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Review

Olive mill waste composting: A review

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A B S T R A C T

Olive mill wastes exacerbate environmental problems in Mediterranean countries. These wastes are highly phytotoxic and contain phenolic compounds, lipids and organic acids. They also contain high percentages of organic matter and a vast range of plant nutrients that could be reused as fertilizers for sustainable agricultural practices. In this paper, recent research on composting wastes of 2-phase and 3-phase olive mills is reviewed, concentrating on factors affecting composting such as bulking agents, aeration strategy, physicochemical characteristics (duration of the thermophilic phase, moisture content, organic matter, volatile solids, total organic carbon, water soluble carbon, total nitrogen, total phosphorus, potassium, C/N ratio, phenols and the humification process), and phytotoxicity. The review highlights the effects of composting operational factors (bulking agent, additives, and aeration strategy) on the physicochemical characteristics of the final compost, and the production of a good quality soil amender or fertilizer.

Contents

1. Introduction

Composting is a bio-chemical aerobic degradation process of organic waste materials. Under suitable conditions, composting has three consecutive phases: a) the initial activation phase, b) a thermophilic phase recognized by a sudden temperature increase, and c) a mesophillic phase where the organic materials cool down to the surrounding temperature (Ryckeboer et al., 2003a). Microbial metabolic activities generate heat which leads to physicochemical changes of the organic matter into biomass, CO_2 and humus-like end-products and, at the end of the process, produce a stable, humus-rich, complex mixture (Cooperband, 2002). The organic matter conversion is caused by the enzymatic activities of specialized microbial populations (Tuomela et al., 2000; Ryckeboer

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et al., 2003b; Federici et al., 2011; Agnolucci et al., 2013). Substrate composition is a key controlling factor for both the degradation and humification processes. The chemical substances (i.e. organic matter, nitrogen, phosphorus and trace elements), which are the most active part of the compost, affect positively the structure, fertility and productivity of the soil environment, and are thus considered critical to agricultural production (Senesi, 1989; Chen et al., 1994; Haider, 1994). Compost as an alternative fertilizer has a series of advantages according to Cooperband (2002) and Rynk (1992), since it: (a) improves soil water capacity and aggregate stability; (b) enhances cation exchange; (c) increases microbial activity, and (d) enhances the degradation of pesticides and other synthetic organic compounds.

Olive oil production plays a key socio-economic role in the Mediterranean, especially in Spain, Italy, Greece, Syria, Turkey, Tunisia, etc. Over 95% of the world's olive oil is produced in this region (Aktas et al., 2001). However, olive oil production causes serious environmental problems due the production of high amounts of by-products, namely olive pomace (OP), and olive mill wastewater (OMW) (for three-phase systems), and two-phase olive mill waste (TPOMW) (for two-phase systems) within the short production season (Roig et al., 2006). Worldwide annual OMW production is estimated to be over 3×10^6 m^3 (Barbera et al., 2013), with an organic load equivalent to about 22 million people per year (Roig et al., 2006). The two-phase (2-P) production system is termed eco-friendly as it requires smaller amounts of water and reduces waste production by 75% (Roig et al., 2006). OMW has very high organic loads (BOD 89–100 g l^{-1}, COD 80–200 g l^{-1} (Rosario et al., 1999) and these cause serious environmental issues, since the OMW organic fraction consists of sugars, polyalcohols, pectins, lipids and significant amounts of aromatic compounds, such as tannins and polyphenols, that are responsible for antimicrobial activities and phytotoxicity (Niaounakis and Halvadakis, 2004). According to Alfano et al. (2008), 2-P systems produce a lignocellulosic olive humid husk (OHH) which is a watery solid byproduct with high contents of water (56.6–74.5%), phenols (0.62–2.39%) and lipids (Ranalli et al., 2002; Alburquerque et al., 2004; Gurbuz et al., 2004; Vlyssides et al., 2004).

The OP produced by three-phase systems is utilized for further oil extraction with organic solvent. However this extraction process is not possible in two-phase (2-P) systems, since their by-products have higher moisture and carbohydrate contents. This 2-P waste tends to adhere to furnace walls hindering the gaseous stream and can cause explosions (Arjona et al., 1999). In addition, drying this 2-P waste consumes energy leading to increased operational costs (Roig et al., 2006). Recently, several chemical, physical and biological methods have been applied for the treatment of OMW and OP. These include lagoons, ultrafiltration/reverse osmosis (Niaounakis and Halvadakis, 2004), flocculation-clarification (Zouari, 1998; Roig et al., 2006), thermal concentration and evaporation (Netti and Wlassics, 1995; Vitolo et al., 1999), incineration and combustion (Vitolo et al., 1999), combustion and gasification (Caputo et al., 2003). Generally, the above methods are costly and do not sufficiently eliminate pollution problems (Paredes et al., 2002). Aerobic biological treatment methods (Tziotzios et al., 2007; Michailides et al., 2011b) are very feasible and economic for OMW treatment. Anaerobic digestion treatments (Hamdi, 1996; Marques, 2001; Filidei et al., 2003), which produce biogas, have been successfully applied to OMW (Rozzi and Malpei, 1996), but their high cost makes them non-viable for use in small-scale olive mills.

On the contrary, compost produced from these olive mill wastes could be used in agriculture as an environmentally friendly, good quality soil amender and fertilizer. Composting is also a suitable technology economically feasible for small or medium-sized olive mills (<1000 t y^{-1}), such as those found throughout Italy and Greece (Alfano et al., 2008). Several solutions for the composting of olive mill solid wastes from 3-P (olive pomace and leaves) or 2-P (OHH) systems have been documented in the literature: Rutgers static-pile with on-demand aeration or forced ventilation (Paredes et al., 2002; Ranalli et al., 2002), dynamic turned pile (Sciancalepore et al., 1996; Ranalli et al., 2001), and bioreactors (Principi et al., 2003). Olive mill wastes can be composted either pure (Principi et al., 2003) or mixed with other wastes that act as bulking agents (Paredes et al., 1996, 1999, 2002; Ranalli et al., 2001; Garcia-Gomez et al., 2003). Other wastes that have been tested include wool waste and wheat straw (Altieri and Esposito, 2010), olive leaves, wood chips and rice by-products (Komilis and Tziouvaras, 2009), sesame bark (Sellami et al., 2008b), poultry manure (Sellami et al., 2008a; Hachicha et al., 2009a,b), sheep manure and grape stalks (Cayuela et al., 2006, 2010), olive leaves (Manios et al., 2006; Alfano et al., 2008; Michailides et al., 2011a), and sewage sludge (Sánchez-Arias et al., 2008).

Intensive agricultural production generally leads to soil fertility loss, soil erosion, water contamination, soil compaction, and reduction of organic matter content. Low organic matter content is a common characteristic of Mediterranean soils, and is highly correlated with their potential productivity and fertility due to its direct impact on physical, chemical and biological properties of soils (Alburquerque et al., 2007). Therefore, the use of organic waste as compost on agricultural land could increase soil organic content, and composting can play a vital role in modern sustainable agricultural practices (Felipo, 1996).

To the best of our knowledge, a review summarizing all research results on olive mill waste composting does not exist in the literature. This paper fills this gap and summarizes results achieved in composting experiments of 3-P and 2-P olive mill wastes combined with various bulking agents. More specifically, it discusses the effects of ventilation and turning, types of bulking agents, organic matter degradation, and humification of the composting substrate. Finally, to demonstrate the feasibility of olive mill waste composting to produce quality end-products, which are non-phytotoxic and rich in humified organic matter, we also present all compost attributes.

2. Olive mill waste composting

Recent research has highlighted the complex interactions between physical, chemical and biological processes that occur during composting. Factors such as temperature, pH, electrical conductivity (EC), moisture, bulk density, porosity, particle size, organic carbon (C), nitrogen (N) content, carbon to nitrogen ratio (C/N), and oxygen supply, have proved to be key elements to improve composting process, since they regulate conditions for microbial growth and development, and organic matter (OM) decomposition (De Bertoldi et al., 1983; Miller, 1992; Haug, 1993; Das and Keener, 1997; Richard et al., 2002; Agnew and Leonard, 2003). The factors influencing composting can be classified into two classes: those depending on the composting mixture's preparation, such as pH, particle size, porosity, total pile volume, initial moisture and nutritional balance; and those of the process management, such as moisture content, temperature, aeration. Table 1 presents the main characteristics and operational parameters of olive mill waste composting mentioned in the available literature.

2.1. Composting phases, temperature and duration

According to Cooperband (2002) compost pile temperature is a key factor for the composting process, since it controls organic material biodegradation and is affected by a series of operational