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Agri-food sludge management using different co-composting strategies: study of the added value of the composts obtained

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ABSTRACT

The growth of the agri-food industry has resulted in a strong increase in its sludge generation. This type of waste is often produced in high amounts, concentrated in certain areas, and shows characteristics similar to those of municipal sewage sludge (except for the absence of heavy metals). Composting has been widely studied as a viable alternative for the treatment and recycling of municipal sewage sludge, but little information is currently available concerning the composting of agri-food sludge. Thus, the aim of this work was to increase our knowledge of how the vegetable-derived sludge produced by the agri-food sector can be managed using different co-composting strategies. The work was concerned mainly with the characteristics of the bulking agents used (type and particle size) and their effects on the development of the process and on the potential added value of the composts obtained. For this, four composting piles were prepared using agri-food sludge and two bulking agents (vine shoot prunings and pepper plant pruning waste) at two particle sizes (<1 cm and <3 cm). The evolution of the process and the final properties of the composts obtained were studied using classical analytical methods together with advanced instrumental methods (thermal analysis and excitation–emission matrix (EEM) fluorescence spectroscopy). In addition, their physical characteristics and potential suppression of phytopathogens (*Fusarium oxysporum* f. sp. *melonis*) were determined. The results showed differences according to the type and size of bulking agent, the mixtures with vine shoot prunings having a higher biodegradability, which was confirmed by thermogravimetry and EEM fluorescence spectroscopy. Melon plants grown in a mixture which included compost produced using vine pruning waste had a greater shoot weight than those grown on peat alone, while the mixture including compost derived from pepper pruning waste gave a shoot weight similar to that of peat-grown plants. Furthermore, the composts elaborated using vine shoot prunings had added value with respect to their use as growing media components for seedling production of melon, due to their suppression of *F. oxysporum* f. sp. *melonis*. Therefore, this study has shown that the nature of the bulking agent used is of major importance not only for the development of the composting process, but also for the final properties and potential added value of the end-products obtained.

1. Introduction

The food and agricultural industry constitutes the main activity of the European manufacturing sector, representing 14.6% of its output (more than 1,048,000 million €), with a growth of around 3.1% in relation to the previous year, during the period 2013–2014 (MAGRAMA, 2015). The production processes of this industry involves high water consumption, generating effluents with a high organic load due to the contribution of plant remains and soluble compounds derived from the raw materials (proteins, carbohydrates, phenolic compounds, etc.), as well as to the presence of oils and fats remaining after their extraction.

In recent years, the industries of the agri-food sector, involved in the processing of fruits and vegetables for the production of juices

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and processed vegetables, have significantly improved the quality of their processing procedures and have installed treatment systems to treat their wastewaters, according to the Directive 91/271/CEE of May 21 (DOCE, 1991). Biological treatment is the process most commonly used to treat wastewaters rich in nutrients (Najafpour et al., 2006) and with high organic content (Christensen et al., 2009), such as those of the food-processing industries. However, this treatment generates a new organic residue, known as agri-food sludge. This type of sludge is usually found in areas of concentrated production; for example, in the Region of Murcia (11,000 km^2), where 15,000 tonnes were produced in the campaign 2011/2012, with a predicted increase to 40,000 tons by the year 2020 (AGROWASTE, 2014).

The characteristics of this waste are similar to those of urban wastewater produced at sewage treatment plants. However, agri-food sludge also shows a significant difference, since it does not contain heavy metals (Li et al., 2013a) or other potentially toxic constituents, since it is generated during the processing of wastewater whose pollutant load is mainly constituted by organic matter (OM) of plant origin. Thus, this sludge has great potential for agricultural uses, due to its high contents of nutrients, such as nitrogen and phosphorus, and OM (Singh and Agrawal, 2008). Currently, the management of this sludge has an associated cost based on the "elimination of the problem" by authorised management agents. In Spain, the management of these wastes is governed by the Law 22/2011, relating to residues and polluted soils (BOE, 2011), which prioritises recycling and other ways of adding value such as energy extraction, thereby avoiding deposition in landfill sites. In addition, under the proposed Plan of the Circular Economy of the European Commission, in 2025 it is intended that the entry of recyclable residues in landfill sites will be prohibited; so, options such as direct application to soil and composting represent viable alternatives for the management of these wastes.

Composting can constitute a suitable method for the recycling of this type of waste, since the compost obtained is a useful organic amendment and/or organic substrate that can be reincorporated into the economic system, helping to solve the disposal problem and reducing emissions of greenhouse gases (Banegas et al., 2007; Himanen and Hänninen, 2011; Lim et al., 2016). Composting is a biological treatment in which aerobic thermophilic and mesophilic microorganisms use OM as substrate, the main products of this process being fully-mineralised materials (carbon dioxide (CO_2), water and ammonium (NH_4^+)) and stabilised OM (mostly humic substances), free of pathogens and phytotoxins, which can be safely used in agriculture (Bustamante et al., 2008a). Diverse biodegradable organic materials can be composted, such as sewage sludge, pruning wastes, animal manures and slurries, forest management residues and remains from the food and agricultural industry. In this sense, the greatest number of studies have been developed using biodegradable organic materials that are generated in large amounts and whose handling or elimination are problematic, such as municipal sewage sludge (Ingelmo et al., 2012). However, not enough information is currently available regarding the composting of sludge from the agri-food industry. Like sewage sludge, agri-food sludge shows several characteristics that require the addition of a bulking agent for its composting, to optimise the properties of the composting mixture - such as the air space, moisture content, carbon to nitrogen (C/N) ratio, particle density, pH and mechanical structure - and thus enhance the decomposition rate. In this sense, ligno-cellulosic by-products, such as wood chips and sawdust, have been commonly used as bulking agents (Pasda et al., 2005; Li et al., 2013b).

The composting of biodegradable solid wastes is deemed useful since its end product (compost) can be used as a nutrient-rich organic fertiliser or for land application (Wu et al., 2014). However, the destination and/or use of the compost will depend on its characteristics, which will be determined to a great extent by the raw materials used and the composting process carried out. In particular, additional value can be provided to agri-food sludge when it is composted appropriately with other organic residues generated in the agri-food industry to produce composts suitable for use in seedling production (Himanen and Hänninen, 2011). Alternatives to chemical fertilisers, such as compost and vermicompost, are becoming increasingly important in the agricultural sector because the use of chemical fertilisers on the soil over a long period of time may affect its ability to sustain healthy plant growth and crop production (Lim et al., 2015a).

In addition, the biopesticidal effect of such composts also might help to reduce the use of chemical fungicides; in contrast, peat is hardly ever suppressive against pathogens (Bonanomi et al., 2010). Hence, compost represents an increasingly-attractive alternative to peat in sustainable agricultural production. Peat is the plant growth substrate used most in seedbeds and nurseries. However, the increasing demand for peat as a growing medium in horticulture and its rising cost have intensified the search for alternative high-quality and low-cost substrates. Because of this, different materials, such as residual biomasses and, especially, organic wastes, mostly after proper composting, have been studied as peat substitutes in potting media (Ceglie et al., 2015).

Therefore, the main aims of this work were: 1) to evaluate different co-composting strategies for the management of the sludge generated by the vegetable processing industry, considering two main variables: the type of bulking agent and its particle size; 2) to study the characteristics of the composts obtained using chemical, thermogravimetric and spectroscopic techniques and to evaluate their potential suppressive capacity against *Fusarium oxysporum*, with a view to their use as substrates or substrate components in seedling production.

2. Material and methods

Four different composting mixtures were tested, using agri-food sludge and two bulking agents prepared at two particle sizes (<1 cm and <3 cm), to select the best bulking agent and to assure the quality of the final product (Bustamante et al., 2013).

2.1. Composting procedure

The bulking agents used in the mixtures were vine shoot prunings (VP), obtained from a vineyard of Petit Verdot 3 years Rootstock SO4 (*Vitis vinifera* L.), planted in 2007 and located in Fuente Alamo (Albacete, Spain), and pepper plant pruning waste (PP), collected from a commercial greenhouse of bell pepper (*Capsicum annuum* L.) located in Almeria (Spain). The agri-food sludge (SSA) was obtained from a treatment plant of the "Sociedad de Depuracion Virgen de los Dolores S.L." (Murcia, Spain), which mainly treats wastewater derived from the processing of artichokes and peppers, by means of sequential biological reactors (SBR). The SSA showed some characteristics similar to those of municipal sewage sludge (Singh and Agrawal, 2008), such as high salinity (EC = 15.1 dS/m), slightly alkaline pH (pH = 7.6); notable concentrations of total organic C (30.3%) and total organic matter (OM = 53.4%); a high content of total nitrogen (3.82%); a low carbon to nitrogen ratio (C/N = 7.93) and high contents of phosphorus and potassium (%P = 0.86 and %K = 0.24). However, the SSA also showed low concentrations of heavy metals (Cu: 59.0 mg/kg; Cr: 54.6 mg/kg; Cd: 0.18 mg/kg; Ni: 20.8 mg/kg; Pb: 8.72 mg/kg; Zn: 155 mg/kg; Hg: 0.03 mg/kg), compared to municipal sewage sludge, mainly due to the different characteristics of the type and origin of the wastewater to be purified (Banegas et al., 2007). The