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Evaluation of laboratory-scale in-vessel co-composting of tobacco and apple waste

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ABSTRACT

Efficient composting process requires set of adequate parameters among which physical–chemical properties of the composting substrate play the key-role. Combining different types of biodegradable solid waste it is possible to obtain a substrate eligible to microorganisms in the composting process. In this work the composting of apple and tobacco solid waste mixture (1:7, dry weight) was explored. The aim of the work was to investigate an efficiency of biodegradation of the given mixture and to characterize incurred raw compost. Composting was conducted in 24 L thermally insulated column reactor at airflow rate of 1.1 L min^{-1}. During 22 days several parameters were closely monitored: temperature and mass of the substrate, volatile solids content, C/N ratio and pH-value of the mixture and oxygen consumption. The composting of the apple and tobacco waste resulted with high degradation of the volatile solids (53.1%). During the experiment 1.76 kg of oxygen was consumed and the C/N ratio of the product was 11.6. The obtained temperature curve was almost a "mirror image" of the oxygen concentration curve while the peak values of the temperature were occurred 9.5 h after the peak oxygen consumption.

1. Introduction

Agro-food industries generate large quantities solid and liquid wastes which must be suitably managed before being discharged to the environment. The solid wastes, which originate from the food processing and agricultural industries, are suitable substrates for composting (Adhikari et al., 2008; Kim et al., 2008; Manios, 2004). Composting is acceptable solution because it reduces the volume of bulky solid waste and results with organic material becoming a stable end product (Haug, 1993; Insam and de Bertoldi, 2007).

Successful composting requires meticulous attention to key parameters and that includes: (i) substrate nature parameters (e.g. C/N ratio, particle size, pH-value) and (ii) process parameters (e.g. temperature, moisture content (MC) and aeration rate), (Diaz and Savage, 2007; Haug, 1993; Rashad et al., 2010). Preferable C/N ratio of the composting substrate is between 25 and 30 (Diaz and Savage, 2007). Composting of the wastes with C/N ratio lower than 20 is feasible (Kumar et al., 2010), but with loss of nitrogen through ammonia volatilization during the process (Diaz and Savage, 2007). A pH-value between 5.5 and 8.5 is optimal for the compost microorganisms, but preferable values are between 6.5 and 7.5. Values out of the optimal range could inhibit microbial activity and initial lag in the composting rate could be expected leading to rate limitations (Sundberg et al., 2004; Yu and Huang, 2009). The particle size of the waste intended for composting is in the range of 10 mm (in forced aeration systems) to 50–100 mm (in passive aeration systems) (Neklyudov et al., 2008). If the particle size is too small, air recirculation through composting mass is inhibited, free air space in the system decreases and reduces oxygen diffusion (Vlyssides et al., 2008). Concerning those aspects, there are not many types of biodegradable waste that can be characterized as "ideal" substrates for composting and mixing with chemical and/or bulking agents is often necessary (An et al., 2012; Iqbal et al., 2010; Yu and Huang, 2009). On the other hand, substrate with physical–chemical characteristics optimal for composting can be obtained by mixing two or more types of biodegradable waste (Diaz et al., 2002; Iqbal et al., 2010; Sundberg et al., 2011; Rashad et al., 2010).

Apple waste, namely apple pomace has many applications, e.g. apple pomace as a substrate for the production of citric acid (Dhillon et al., 2011) and apple pulp as a biogas production source (Coalla et al., 2009), but it is rare as composting substrate. The main characteristics that makes fruit waste not preferable or not acceptable for composting are low pH-value (Dhillon et al., 2011) and high moisture content (van Heerden et al., 2002; Kim et al., 2008). On the other hand, tobacco solid waste is rich in nitrogen (Tso, 1990) and the consequence of that is a lower C/N ratio (Piotrowska-Cyplik et al., 2009). As reported in recent researches, tobacco waste from cigarette manufacturing (Briški et al., 2003; Briški et al., 2012) and tobacco waste briquettes (Piotrowska-Cyplik et al., 2009) was

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successfully composted in the reactor systems. However, tobacco waste from primary tobacco production is a dry and dusty material consisted of very small particles and mechanical or manual stirring was necessary for efficient composting of that kind of waste in a packed bed reactor (Kopčić et al., 2013).

Both apple and tobacco waste showed their biological potential for microbial degradation in fermentation and/or aerobic biodegradation processes but with certain disadvantages in their physical–chemical characteristics for efficient composting, as described above. An alternative to overcome such disadvantages and to recycle both wastes is the co-composting of selected wastes in the proper ratio (Fernández et al., 2008; Manios, 2004; Vlyssides et al., 2008).

The aim of the work was to investigate feasibility of composting of the mixture of apple and tobacco solid waste in the laboratory-scale thermally insulated reactor. The study objectives were: (a) to determine physical–chemical properties of apple waste and tobacco waste, (b) to evaluate the efficiency of co-composting of selected wastes mixed in proper ratio, (c) to better understand correlation between oxygen uptake and temperature, and (d) to evaluate proposed mathematical model.

2. Materials and methods

2.1. Composting materials

Mixture of apple waste and tobacco solid waste were used as a composting substrate. Apples were collected in autumn on orchard in northern part of Croatia. Apples were manually pealed and non-edible parts were chopped into pieces with sizes ranging from 1 to 50 mm, where about 70% of the particles were exceeded 20 mm. The apple waste used for the experiment was consisted of an apple skin, cores with seeds, stems and decaying parts of apple pulps and the waste was kept in the freezer at −18 °C until composting experiment. The tobacco waste was collected from the tobacco primary production in *Hrvatski duhani d.d.* Virovitica, Croatia. The waste was composed of tobacco leaf residues and very fine, powdery mixture of tobacco residues and soil particles. The tobacco waste was stored in the dry place until further use. Prior the experiment major physical–chemical properties of each waste material were determined: dry solids (DS), moisture content (MC), volatile solids (VS), carbon (C) and nitrogen (N) content and pH-value. The waste mixture was designed to have a carbon to nitrogen ratio (C/N) of 25 and initial moisture content of 60% (w.w.). According to the obtained C/N ratio of each material and to the targeted value of C/N ratio of the composting substrate, apple and tobacco waste were mixed in the ratio of 1:7 (dry weight). Before composting, pH-value of the mixture was checked and water was added in order to obtain intended MC of the composting substrate.

2.2. Experimental setup

The reactor was 24 L cylindrical, vertically positioned with a diameter of 190 mm and the height of 940 mm (Fig. 1). The reactor was of polyethylene and insulated with 50 mm thick polyurethane. Reactor was placed on the scale (M-3-1086 Sklad, Primjer, Zagreb, Croatia) in order to regularly check the changes of the mass of the substrate.

The day before the experiment frozen apple waste was placed in a refrigerator at 4 °C for 24 h to defrost. The initial mixture was prepared of 5.4 kg of the tobacco waste and 3.7 kg of the defrosted apple waste. To ensure the intended moisture content, 5.7 L of tap water was added to the waste mixture. Before the experiment, initial pH-value, moisture content (MC) and C/N ratio of the mixture were determined. The reactor was filled from the top with 14.8 kg of solid waste mixture. The substrate was forcefully aerated with constant airflow rate set to 1.1 L min^{-1} (equivalent to 0.31 L min^{-1} $kg^{-1}{}_{init.volat.solids}$) from the bottom of the reactor during 22 days of the experiment. The airflow rate was selected on the basis of the preliminary experiment (results not presented) as high enough to overcome the pressure drop through the composting mass and to obtain a constant outgoing gas flow for oxygen monitoring purposes. The trial length of the experiment of 22 days was considered representative of the overall composting process evolution. Upward aeration was provided by an air compressor (DE 50/204 FIAC, Italy) and output pressure of the air was set to 1.0 bar. Air flow rate was regulated by valve of an airflow-meter of measuring range of 0–2.313 L min^{-1} (Cole Parmer, USA,). In order to reduce and minimize drying of the substrate bed in the reactor, air was saturated with water by passing through Dreschel bottle (not presented in the scheme, Fig. 1) before entering the reactor.

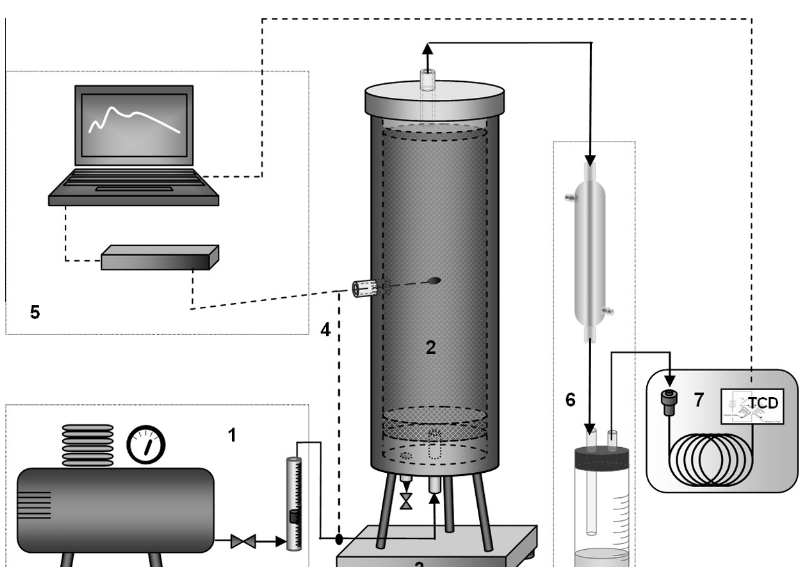

Fig. 1. Schematic diagram of composting process: 1-air compressor and flow regulation; 2-composting reactor; 3-scale; 4-temperature probes; 5-data acquisition, monitoring and storage; 6-condensate collecting; 7-gas chromatograph.