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A systematic review on the composting of green waste: Feedstock quality and optimization strategies

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ABSTRACT

Green waste (GW) is an important fraction of municipal solid waste (MSW). The composting of lignocellulosic GW is challenging due to its low decomposition rate. Recently, an increasing number of studies that include strategies to optimize GW composting appeared in the literature. This literature review focuses on the physicochemical quality of GW and on the effect of strategies used to improve the process and product quality. A systematic search was carried out, using keywords, and 447 papers published between 2002 and 2018 were identified. After a screening process, 41 papers addressing feedstock quality and 32 papers on optimization strategies were selected to be reviewed and analyzed in detail. The GW composition is highly variable due to the diversity of the source materials, the type of vegetation, and climatic conditions. This variability limits a strict categorization of the GW physicochemical characteristics. However, this research established that the predominant features of GW are a C/N ratio higher than 25, a deficit in important nutrients, namely nitrogen (0.5–1.5% db), phosphorous (0.1–0.2% db) and potassium (0.4–0.8% db) and a high content of recalcitrant organic compounds (e.g. lignin). The promising strategies to improve composting of GW were: i) GW particle size reduction (e.g. shredding and separation of GW fractions); ii) addition of energy amendments (e.g. non-refined sugar, phosphate rock, food waste, volatile ashes), bulking materials (e.g. biocarbon, wood chips), or microbial inoculum (e.g. fungal consortia); and iii) variations in operating parameters (aeration, temperature, and two-phase composting). These alternatives have successfully led to the reduction of process length and have managed to transform recalcitrant substances to a high-quality end-product.

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1. Introduction

The growth of urban green areas worldwide has led to an increase of the amounts of green waste (GW) generated. This, in turn, has become an environmental problem in developing and developed countries (Zhang and Sun, 2017b). Along with other bio-waste (i.e. food waste), GW constitutes the highest fraction of municipal solid waste (MSW) (Kumar et al., 2010; U. S. Environmental Protection Agency, 2010; Wei et al., 2017). GW consists of tree wood and bark, pruning from young trees and shrubs, dead and green leaves, grass clippings and soil, and originates from municipal parks, gardens, reserves, and domestic dwellings, among others (Bustamante et al., 2016; Haynes et al., 2015; Vasarevičius et al., 2011). GW is expensive and unattractive to transfer, due to its low bulk density and its low value, respectively. The principal management cost is related to collection and transportation to landfill or treatment facilities (López et al., 2010).

Composting is a suitable method for the recycling of GW, since the compost obtained is a useful organic amendment and/or organic substrate that can be reincorporated into the economic system (Wei et al., 2017; Zhang and Sun, 2016a), helping to solve the disposal problem and to reduce emissions of greenhouse gases (Morales et al., 2016). In addition, a positive aspect is that GW often shows low contents of micro-pollutants. This aspect favors the production of a compost with adequate properties that can fulfil the quality standards and utilization restrictions for compost use in organic farming systems (Bustamante et al., 2016). However, composting of the lignocellulosic fraction of GW is challenging due to its low decomposition rate (Zhang and Sun, 2016b).

GW contains organic compounds that are recalcitrant to biodegradation (e.g. lignin that typically sheaths cellulose preventing and slowing its aerobic decomposition) or slowly/moderately degradable (e.g. hemicellulose, cellulose). The ratio of cellulose to lignin could be an index to judge the aerobic degradability of GW and the composting process, as proposed by Komilis and Ham (2003). In addition, if the composting is not properly operated and controlled (e.g. oxygen supply, humidification, nutrient balance), the process can be slow (i.e. between 90 and 210 days), demand large areas for treatment (Khalil et al., 2008), generate malodorous gases (López et al., 2010), and can produce a low quality product unsuitable for commercial use (Gabhane et al., 2012; Zhang and Sun, 2017b). Likewise, GW composition is highly variable and depends on the predominant source vegetation, the season of the year, and the local collection policies, among others (López et al., 2010). This variability in the composition of GW can affect its decomposition.

In this context, the reduction of the time required for composting and the increase of the quality of the product have become important goals in the use of composting for GW valorization (Zhang and Sun, 2016a). Recently, an increasing number of studies have focused on the optimization of GW composting with promising results in the reduction of processing time, the minimization of gas emissions, and the improvements of end-product quality (Belyaeva and Haynes, 2009; Bustamante et al., 2016; Zhang and Sun, 2016a; Zhang et al., 2013). The identified strategies include: (i) operational changes on the process; (ii) changes on the oxygen provision; (iii) pre-treatment; (iv) addition of microbial inoculum; and (v) co-composting with different supplementary materials (bulking or amendment).

The main objective of this research was to investigate aspects of the physicochemical quality of GW and the effect of certain strategies to improve the process and end-product quality. To achieve that, an initial literature search identified 447 papers published between 2002 and 2018. After a screening process (see Fig. 1), 41 papers about feedstock mixture (GW) and 32 papers on optimization strategies were screened down, reviewed, and systematically analysed. The composition of GW that has been typically reported in the literature comprises of leaves, grass clippings, pruning waste, branches, wood trimmings, yard trimmings, small plants, weeds, vegetable waste. Those materials were discussed in this review. In addition, information on the physicochemical characteristics, identifying reference values for the parameters reported by the literature, was analysed and reviewed. Finally, different optimization strategies were selected to analyze the effect on the process (e.g. length, gas emissions, temperature, pH, moisture) and on end-product quality.

Despite the large amount of literature on GW composting, the present work is the first that addresses and integrates research that deals with the quality of the feedstock materials, end-product quality and optimization strategies during GW composting.

2. Methodology

2.1. Literature search

A systematic literature review, which included the definition of a search protocol, the identification of keywords and sources of available information, was carried out (Caro Gutiérrez et al., 2005). The academic databases Science Direct® and Scopus® were used.

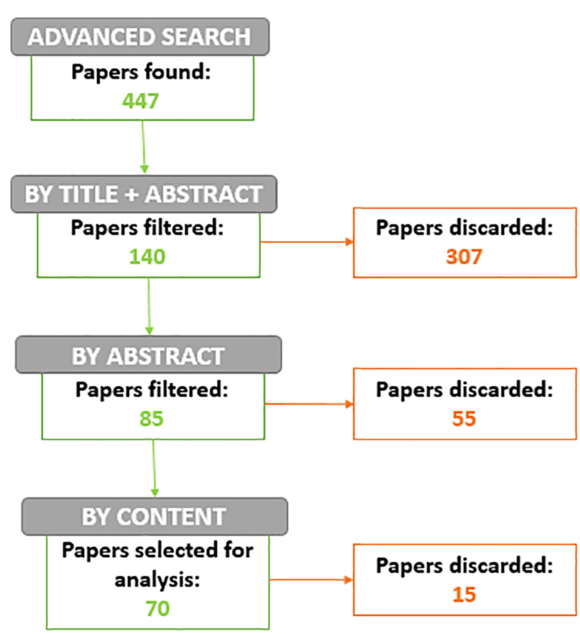

Fig. 1. Outline of the screening process to finally select the 70 papers used in this study.

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