

Full Length Research Paper

# Physico-chemical properties of indigenous micro organism-composts and humic acid prepared from selected agro-industrial residues

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Paddy husk (PH) and corn stalks (CS) residues are managed through burning. Besides contributing to environmental pollution, burning causes loss of vegetation cover, erosion, run off and loss of organic matter. In order to minimize this problem, a study was conducted to manage PH and CS residues through composting and to determine the physical and chemical properties of different composts and humic acid extracted from the final product. The study had six treatments namely: (T1) indigenous microorganisms (IMOIV)<sub>Steamed white rice (SWR)</sub>(30%)+PH (40%)+Chicken Dung (30%), (T2) <sub>SWR</sub> (30%)+CS (40%)+Chicken Dung (30%), (T3) IMOIV<sub>Aerated Fish Pond Water (AFPW)</sub>(30%)+Paddy husk (40%)+Chicken Dung(30%), (T4) IMOIV<sub>AFPW</sub> (30%)+CS (40%)+Chicken Dung(30%), (T5) IMOIV<sub>Kitchen Waste (KW)</sub>(30%)+PH (40%)+Chicken Dung (30%) and (T6) IMOIV<sub>KW</sub> (30%)+CS (40%)+Chicken Dung (30%). Composting was conducted in a white polystyrene box with a size of 30 x 15 x 25 cm. The composts produced in this study were analyzed for C:N and C:P ratio, pH (H<sub>2</sub>O and KCl), nutrients, heavy metals, organic carbon, organic matter, ash, cation exchange capacity (CEC), humic acid (HAs) and total microbial count. The HAs were evaluated for elemental composition, acidic functional groups, E<sub>4</sub>/E<sub>6</sub> ratio and spectral characteristics using standard procedures. Results show that all IMO-composts were granular, dark brown in colour without foul odour and attained an ambient temperature at 34 days of composting indicating the stable nature of the composts. The number of bacteria and filamentous fungi involved during composting decreased at the end of the all treatments. The E<sub>4</sub>/E<sub>6</sub>, acidic functional groups; carboxyl-COOH, phenolic-OH and total acidity of the compost were consistent with the standard range. IMO-compost from CS had better quality (chemical characteristics) compared to that of paddy husk. High quality compost could be produced from CS.

**Key words:** Paddy husk (PH), corn stalks (CS), indigenous microorganisms (IMO)-compost, humid acid (HA).

## INTRODUCTION

Rice and corn make up 85% of the world grain production and rice is food staples for most of the world's population while corn is the third most commonly consumed grain worldwide. 99% of harvested rice is used for human consumption with over half of the world's population

depending on rice for food and most corn is grown for food, livestock and other products such as corn syrup, sweeteners, corn oil, ethanol and industrial products, such as fuel. Both crops are cultivated globally and it is the most popular crop in Asia where the annual production is rapidly increasing to meet the domestic and export demand. However, Agro-industrial wastes have become a major problem in terms of disposal because most farmers dispose them through burning. This inexpensive method of crop residue disposal is practiced

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in many parts of the world to clear the excess residue from land for faster crop rotation, control undesirable weeds, pests and diseases and to return some nutrient to the soil.

Open burning emits a large amount of harmful air pollutants (particles and inorganic and organic gases), which have severe impact on human health, polycyclic aromatic hydrocarbons (PAHs) (Pope et al., 2009; Korenaga et al., 2001) and the danger of soil erosion due to repeated burning (Kahlon and Dass, 1987). In addition, disposal in water bodies (for example, river or lake) may contribute to a decrease in water quality. Because of these concerns, there is a need to find efficient alternatives for agro-industrial wastes management. Many alternatives for the disposal of these residues have been proposed, composting being one of the most attractive on account of its low environmental impact and cost (Bustamente et al., 2008; Canet et al., 2008; Lu et al., 2008), as well as its capacity for generating a valuable product used for increasing soil fertility (Weber et al., 2007) or as a growing medium in agriculture and horticulture (Pérez-Murcia et al., 2005). The objectives of this study were: (1) to prepare compost with the residues of CS and paddy husk, (2) to assess the properties of the substrate during the composting process to get matured compost and (3) to assess the quality of humic acid extracted from the final product.

## MATERIALS AND METHODS

Indigenous microbes were collected from three sites. (i) On undisturbed area under bamboo trees by using SWR, (ii) AFPW, UPM fish pond and (iii) KW from food stores at Universiti Putra Malaysia Bintulu Sarawak Campus. Four litres of water samples of AFPW were collected at seven different sampling points in the pond in sterile 5,000 mL bottles. KW was collected from Sri Rajang College Cafeteria (2) with a ratio of (rice, meat and a vegetable, 3:1:1). Distilled water was added gradually to equal the weight of the kitchen waste mass, 1:1 ratio and ground using food blender (Wang et al., 2005). The AFPW and KW were left to ferment at 30±2°C for 5 days until all the solid form changed to slurry form. Small wooden box (30 x 15 x 10 inches) was filled with 5 cm of SWR and covered with paper towel. Rubber bands were used around the top of the box to secure the paper towel in place. The top of the box was covered with wire screen to prevent animals from tampering with the rice. The top of the wire was covered with a sheet of plastic to protect the box from rain and it was placed under bamboo trees without direct sunlight. The box was partially buried 5 cm deep in the soil and covered with fallen leaves.

The plastic sheet was anchored on all sides with small rocks to prevent it from being dislodged by wind. The box was left for 5 days. After this period, the moist rice was covered with white mold (mycelium) and during this phase; IMO, IMO (I) was obtained. The desired microbes from different sources (SWR, AFPW and KW) were cultured to increase their population. Granulated brown sugar was added gradually to equal the weight of the molded rice mass in a ratio of 1:1. A 1,300 g of molded rice and granulated brown sugar were weighed and hand kneaded until the material had the consistency of gooey molasses and then transferred to a clean glass bottle filled two-third full and covered with paper towel secured in place with rubber bands. The bottle was stored at

30±2°C away from direct sunlight for 5 days to allow the mixture to ferment (Hoon and Michael, 2008). Similar procedure was used to process AFPW and KW. After this period, second phase of indigenous microorganisms called IMO (II) was carried out. A 2.5 g of fermented SWR, AFPW and KW were mixed with 1,000 mL fermented rice waste water for each followed by the addition of 2,500 g of ground corn until the mixture was semi moist (roughly 65 to 70% moisture).

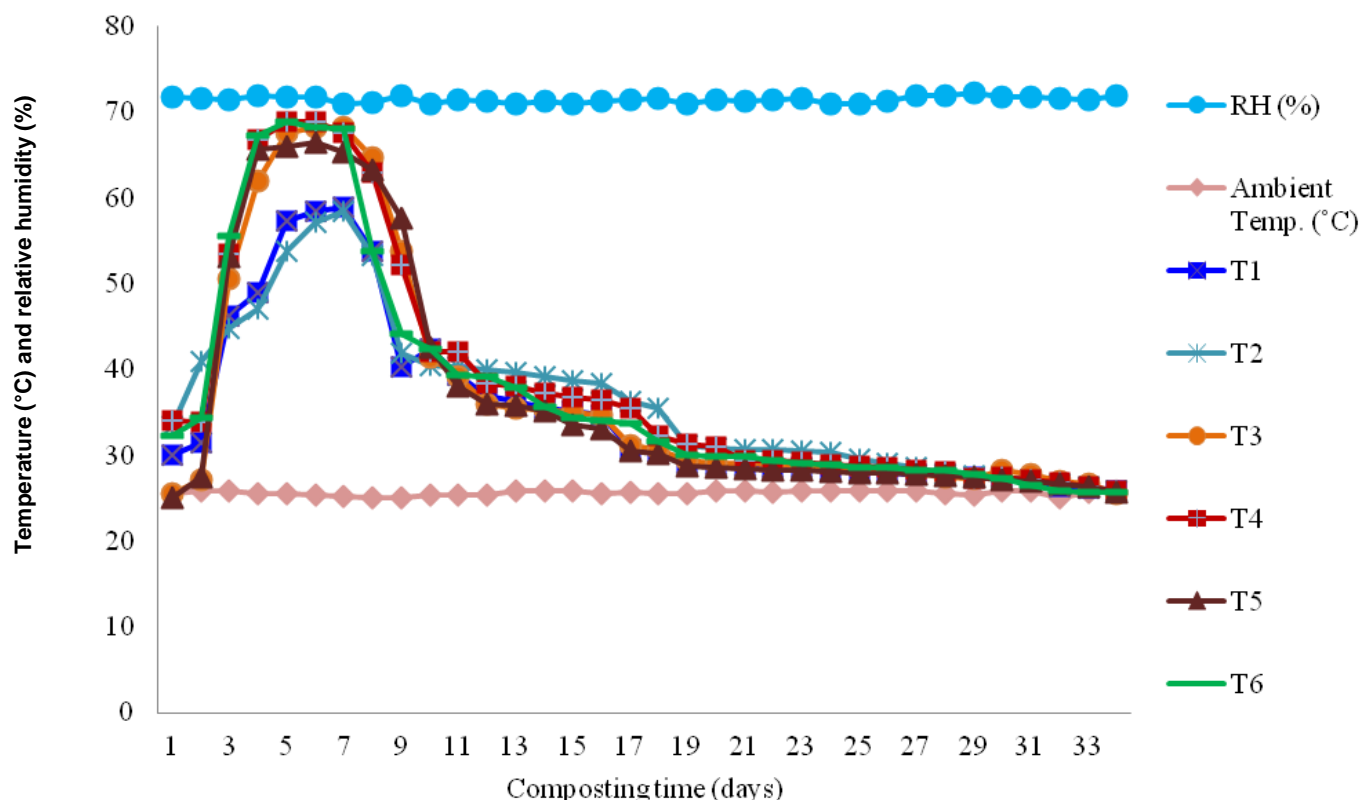
A mound of the mixture was placed in polystyrene box at 30±2°C to protect it from the sunlight and allow the microbes to propagate for 5 days and IMO (III) was produced in this phase. A 3,502.5 g of IMO (III) and air dried soil were mixed gradually and allowed to ferment for 15 days at 30±2°C. At this stage, IMO (IV) was produced. The two agro-industrial wastes; CS and PH were collected from university farm, Universiti Putra Malaysia Bintulu Campus Sarawak. The selected wastes were air dried and ground (approximately 2 mm in size) for composting. A mound of the substrate was placed inside a white polystyrene box with a size of 30 x 15 x 25 cm and protected from direct sunlight in a controlled condition. The study had the following treatments:

1. (T1) IMO(IV)Steamed white rice (SWR)(30%)+Paddy Husk(40%)+Chicken Dung(30%)
2. (T2) IMO(IV)Steamed white rice (SWR)(30%)+Corn Stalk(40%)+Chicken Dung(30%)
3. (T3) IMO(IV) AFPW (30%)+PH (40%)+Chicken Dung(30%)
4. (T4) IMO(IV) AFPW (30%)+CS (40%)+Chicken Dung(30%)
5. (T5) IMO(IV) KW (30%)+PH (40%)+Chicken Dung(30%)
6. (T6) IMO(IV)KW (30%)+CS (40%)+Chicken Dung(30%)

Composting was carried out for 34 days until the temperature of pile was equalled ambient temperature. The external surface and internal pile was periodically examined in the morning, afternoon and evening daily using a digital thermometer. Each time the pile temperature declined after a peak, the mixture was manually turned and the moisture of the compost was maintained at 65%. The amount of added water was calculated on the basis of the material moisture content prior to turning. The compost was air-dried and analyzed. Kjeldhal method was used to determine total N (Bremner, 1965). Decomposition was calculated after ignition of the dry sample at 550°C for 8 h (Tan, 2005). Compost total P was extracted using the single dry ashing method followed by blue method (Murphy and Riley, 1962). Cations were extracted using the leaching method (Tan, 2005) and their concentrations determined using atomic absorption spectrometry (AAS). Compost CEC was determined by the leaching method followed by steam distillation (Bremner, 1965).

The pH of the compost was determined in 1:4 compost:distilled water suspension and KCl using a glass electrode (Tan, 2005). The HAs extraction was carried out by method of Stevenson (1994). The HA was purified by the method of Ahmed et al. (2004), using distilled water and through centrifugation at 10,000 rpm for 10 min to reduce mineral matter and HCl during acidification. After the purification, the HA was oven dried at 40°C until constant weight was attained. The ash, organic carbon and organic matter of the HA were determined by the dry combustion method (Chefetz et al., 1996). Carboxylic-COOH, phenolic-OH and total acidity of HA were determined using the method described by Inbar et al. (1990). Level of humification (E4/E6) of HA was determined by spectroscopy (Campitelli and Ceppi, 2008) and analyzed using ultraviolet/visible (UV-Vis) spectrophotometer (Perkin-Elmer Lambda 11). The transmission fourier transform infrared (FT-IR) spectra were recorded on pellets obtained by pressing a mixture of about 1 mg of HA and 100 mg of KBr (FT-IR grade).

A pellet was prepared using a press and FT-IR spectra were recorded using Nicolet 380 FT-IR spectrometer. A spectrum was acquired in the 4000 to 400 cm<sup>-1</sup> range with 2 cm<sup>-1</sup> resolution



**Figure 1.** Evolution of the temperature within the piles in different treatments of IMO-compost and ambient temperature with relative humidity.

and 32 scans were performed on each acquisition. All the experiments were conducted in a completely randomized design (CRD) with three replications. The data were subjected to analysis of variance (ANOVA) and tested for significance using Tukey's Test (SAS version 9.2) by PC-SAS software (SAS Institute, Cary, NC, USA, 2008). A representative sub-sample (10 g) was taken from 4 different point of homogenized compost pile inside polystyrene box (bottom, surface, side and centre) at each stage of composting raw mixture (1, 2, 3, 4 and 5 weeks of composting) to determine the total aerobic mesophilic and filamentous fungi (USEPA, 1999). A sub-sample of 10 g biosolid was added to 90 mL sterile buffered peptone solution using an aseptic technique to allow the microorganism to migrate into the solution. Series of dilutions were prepared ( $10^{-1}$ ,  $10^{-2}$  ...  $10^{-10}$ ) using a sterile 0.8% NaCl solutions. Microorganisms were counted after plated sterile Petri dishes with 0.1 mL from diluted liquid and incubated at the temperatures ( $30 \pm 2^\circ\text{C}$ ) for 48 to 72 h for total aerobic mesophilic (plate count agar) and filamentous fungi (potato dextrose agar).

## RESULTS AND DISCUSSION

The temperature variation (Figure 1) went through typical changes for each type of substrate and process used (Miller, 1996) indicating the critical role temperature of in composting. During aerobic composting, the average temperature curve of the treatments showed four phases (Figure 1). Initial, mesophilic phase, psychrophilic and

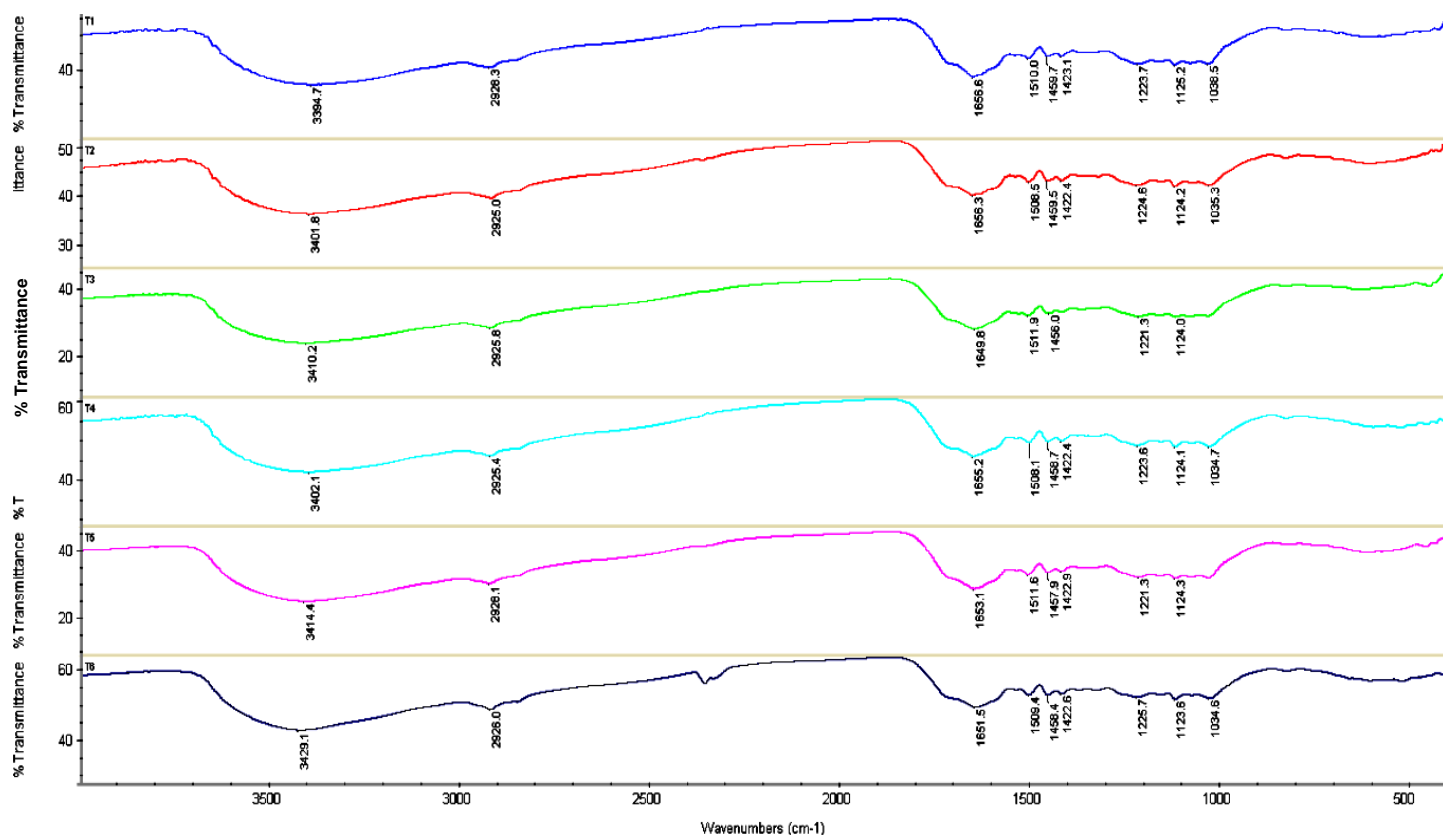
mesophilic microorganisms in the piles increased during the second day of composting (Figure 1). During this phase, temperature increased to 10 to  $42^\circ\text{C}$  as a consequence of biodegradation of organic compounds (Morita, 1975) thermophilic phase. The temperature of the composts reached the thermophilic phase ( $>50^\circ\text{C}$ ) between 3 to 5 days of composting. This was the stage where temperature exceeds tolerance limit of mesophilic microorganisms and promoted the development of thermogenic microorganisms (Figure 1). The microorganisms consumed soluble organic matter and ambient nutrients, which then underwent aerobic degradation to generate heat, biomass and carbon dioxide (Middle mesophilic phase).

The compost temperature of T1, T2 and T6 decreased from 65 to  $50^\circ\text{C}$  at day 8, while those of the other treatments decreased slowly at day 9 cooling phase. The composts temperature decreased after day 10. This decrease could be attributed to depletion of organic matter (Figure 1). The main physico-chemical properties of the composts are presented in Table 1. The pH values were within the optimal range for the development of bacteria 6 to 7.5 and fungi 5.5 to 8. Two phases of the composting process were recorded: a phase of stabilization (about 29 days) where temperature peaked

**Table 1.** Physico-chemical properties of different (initial and final) IMO-composts.

<b>Characteristic</b>	<b>T1</b>	<b>T2</b>	<b>T3</b>	<b>T4</b>	<b>T5</b>	<b>T6</b>
<b>Initial</b>						
pH <sub>water</sub>	6.84 <sup>cb</sup>	7.44 <sup>abc</sup>	6.73 <sup>bc</sup>	7.85 <sup>a</sup>	6.64 <sup>bc</sup>	7.57 <sup>ab</sup>
pH <sub>KCl</sub>	6.60 <sup>bc</sup>	7.12 <sup>a</sup>	6.69 <sup>abc</sup>	7.05 <sup>ab</sup>	6.56 <sup>c</sup>	7.13 <sup>a</sup>
Total N (%)	4.46 <sup>a</sup>	3.49 <sup>a</sup>	3.11 <sup>a</sup>	4.10 <sup>a</sup>	3.92 <sup>a</sup>	3.17 <sup>a</sup>
Total P (%)	0.68 <sup>ab</sup>	0.84 <sup>a</sup>	0.73 <sup>ab</sup>	0.74 <sup>ab</sup>	0.76 <sup>ab</sup>	0.67 <sup>b</sup>
TOC (%)	38.70 <sup>bc</sup>	40.60 <sup>ab</sup>	38.67 <sup>bc</sup>	42.15 <sup>a</sup>	37.12 <sup>c</sup>	39.83 <sup>abc</sup>
C:N ratio	9.06 <sup>a</sup>	12.12 <sup>a</sup>	12.82 <sup>a</sup>	10.39 <sup>a</sup>	9.49 <sup>a</sup>	13.19 <sup>a</sup>
C:P ratio	56.76 <sup>a</sup>	48.69 <sup>a</sup>	52.96 <sup>a</sup>	56.83 <sup>a</sup>	49.46 <sup>a</sup>	57.25 <sup>a</sup>
CEC (cmol kg <sup>-1</sup> )	45.00 <sup>b</sup>	53.33 <sup>ab</sup>	52.67 <sup>ab</sup>	58.33 <sup>ab</sup>	52.67 <sup>ab</sup>	64.00 <sup>a</sup>
Ash (%)	33.33 <sup>ab</sup>	30.00 <sup>bc</sup>	33.33 <sup>ab</sup>	27.33 <sup>c</sup>	36.00 <sup>a</sup>	31.33 <sup>abc</sup>
OM (%)	66.67 <sup>bc</sup>	70.00 <sup>ab</sup>	66.67 <sup>bc</sup>	72.67 <sup>a</sup>	64.00 <sup>c</sup>	68.67 <sup>abc</sup>
HA (%)	1.77 <sup>cd</sup>	4.13 <sup>ab</sup>	2.53 <sup>bcd</sup>	3.77 <sup>abc</sup>	1.60 <sup>d</sup>	4.73 <sup>a</sup>
<b>Macronutrients</b>						
K (%)	0.90 <sup>b</sup>	1.60 <sup>a</sup>	0.96 <sup>b</sup>	1.49 <sup>a</sup>	0.98 <sup>b</sup>	1.34 <sup>a</sup>
Ca (%)	0.89 <sup>a</sup>	1.09 <sup>a</sup>	0.95 <sup>a</sup>	1.06 <sup>a</sup>	1.06 <sup>a</sup>	1.06 <sup>a</sup>
Na (mg kg <sup>-1</sup> )	1656.70 <sup>a</sup>	2040.00 <sup>a</sup>	1710.00 <sup>a</sup>	2073.30 <sup>a</sup>	1900.00 <sup>a</sup>	1900.00 <sup>a</sup>
Mg (mg kg <sup>-1</sup> )	2710.00 <sup>b</sup>	3710.00 <sup>a</sup>	2873.30 <sup>ab</sup>	3316.70 <sup>ab</sup>	3266.70 <sup>ab</sup>	2990.00 <sup>ab</sup>
<b>Heavy metals</b>						
Fe (mg kg <sup>-1</sup> )	68.30 <sup>a</sup>	370.00 <sup>a</sup>	1066.70 <sup>a</sup>	728.30 <sup>a</sup>	572.50 <sup>a</sup>	1015.00 <sup>a</sup>
Cu (mg kg <sup>-1</sup> )	1480.00 <sup>a</sup>	1276.70 <sup>b</sup>	1383.30 <sup>ab</sup>	1406.70 <sup>a</sup>	1483.30 <sup>a</sup>	1470.00 <sup>a</sup>
Zn (mg kg <sup>-1</sup> )	85.00 <sup>a</sup>	150.00 <sup>a</sup>	86.67 <sup>a</sup>	118.33 <sup>a</sup>	83.33 <sup>a</sup>	91.67 <sup>a</sup>
<b>Final</b>						
pH <sub>water</sub>	7.93 <sup>c</sup>	8.40 <sup>ab</sup>	8.16 <sup>bc</sup>	8.27 <sup>abc</sup>	7.96 <sup>c</sup>	8.58 <sup>a</sup>
pH <sub>KCl</sub>	7.35 <sup>b</sup>	8.29 <sup>a</sup>	7.47 <sup>b</sup>	8.10 <sup>a</sup>	7.47 <sup>b</sup>	8.25 <sup>a</sup>
Total N (%)	3.80 <sup>a</sup>	3.66 <sup>a</sup>	3.85 <sup>a</sup>	5.75 <sup>a</sup>	3.75 <sup>a</sup>	4.33 <sup>a</sup>
Total P (%)	0.89 <sup>bc</sup>	1.13 <sup>a</sup>	0.88 <sup>bc</sup>	1.24 <sup>ab</sup>	0.86 <sup>c</sup>	1.12 <sup>abc</sup>
TOC (%)	31.71 <sup>a</sup>	36.73 <sup>a</sup>	33.25 <sup>a</sup>	25.13 <sup>a</sup>	32.09 <sup>a</sup>	30.16 <sup>a</sup>
C:N ratio	8.37 <sup>a</sup>	10.06 <sup>a</sup>	8.93 <sup>a</sup>	4.44 <sup>a</sup>	8.63 <sup>a</sup>	7.60 <sup>a</sup>
C:P ratio	36.11 <sup>a</sup>	32.38 <sup>a</sup>	38.37 <sup>a</sup>	20.04 <sup>a</sup>	38.38 <sup>a</sup>	27.09 <sup>a</sup>
CEC (cmol kg <sup>-1</sup> )	66.00 <sup>b</sup>	64.00 <sup>b</sup>	62.67 <sup>b</sup>	83.33 <sup>a</sup>	59.33 <sup>b</sup>	89.67 <sup>a</sup>
Ash (%)	45.33 <sup>a</sup>	36.67 <sup>a</sup>	42.67 <sup>a</sup>	56.67 <sup>a</sup>	44.67 <sup>a</sup>	48.00 <sup>a</sup>
OM (%)	54.67 <sup>a</sup>	63.33 <sup>a</sup>	57.33 <sup>a</sup>	43.33 <sup>a</sup>	55.33 <sup>a</sup>	52.00 <sup>a</sup>
HA (%)	3.97 <sup>c</sup>	9.70 <sup>ab</sup>	5.47 <sup>c</sup>	11.60 <sup>a</sup>	4.33 <sup>c</sup>	8.40 <sup>b</sup>
<b>Macronutrients</b>						
K (%)	1.12 <sup>b</sup>	2.27 <sup>a</sup>	1.11 <sup>b</sup>	2.43 <sup>a</sup>	1.14 <sup>b</sup>	2.21 <sup>a</sup>
Ca (%)	0.97 <sup>b</sup>	1.33 <sup>a</sup>	1.01 <sup>b</sup>	1.43 <sup>a</sup>	1.03 <sup>b</sup>	1.34 <sup>a</sup>
Na (mg kg <sup>-1</sup> )	1720.00 <sup>b</sup>	2476.70 <sup>a</sup>	1986.70 <sup>ab</sup>	2493.30 <sup>a</sup>	1800.00 <sup>b</sup>	2380.00 <sup>ab</sup>
Mg (mg kg <sup>-1</sup> )	3453.30 <sup>c</sup>	5076.70 <sup>a</sup>	3566.70 <sup>bc</sup>	5230.00 <sup>a</sup>	3533.30 <sup>bc</sup>	4696.70 <sup>ab</sup>
<b>Heavy metals</b>						
Fe (mg kg <sup>-1</sup> )	2220.00 <sup>abc</sup>	3670.00 <sup>a</sup>	931.70 <sup>bc</sup>	2006.70 <sup>abc</sup>	676.70 <sup>c</sup>	2778.30 <sup>ab</sup>
Cu (mg kg <sup>-1</sup> )	923.30 <sup>d</sup>	1220.00 <sup>b</sup>	1073.30 <sup>c</sup>	1426.70 <sup>a</sup>	1193.30 <sup>bc</sup>	1480.00 <sup>a</sup>
Zn (mg kg <sup>-1</sup> )	175.00 <sup>cd</sup>	281.67 <sup>ab</sup>	111.67 <sup>d</sup>	308.33 <sup>a</sup>	140.00 <sup>cd</sup>	211.67 <sup>bc</sup>

Different letters within a column indicate significant difference between means using Tukey's Test at p = 0.05. nd: Not determined.



**Figure 2.** FT-IR spectra of extracted HAs in different treatments final IMO-compost.

at 68°C after 5 days of processing and pH slightly increased to 8.5 due to biodegradation of acid compounds (carboxylic and phenolic groups) or because of the mineralization of protein, amino acids and so on. The change in the C:N and C:P ratios from 13.19 and 57.25 to 10.06 and 38.38 and the amount of ash could be attributed to microbial activity on the cellulosic substrate and nitrogen (Table 1). The high ash content suggests high mineral matter in the composts. The increase in total nitrogen during composting was caused by decrease in substrate carbon (Soumare et al., 2002). Organic matter is decomposed and transformed to stable humic compounds (Amir et al., 2004). The final compost had higher content of HAs suggesting stability of it (Auldry et al., 2009; Auldry et al., 2010).

The high  $E_4/E_6$  ratios had a lower degree of aromatic condensation and the presence of a relatively large proportion of aliphatic structure (Campitelli et al., 2006; Rivero et al., 2004) and this observation is consistent with a previous study (Wei et al., 2007) where it was reported that composts had lower degree of aromatization compared to the soil. The carbon content of the HA of the compost was in the range of standard values (Table 2). The values of acidic functional groups; carboxyl-COOH, phenolic-OH and total acidity of humic acid of the compost were consistent with the standard range. The

FT-IR spectra of HAs of the composts are shown in Figure 2. The FT-IR spectra showed that the HAs from the different composts had the features typical of HAs. In general, the spectra of the composts were similar. The major spectral bands were assigned as follows: the broad at about 3300 to 3400  $\text{cm}^{-1}$  was due to O-H stretching of phenolic or alcoholic hydroxyl groups. The band at 2920 to 2930  $\text{cm}^{-1}$  represents aliphatic C-H vibrations of aliphatic methyl and methylene groups (Orlov, 1986).

The carboxylic band at 1730  $\text{cm}^{-1}$  forms only a shoulder on the main band at about 1600 to 1660  $\text{cm}^{-1}$  and it can be assigned to C=O vibrations of carboxylates, C=C vibrations aromatic and olefinic; amide (I), ketone and quinone groups (Piccolo et al., 1992; Stevenson, 1982). The bands at 1510 to 1550  $\text{cm}^{-1}$ ; 1380 to 1480  $\text{cm}^{-1}$ ; 1220 to 1280  $\text{cm}^{-1}$  and 1030 to 1070  $\text{cm}^{-1}$  could be attributed to N-H deformation of aromatic amine or amide (amide-II band); C-H deformation and CH<sub>3</sub> symmetric and asymmetric stretching; carboxylic C-O stretching and phenol C-O-H deformation and C-O-C of carbohydrates, aromatic ethers, Si-O-C groups (Fukushima et al., 1996; Wang et al., 1990; Stevenson and Goh, 1971). Microbial activity during composting was mainly due to the aerobic mesophilic community. Regardless of treatments, they were between  $4.76 \times 10^8$  to  $3.17 \times 10^8$  CFUg<sup>-1</sup> of fresh compost. That of filamentous fungi ranged between 4.92

**Table 2.** Comparison of the chemical properties of HAs in different treatments of final IMO-composts.

Characteristic	T1	T2	T3	T4	T5	T6	Standard range*
HA (%)	3.97 <sup>c</sup>	9.70 <sup>ab</sup>	5.47 <sup>c</sup>	11.60 <sup>a</sup>	4.33 <sup>c</sup>	8.40 <sup>b</sup>	nd
E4/E6	9.77 <sup>a</sup>	8.78 <sup>a</sup>	8.23 <sup>a</sup>	9.11 <sup>a</sup>	8.09 <sup>a</sup>	8.76 <sup>a</sup>	7-8
Carbon (%)	53.94 <sup>d</sup>	56.26 <sup>a</sup>	53.29 <sup>e</sup>	55.10 <sup>c</sup>	55.68 <sup>b</sup>	56.26 <sup>a</sup>	56-62
Phenolic	133.33 <sup>a</sup>	100.00 <sup>a</sup>	133.33 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	166.67 <sup>a</sup>	240-540
Carboxylic	266.67 <sup>a</sup>	250.00 <sup>a</sup>	283.33 <sup>a</sup>	266.67 <sup>a</sup>	316.67 <sup>a</sup>	266.67 <sup>a</sup>	150-440
Total acidity	400.00 <sup>a</sup>	350.00 <sup>a</sup>	416.67 <sup>a</sup>	366.67 <sup>a</sup>	416.67 <sup>a</sup>	433.33 <sup>a</sup>	500-700
OM (%)	93.00 <sup>d</sup>	97.00 <sup>a</sup>	92.00 <sup>e</sup>	95.00 <sup>c</sup>	96.00 <sup>b</sup>	97.00 <sup>a</sup>	nd
Ash (%)	7.00 <sup>b</sup>	3.00 <sup>e</sup>	8.00 <sup>a</sup>	5.00 <sup>c</sup>	4.00 <sup>d</sup>	3.00 <sup>e</sup>	nd

Different letters within a column indicate significant difference between means using Tukey's Test at  $p = 0.05$ . \*Standard data range (Tan, 2003). nd: Not determined.

**Table 3.** Microbial account in different treatments during composting (expressed as CFU g/fresh material).

Characteristics	T1	T2	T3	T4	T5	T6
<b>1<sup>st</sup> week</b>						
Aerobic mesophile (CFUg <sup>-1</sup> )	4.42 x 10 <sup>8</sup>	4.59 x 10 <sup>8</sup>	4.76 x 10 <sup>8</sup>	4.37 x 10 <sup>7</sup>	3.97 x 10 <sup>7</sup>	3.17 x 10 <sup>8</sup>
Filamentous fungi (CFUg <sup>-1</sup> )	4.92 x 10 <sup>7</sup>	4.23 x 10 <sup>7</sup>	3.54 x 10 <sup>7</sup>	3.44 x 10 <sup>7</sup>	3.33 x 10 <sup>7</sup>	2.25 x 10 <sup>7</sup>
<b>2<sup>nd</sup> week</b>						
Aerobic mesophile (CFUg <sup>-1</sup> )	2.66 x 10 <sup>b</sup>	2.95 x 10 <sup>b</sup>	3.24 x 10 <sup>b</sup>	2.80 x 10 <sup>b</sup>	2.36 x 10 <sup>b</sup>	1.92 x 10 <sup>b</sup>
Filamentous fungi (CFUg <sup>-1</sup> )	3.21 x 10 <sup>6</sup>	1.11 x 10 <sup>5</sup>	1.96 x 10 <sup>5</sup>	1.76 x 10 <sup>5</sup>	1.55 x 10 <sup>5</sup>	1.98 x 10 <sup>5</sup>
<b>3<sup>rd</sup> week</b>						
Aerobic mesophile (CFUg <sup>-1</sup> )	2.38 x 10 <sup>4</sup>	2.32 x 10 <sup>4</sup>	2.25 x 10 <sup>4</sup>	2.33 x 10 <sup>4</sup>	1.48 x 10 <sup>5</sup>	1.22 x 10 <sup>5</sup>
Filamentous fungi (CFUg <sup>-1</sup> )	1.83 x 10 <sup>4</sup>	1.06 x 10 <sup>3</sup>	0.85 x 10 <sup>3</sup>	1.13 x 10 <sup>3</sup>	0.95 x 10 <sup>3</sup>	1.16 x 10 <sup>4</sup>
<b>4<sup>th</sup> week</b>						
Aerobic mesophile (CFUg <sup>-1</sup> )	1.35 x 10 <sup>3</sup>	1.80 x 10 <sup>3</sup>	1.76 x 10 <sup>4</sup>	1.16 x 10 <sup>4</sup>	1.32 x 10 <sup>4</sup>	1.20 x 10 <sup>4</sup>
Filamentous fungi (CFUg <sup>-1</sup> )	1.08 x 10 <sup>3</sup>	<10	<10	<10	<10	1.15 x 10 <sup>3</sup>
<b>5<sup>th</sup> week</b>						
Aerobic mesophile (CFUg <sup>-1</sup> )	1.20 x 10 <sup>2</sup>	1.70 x 10 <sup>2</sup>	1.58 x 10 <sup>2</sup>	1.13 x 10 <sup>2</sup>	1.12 x 10 <sup>2</sup>	1.10 x 10 <sup>2</sup>
Filamentous fungi (CFUg <sup>-1</sup> )	<10	<10	<10	<10	<10	<10

CFU = Colony formed unit.

x 10<sup>6</sup> to 2.25 x 10<sup>6</sup> CFUg<sup>-1</sup> of fresh compost (Table 3). The microbial density decreased after 4 weeks of composting. The range was between 1.80 x 10<sup>3</sup> and 1.16 x 10<sup>4</sup> of total aerobic mesophilic. No filamentous fungi were detected in T2 (IMOSWR-CS), T3 (IMOAFPW-PH), T4 (IMOAFPW-CS) and T5 (IMOKW-PH) while the result shown 1.08 x 10<sup>3</sup> on T1 (IMOSWR-PH) and 1.15 x 10<sup>3</sup> on T6 (IMOKW-CS).

Results show that at the early phase of the composting process (temperature of 20 to 40°C) mesophilic bacteria were the dominant degraders of fresh organic residue. Mesophilic microorganisms were partially killed or inactivated during the thermogenic stage (temperature 40

to 60°C). On compost sanitation, pathogen fungi received more attention than any other microorganisms (Strauch, 1996). Fungi and spores are known to be resistant to adverse conditions and longevity in soil, although they are unable to withstand the temperature that prevails in compost piles during peak heating. Other major environmental factors such as temperature, moisture content and acidity may have caused elimination of fungi and their propagules during composting (Beffa et al., 1996; Bollen, 1993). In this study, the number of filamentous fungi decreased slowly which may be explained by the non-aggressive environmental factors prevailing in the residues heap at the end of the composting process:

medium temperature and moisture content and a slight alkalinisation (pH around 7.9 to 8.2).

## Conclusion

IMO-compost from CS had better quality (chemical characteristics) compared to that of PH. High quality compost could be produced from CS.

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## Abbreviations:

**PH**, Paddy husk; **CS**, corn stalks; **IMO**, indigenous microorganisms; **SWR**, steamed white rice; **AFPW**, aerated fish pond water; **KW**, kitchen waste; **HAs**, humic acid; **CEC**, cation exchange capacity.

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