally, composting is carried out by two mechanisms either a thermophilic process or through vermicomposting. In thermophilic process, the microorganisms are responsible for composting the solid waste. The composting process is carried out by three classes of microorganisms that are Psychrophiles (low temperature microbes), Mesophiles (medium temperature microbes) and Thermophiles (high temperature microbes). This study describes the thermophilic process, since it is more efficient and more common than vermicomposting. Two methods can be regarded as practical for OMSW composting; either aerated static pile or windrow composting. In continuation of our work on the treatment of olive mill wastes, this manuscript proposes a holistic approach for the treatment and recycling of OMSW by applying a window composting system.

MATERIALS AND METHODS

Concise and sufficient details are provided to allow the work to be repeated by others. Two bens were constructed to carry out composting process (thermophilic process) for the treatment of Olive Mills Solid Waste (OMSW or called jift). The ratio of C/N in some materials are shown in Table 1. Table 2 describes the contents of each ben for the first trial. The calculated value of C/N indicates the low nitrogen content in the mixture. Therefore, cow manure or urine was added as a source of nitrogen to reach the recommended value of C/N (30-35), which is considered optimal for the initiation of the process. Urea may be considered as the best source of nitrogen, but in our case, a natural fertilizer is required, so it is not appropriate to add an industrial fertilizer. The pH and temperature were measured in order to study the stability of the compost. The initial temperature in the bens was 22.2°C, and the pH was 5.3. Normally, the temperature will start rising 2-4 days after mixing. The amount of water, used weekly, to wetting OMSW was 1.5-2.0 L, and some times, it was dropped to 1.0 L depending on precipitation in the area. Temperature was measured once a day at several sites and depths. In both bens, the temperature of OMSW increased slightly with some differences between the two bens.

A second trial was attempted. The quantities of materials used in the composting process of the second trial were calculated and recorded in Table 3. The bens were cleaned from the previous compost and the new composting process was started. All mistakes in the first trial were avoided and the quantity of materials (OMSW, wheat straw, cow manure, etc.) was calculated by spreadsheet model aimed to reaching to the specific ratio of C/N value and moisture. The pH and temperature were measured in order to study the stability of the compost. The initial temperature was 22.2°C and the pH was 5.3. UASB reactor was re-started to treat OMW that has high COD value (27,000 mg L⁻¹) and the hydraulic retention time is 3 days. The final product which was out from reactor (Treated OMW) has COD value around 4000 mg L⁻¹.

RESULTS

The three different stages of temperature progress are illustrated in Fig. 1.

C/N ratio was calculated by the following equation to determine if the compost system needs nitrogen:

\[ \frac{C}{N} = \frac{\text{Total weight of carbon in the sample}}{\text{Total weight of nitrogen in the sample}} \]

\[ = \frac{C_a \cdot a(1 - m_a) + C_b \cdot b(1 - m_b) + \ldots}{N_a \cdot a(1 - m_a) + N_b \cdot b(1 - m_b) + \ldots} \]

\[ A = \text{The weight of sample (a)} \]

\[ C_a = \text{The weight of carbon in sample (a)} \]

\[ N_a = \text{The weight of nitrogen in sample (a)} \]

\[ M_a = \text{The moisture content in sample (a)} \]
The temperature evolution curve of composting process of OMSW is shown in Fig. 2. The C/N ratio and moisture content were calculated by using spreadsheet modeling to determine if the compost system needs additional source of nitrogen. Fig. 3 shows the calculation page from spreadsheet model. The amount of water was used to wetting OMSW depends on the humidity measurement as shown in Fig. 4. The temperature evolution curve of composting process of OMSW wetted by tab water is shown in Fig. 5 and that wetted by OMW is shown in Fig. 6.

**DISCUSSION**

Composting olive mill waste and sheep manure for orchard use, where an industrial-scale composting plant has been designed, for producing organic fertilizers from olive mill waste using the windrow pile system, was reported. On the other hand, experimental use of composted grape seed and olive mill residues for amelioration of fertility and structural stability of soils has been investigated. Good composting requires an environment in which microorganisms will grow up, to produce fecundity compost and so, we must find the best environment to support microbial vitality. Organisms such as microbes need some necessary factors to stay alive, and these are water, air, suitable temperatures and nutrient. The factors of the compost environment required for the long rapid, and efficient composting are moisture, aeration and temperature. The ideal moisture level is 40-60%. Microorganisms need moisture to thrive. In the composting process, in addition to OMSW (the main component), other material can be mixed in order to accelerate the process and also to improve the end product. The normally used material is wheat straw which reduces the moisture content and increase the free air space. Sometimes, water (either tap water or wastewater) may be added to the composting system to keep it moist. Compost should be kept moist, but not saturated. If the materials are too wet, they will compact and restrict the airflow through the pile. This leads to anaerobic (no oxygen) conditions, which slows down the degradation process and causes foul odors. A pile which becomes too wet should be turned; turning the compost will dry it out and add oxygen. Aeration means adding oxygen to the compost system. Microbes need water as well as oxygen to break down organic materials efficiently. Because they reproduce so quickly under ideal conditions, microbes may deplete the available oxygen through their activity. Therefore, it is important to aerate the compost by turning the accumulated compost, by air compressor or by adding bulky materials. These materials, such as leaves, hay or straw, provide channels to oxygen inflow into and through the compost. This system also keeps the accumulation compost from settling and compacting. Temperature is the most important factor that indicates how well the system is working and indicates how the decomposition has progressed. Psychrophiles are organisms that reproduce and grow best at low temperatures, typically in the range -10 to 20°C. They possess enzymes that are adapted to function at low temperatures and are denatured at moderate temperatures. They also exhibit polyunsaturated fatty acids in their lipids. On the other hand, most of the microorganisms on earth belong to the group of mesophiles. Mesophiles grow best in temperatures between 10-50°C (50-122°F). They are found in soil and water environments. Most of the diseases, caused by bacteria and viruses that affect humans come from the mesophile group. After the Psychrophiles and Mesophiles finish their work, the system enters the last stage. Decomposition occurs most rapidly during the thermophilic stage of composting (40-60°C), which lasts for several weeks or months depending on the size of the system and the composition of the ingredients. During the previous stages, a lot of pathogenic organisms are formulated, and so, the thermophilic stage is considered important for reduction of pathogens during composting and destroying thermo-sensitive pathogens. The compost should be maintained at minimum operating conditions at 40°C for five days, with temperatures exceeding 55°C for at least four hours of this period. Most species of microorganisms cannot survive at temperatures above 60-65°C, and so, the temperature of the system should be controlled.

After the thermophilic phase, the compost temperature drops and is not restored by turning or mixing. At this
point, decomposition is taken over by mesophilic microbes through a long process of “curing” or maturation. Although, the compost temperature is close to ambient during the curing phase. Chemical reactions continue to make the remaining organic matter more stable and suitable for use with plants.

Carbon to nitrogen ratio is considering one of the most important factors that should be measured before the composting process. If the compost mixture is too low in nitrogen, it will not heat up and the compost will stay in Psychrophiles phase. In contrast, if the nitrogen proportion is too high, the compost may become too hot and will kill the compost microorganisms. Besides nitrogen, the carbon also plays a vital role in the composting process, since carbon provides the energy for microorganisms to multiply and so, the shortage of carbon content causes shortage in microorganism. The usual recommended range for C/N ratios in the composting process is about 30/1. As carbon gets converted to CO$_2$, the C/N ratio decreases during the composting process. When composting high carbon materials such as jift, nitrogen may be required to reduce the C/N ratio to the optimal range. Animal manure and Urine are used as a source of N, since the OMSW contains toxic polyphenols which is toxic to many bacteria and microorganism. Some fluctuations in temperature curve do appear, and this depends on the weather. During the thermophilic stage, the optimal temperature range is 55-60°C. Temperatures above 65°C should be avoided in order to prevent ashing. On the other hand, temperatures below 45°C are not desirable, since they indicate a much slower biodegradation rate.

Temperature was measured once a day at several sites and depths. In both bens, the temperature of OMSW increased slightly with some differences between the two bens. Some fluctuations in temperature curve do appear when the compost were wetted or aerated. Otherwise, when the temperature of the system was increased up to 65°C, the aeration system automatically starts working to reduce the temperature. As far as the end of the process and subsequent storage are concerned, the end of the composting process does not mean a complete cessation of all biological processes. It merely signifies a stage when a steady-state has been reached, when formation of new organic molecules by microorganisms happens in about the same rate as their biodegradation. Heat generation rate is low and its dissipation to the surroundings occurs at a rate that leaves the pile temperature very close to ambient levels. At this point, nitrifying bacteria becomes active. Long-term storage of compost should be done under cover, where compost is not exposed to high temperatures of summer and leaching by winter rains.

![Fig. 2: Temperature evolution curve of composting process of OMSW](image)

![Table 2: Amount of compost materials used in each ben](image)

<table>
<thead>
<tr>
<th>OMSW (jift) (kg)</th>
<th>Wheat straw (kg)</th>
<th>Cow manure (kg)</th>
<th>Urine (kg)</th>
<th>Wetted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bens #1</td>
<td>200</td>
<td>40</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Bens #2</td>
<td>200</td>
<td>40</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>*: Treated olive mill wastewater</td>
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![Table 3: Amount of compost materials that were used in each ben, using spreadsheet model](image)

<table>
<thead>
<tr>
<th>OMSW (jift) (kg)</th>
<th>Wheat straw (kg)</th>
<th>Cow manure (kg)</th>
<th>Urine (kg)</th>
<th>Wetted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bens #1</td>
<td>200</td>
<td>10</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Bens #2</td>
<td>200</td>
<td>10</td>
<td>60</td>
<td>40</td>
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![Fig. 3: Calculating page from spreadsheet model](image)
organic fertilizers using the windrow pile system. The treatment was achieved by micro-bores which were capable in degrading the organic contents of the OMSW, thus in, reducing the environmental impact of olive mill solid waste. Among the different ways of OMSW detoxification, composting seems to be the most logical from both ecological and economical points of view. The compost application will increase soil fertility and will also lead to increased carbon sequestration by soils. On the other hand, uses of compost are soil amendment and as an ingredient in growing media.

REFERENCES


CONCLUSION

A research work was needed since the olive mills produce two identifiable and separate waste streams, namely the wastewater and the solid residues. The later poses acute environmental problems and contains the pulp, pits and skins of the olive that remain after the olive oil production process. It is acidic, has high BOD and COD values and contains a toxic levels of high organic matter concentration (94%) such as poly-phenols, giving it an elevated polluting load. Composting olive mill solid waste and cow manure has been designed for producing


