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Combustion Ash From Tomato Stem and Leaf Pellets as a Fertilizer

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Abstract

In this study, we aimed to the pelletizing and utilizing of tomato stems and leaves as an energy source, and analyzed inorganic compounds (N, P, K, Ca, Mg, Fe and Si) of the combustion ash of 20% tomato pellets, and wood pellets. Amount of N, P, K, Ca, Mg, Fe and Si of 20% tomato pellets were 0.06 g/kg, 5.06 g/kg, 42.92 g/kg, 37.66 g/kg, 5.08 g/kg, 0.15 g/kg and 2.22 kg/kg, respectively. The P, K, Ca and Mg contents of 20% tomato pellets was higher than combustion ash of wood pellets, 1.27 mg/kg, 28.57 mg/kg, 33.79 mg/kg and 4.42 mg/kg, respectively. Furthermore, N, Fe and Si contents of combustion ash of 20% tomato pellets was lower than combustion ash of wood pellets. Therefore, we suggested that combustion ash of tomato stems and leaves pellets could be utilized by mixed nitrogen fertilizer or soil of over-nitrogen.

Keywords: fertilizer, combustion ash, biomass, pellet, waste of agriculture

1. Introduction

The issue of global warming has recently assumed serious proportions worldwide, creating a societal demand for the use of biomass energy from recycled sources. Thus, the development of renewable biomass has become highly important. Processes for producing biofuel pellets for both domestic and industrial uses have recently attracted increased attention. The production of such pellets has grown rapidly in Europe, North America, and China in the last few years (Peksa-Blauchard et al., 2007; Samuelsson et al., 2009).

In agriculture, most of the leaves, stems, and roots produced after crop harvests are disposed of as general waste (Kulcu & Taldiz, 2004). The tomatoes leaves and stems waste, is the most widely produced vegetable in the world and is a major vegetable in Japan, amount to approximately 7 million tons per year; this weight is the same as that of the harvested fruits and represents a greater volume (Kozai, 2009). Although agricultural wastes are partly composted, most are mixed into soil and disposed of as industrial wastes by waste disposal services. However, agricultural wastes, as well as industrial by-products, are possible materials for biofuel pellet production (Gill et al., 2010).

Previous studies have examined the potential of olive plants and grape seeds (Gonzalez et al., 2004; Gill et al., 2010), which are disposed of as general wastes in northern Europe, as well as that of bamboo (Sakuma, 2007) and marijuana (Akahoshi et al., 2007) in Japan, for pelletization. In addition, Sato (2012) found that agricultural wastes may produce promising pellets, by combusting pellets from a mixture of 80% wood and 20% tomato stems and leaves. Moreover, tomato absorbs various fertilizers during its growth process and may thus contain many inorganic components (Sato et al., 2012). Therefore, we hypothesized that tomato pellet combustion ash would serve as a better fertilizer than wood pellet combustion ash.

Biomass is widely used as an alternative to fossil fuels, and the ash remaining after the combustion of wood biomass has been used as fertilizer. Uchiyama et al. (2001) reported that the combustion ash from the burning of poultry manure in a biomass boiler may be used as a fertilizer, whereas Tani (2009) investigated the use of the ash produced after the combustion of paper and pulp. In addition, the combustion ash from wood pellets used as fuel has been employed as a fertilizer (Takahashi et al., 2008). If the K and Ca contents in the combustion ash of wood pellets are high, and the contents and elutions of heavy metals are at the upper limits allowed for sludge manure or the standard levels of special fertilizer, the application of the ash is not hazardous to plants (Orihashi et al., 2011). Incidentally, toxic compounds included in industrial waste was set upper limit for using as fertilizer. Upper limit of heavy metal, As, Cd, Hg, Ni, Cr and Pb, are 50, 5, 2, 300, 500 and 100 ppm, and that of organic phosphorus was 1 ppm. In this study, we aimed to pelletize and utilize tomato stems and leaves as an energy source. We also analyzed the levels of inorganic compounds (N, P, K, Ca, Mg, Fe, and Si) in the combustion ash of pellets from a mixture of 80% wood and 20% tomato stems and leaves, as well as those in ash from entirely wood pellets.

2. Materials and Methods

2.1 Materials and Sample Preparation

Tomato leaves and stems were obtained from the cultivar "Round" cultivated on a contract farm at the Research Institute, KAGOME Co., LTD. Cedar chips were obtained from Tokyopellet Co., Ltd. (Tokyo, Japan). Moisture content of tomato leaves and stems was about 90%. All materials were cut about 3-5 cm, dried completely for 3 days at 80 °C using a ventilating dryer (FC-2000; AS ONE Corporation, Osaka, Japan), crushed to 10 mm using a crusher (MF10, IKA® Japan K.K., Nara, Japan), and then prepared to a moisture content of 11% by adding distilled water. The materials were then pelletized using a pelletizer (EDRF-075B small pelletizer; Earth Engineering Corporation, Ishikawa, Japan). The moisture contents of the pellets were determined using a digital moisture measuring system (SHIMADU MOC 120H; Shimadzu Co., Kyoto, Japan). The results of the ultimate and industrial analyses of the tomato and wood pellets are shown in Table 1. "Wood pellets" are those pelletized from cedar chips, "tomato pellets are those pelletized from tomato leaves and stems, and "20% tomato pellets" are those pelletized from 80% wood and 20% tomato stems and leaves.

2.2 Ultimate and Industrial Analyses of Tomato and Wood Pellets

Ultimate and industrial analysis of tomato and wood pellets were conducted according to wood pellet quality standard instituted by Japan Wood Pellet Association. Percentage of C, H, N, S were analysed according to JIS Z7302-1, 7302-7, and 7302-8, lower heating value (LHV) and ash content were measured according to JIS Z7302-1, 7302-2 and 7302-4 (Japan Wood Pellet Association, 2011).

Table 1. Ultimate and industrial analyses of tomato and wood pellets

	Ultimate analysis (%)				Industrial analysis (%)		Lower heating value
	C	H	N	S	Moisture percentage	Ash percentage	(MJ/kg)
20% tomato pellets	41.2	2.1	5.1	0.4	11.8	13	14.8
wood pellets	46.5	6.8	1.9	0.1	7.7	0.5	17.1

2.3 Inorganic Analysis

0.5 g of pellet or 0.25 g of combustion ash milled by mortar were decomposed according to wet ashing method and prepared constant volume (100 mL). N was analyzed by semimicro-Kjeldahl method (Goh, 1972), P by molybdenum yellow method (Basson et al., 1981), and Fe by the phenanthroline method (Fadrus & Malý, 1975). Si by molybdenum method (Woods & Mellon, 1941), K, Ca, and Mg were analyzed with an atomic absorption photometer (AA-7000, Shimadzu Co. Ltd., Kyoto, Japan). The analysis was performed in triplicates.

2.4 Statistical Analysis

Data are shown as mean values ± standard error, and was analyzed ANOVA method and performed using Tukey-Kramer test, again with a significance level of $P < 0.05$.

3. Results

Ultimate and industrial analyses of tomato and wood pellets is shown in Table 1. Moisture, ash percentage and LHV of 20% tomato pellet were lower than those of wood pellet. Percentage of N and S were greater than those of wood pellets.

The amounts of the combustion ash and their inorganic components (N, P, K, Ca, Mg, Fe, and Si) per 1 kg of pellets are shown in Table 2. The amounts of combustion ash for the wood and 20% tomato pellets were 2.8 g/kg and 25.3 g/kg, respectively, with the 20% tomato pellets producing approximately 9 times more ash than the wood pellets. The N, P, K, Ca, Mg, Fe and Si contents in the 20% tomato pellets were 0.06 g/kg, 5.06 g/kg, 42.92 g/kg, 37.66 g/kg, 5.08 g/kg, 0.15 g/kg and 2.22 g/kg, respectively, whereas those in the wood pellets were

0.14 g/kg, 1.27 g/kg, 28.57 g/kg, 33.79 g/kg, 4.42 g/kg, 0.83 g/kg and 5.50 g/kg, respectively. These results demonstrated that the P, K, Ca and Mg contents in the combustion ash of the 20% tomato pellets were significantly higher than those in the ash of the wood pellets. The Fe and Si contents in the combustion ash of the 20% tomato pellets were 0.15 g/kg and 2.22 g/kg, respectively, whereas those in the ash of the wood pellets were 0.83 g/kg and 5.50 g/kg, respectively.

Table 2. Amount of combustion ash and contents of inorganic components in combustion ash per 1 kg of pellets

	Amount of ash (g/kg ± SD)	Inorganic contents (g/kg ± SD) N	P	K
Combustion ash of tomato pellets	0.00 ± 0.00[z]	0.37 ± 0.03 a	5.16 ± 0.02 a	40.49 ± 1.30 a
Combustion ash of 20% tomato pellets	25.30 ± 1.68 a[y]	0.06 ± 0.01 b	5.06 ± 0.11 a	42.92 ± 2.84 a
Combustion of wood pellets	2.77 ± 0.09 b	0.14 ± 0.02 c	1.27 ± 0.17 b	28.57 ± 3.00 b

	Inorganic contents (g/kg ± SD) Ca	Mg	Fe	Si
Combustion ash of tomato pellets	37.53 ± 1.77 a	5.50 ± 0.47 a	0.29 ± 0.04 a	2.70 ± 0.81 a
Combustion ash of 20% tomato pellets	37.66 ± 1.26 a	5.08 ± 0.53 a	0.15 ± 0.06 b	2.22 ± 0.68 a
Combustion of wood pellets	33.79 ± 0.15 b	4.42 ± 0.53 b	0.83 ± 0.23 c	5.50 ± 0.82 b

[z] Accidental fire by residual ash

[y] Different letters indicate significant differences between pellets at the 5% level according to the Turkey-Kramer test (n=3).

4. Discussion

Ultimate and industrial analysis value, and LHV are not reached the wood pellet quality standard, but Sato et al. (2012) suggested that tomato pellets may be utilized as an energy source.

Si content in combustion ash of the wood pellets was lower than that of 20% tomato pellets. High levels of Si in the soil can also increase its level in pellets due to the attachment of soil particles during forest growth and storage, and the combustion of these bulk pellets may form solid lumps known as clinker and slag. Clinker causes decreased combustion efficiency and corrodes burners (Carl et al., 2008; Ohman et al., 2004). Ohman et al. (2004) reported that the Si contents in pellets that were pelletized immediately after harvest and six months after cutting, were 0.8% and 4.0%, respectively. The Si contents in the latter pellets were elevated due to the attachment of soil particles, and the amount of slug formation also increased due to the increase in Si. Thus, if tomato material is mixed with wood in the pellets, it is predicted that the corrosion of the burner will decrease.

The results suggested that the combustion ash of 20% tomato pellets may serve as an efficient fertilizer for vegetable cultivation, as the P, K, Ca and Mg contents in the combustion ash of these pellets were greater than those of ash from the wood pellets. Although the Fe content in the combustion ash of the 20% tomato pellets was the same as that in the ash of the wood pellets, trace amounts of Fe and Si are sufficient in vegetable cultivation. The P, K, Ca, and Mg contents of poultry manure ash, as well as its amount, have all been reported to be greater than those of wood pellet ash; the alkalinity of this combustion ash may have a corrective effect on the soil pH in acidic soil, and combustion ash may be used as compost (except on acidic soil) after a neutralization treatment with waste sulfuric acid (Uchiyama et al., 2001). Additionally, the combustion ash of pulp has been reported as alkaline and containing high levels of Ca; it may therefore be used as a lime fertilizer and soil improvement agent (Tani, 2009). The 20% tomato pellets produced a great large amount of combustion ash, and the inorganic contents of this combustion ash were greater than those in the ash of the wood pellets. The results indicate that these combustion ashes are suitable for use in acidic soil, as is the combustion ash of poultry manure, or for use in normal soils after neutralization treatment.

N, P, and K are the three major nutrients of fertilizer and play major roles in protein synthesis and energy metabolism (Watanabe, 2010). The N content in the combustion ash of the 20% tomato pellets was 10.6 mg/kg, which represents a trace amount, and N must therefore be supplemented when using this combustion ash as a fertilizer. Therefore, the combustion ash of 20% tomato pellets may be used efficiently when mixed with N fertilizer or applied to soil with excess N.

5. Conclusion

We aimed to the pelletizing and utilizing of tomato stems and leaves as an energy source, and analyzed inorganic compounds (N, P, K, Ca, Mg, Fe and Si) of the combustion ash of 20% tomato pellets, and wood pellets. The P, K, Ca and Mg contents of 20% tomato pellets was higher than combustion ash of wood pellets. N, Fe and Si contents of combustion ash of 20% tomato pellets was lower than combustion ash of wood pellets. Therefore, we suggested that combustion ash of tomato stems and leaves pellets could be utilized by mixed nitrogen fertilizer or soil of over-nitrogen. Future studies should investigate the effects of using combustion ash as an alternative fertilizer on plant growth.

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