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CO-COMPOSTING OF RICE STRAW

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ABSTRACT

In the first study, rice straw was amended with animal manure and molasses (windrow A) in ratio of 1: 0.88 : 0.04 , and the second study , rice straw was blended with chicken manure and molasses (windrow B) in ratio of 1 : 0.58: 0.02 The changes in physicochemical pattern and microbiological dynamics were studied during the composting period. Windrow B gave the highest values of temperature at earlier stages of composting process. There was no difference in pH and C: N ratio detected in the both studies. The final pH and C: N ratio of windrows A and B were 7.7 & 7.3 and 15.8 & 11, respectively.

Total microbial activity increased during the thermophilic phase and decreased again during maturation in both windrows A and B. Bacteria dominated during the thermophilic phase while fungi, actinomycetes and yeasts were below the detection time. However, they regrew again in the later stage (maturation phase). Spore-forming bacteria were detected throughout the entire processes, reaching a peak value 9.2 and 9.8 $\log_{10}$ CFU g^{-1} dry wt for windrows A and B, respectively. The highest activity of cellulolytic bacteria was observed during the thermophilic stage, and then declined during curing phase.

In comparison of the composting performance between windrows A and B , the study found that rice straw blended chicken manure (windrow B) offered the better organic matter decomposition pattern with the highest value of microbial load.

Key words: animal manure, co-composting, chicken manure, straw and microbial dynamics

INTRODUCTION

Fibrous by-products such as cereal straws are very abundant and likely to increase in quantity in the future because the urging need to produce more and more cereal grains for human consumption.

Straw are almost entirely made of cell-walls. And cell-walls are made of highly lignified structural carbohydrates and of small amounts of structural proteins and minerals.

Straws are actually under-utilized as animal feed; due to their low digestibility there were technical possibilities of upgrading of nutritive value of straws by means of the proper association with other ingredients to make good compost.

Composting is an attractive prospective in a policy of waste recycling to produce humus-like compounds to be used for improvement both soil and plant growth. Composting is an aerobic process in which microorganisms convert a mixed organic substrate into carbon dioxide, water, minerals and stabilized organic matter under controlled conditions, particularly of moisture and aeration are required to yield temperature conductive to the microorganisms involved in the composting process (Chen and Inbar, 1993).This process has many advantages including sanitation, mass and bulk reduction and decrease C: N ratio. The stabilized compost produced should benefit the plant growth and be suitable for agricultural applications (Campbell *et al* 1995).

Rice straw is rich in carbon and poor in nitrogen, which limits the composting process. This high C: N can be decreased by increasing the basal nitrogen content of rice straw by adding different organic matter and chicken manure. Rapid composting requires two kinds of substrates: carbon–rich materials such as rice straw, nitrogen-rich materials like animal manure and chicken manure (Hellal, 2007). In this respect, Rashid et al (2001) compared the rice straw and nitrogen materials (cow dung + soybean plants) at rates from 70 to 100% rice straw. The mixture containing 70 % rice straw produced the most suitable compost in terms of maturity and nutrient status.

Composting of rice straw with poultry manure and oilseed rape cake and its application at 20-30 g pot^{-1} to faba bean plants improved selected soil chemical, physical and biological properties (Abdelhamid *et al* 2004). Lee (2006) reported that the mixture containing 70-80% rice straw and 60-70% hardwood bark were produced the most suitable compost in terms of nutrients and maturity .Hellal (2007) reported that compost produced from the mixture of rice straw and chicken manure gave the highest straw yield of barely in calcareous soil.

The main objective of this study was to investigate the performance of the composting rice straw with animal manure or chicken manure using co-composting method and to optimize its use.

MATERIALS AND METHODS

1-Raw materials for composting:

Rice straw was collected from farm of Agriculture Faculty, Ain Shams University, Egypt, stored and minced manually to 2.5-5cm in size. They were mixed with animal manure or chicken manure and molasses.

Windrow (A) contained rice straw, animal manure and molasses in ratio 1: 0.88: 0.04 and windrow (B) contained rice straw, chicken manure and molasses in ratio 1: 0.58: 0.02. Physical and chemical of raw materials characteristics are reported in Table (1).

The equations of Richard and Nancy (1996) were used to adjust the desirable moisture content 60% and proper level of C: N ratio 30:1 without excessive change of moisture content.

Table (1) Characteristics of raw materials

Material	Carbon%	Nitrogen%	C:N ratio	Moisture content%
Rice straw	47.0	0.67	70.0	15
Animal manure	35.0	1.70	20.5	77
Chicken manure	43.0	2.40	18.0	54
Molasses	31.5	5.10	6.20	43

2-Composting operation:

Two separate batch windrows were set-up for this study. Each windrow consisted of cement basin filled with mixture of rice straw, animal manure or chicken manure and molasses.

Rice straw and animal manure or chicken manure was put in alternate layers and molasses was spread on each layer. After filling, the pile was covered with a layer of rice straw of 15 cm. The materials were allowed to remain in the pile with turning every day in the first 9 days and weekly thereafter and watering for three months. Moisture content was maintained at 60% throughout the active period by frequent checking. Temperature was measured periodically at three sites of the piles (top, middle and bottom) at 0, 1, 3, 5, 7, 9, 15, 20, 25, 30, 40, 50 and 60 days, prior to each turning. Samples were taken for analysis immediately after turning. A sample was a composite of 6 composted samples taken from different sites of the piles. Electrical conductivity (EC), pH, total ash, total nitrogen (TN) and microbiological pattern were determined. Compost pH and EC were measured at a week intervals for the composting period.

3-Physical and chemical analysis:

Samples taken from three sites of the piles were assembled, mixed and used to determine moisture content where the weight loss at 105 °C for 3 h was recorded. The temperature was continuously measured in the composting pile using measuring lances. Compost pH and EC were measured on wet compost to water mix in ratio 1: 5 (Rynk, 1992). Total ash was measured by burning the samples at 550 °C for 4 h up to a constant weight and total nitrogen (TN) was determined by Kjeldahl method (AOAC, 1990). Organic carbon was calculated according to Adams *et al* (1951):

Percentage of organic carbon= % volatile solids (VS) ÷1.8
where %VS = 100 - % ash.

4-Microbiological analysis:

The total aerobic heterotrophic culturable mesophilic bacteria (THB) were determined by the dilution plate count technique on nutrient agar. The plates were incubated for 3 days at 30° C (Hassen *et al* 2001).

For the enumeration of spore- forming bacteria, the same substrate was used but the samples were pre-incubated in the water-bath at 80 °C for 10 min (Hassen *et al* 2001) . Cellulolytic bacteria were determined according to method of Hendricks *et al* (1995) and Actinomycetes was measured on ISP medium 4 and incubated at 30 °C for 7 days (Lacey, 1973). The number of viable yeasts and filamentous fungi was measured by plating appropriately diluted suspension onto Sabouraud- Dextrose Agar supplemented with 30μg/ml streptomycin and incubated at 30° C for two days (Booth, 1971).

RESULTS AND DISCUSSION

1-Physical and chemical evaluation during composting processes:

1.1. Temperature

Temperature of composting piles increased rapidly within the first three days of composting processes (Fig 1), then gradually decline and finally stabilized near ambient level within 35 to 50 days of composting. Windrow B gave the highest values of temperature at earlier stages of composting processes and remained at this value for 15 days before it declined to the ambient temperature (Fig 1).

High temperature has been considered as consequences of microbial activity, where heat is liberated through respiration of microbes and built up within the pile (De Bertoli *et al* 1983, Tiquia *et al* 1996 and Tiquia & Tam, 2000). As well as, the temperature in a compost pile is indicative of the intensity of activity of the microorganisms as the convert the biodegradable organic matter such as carbohydrate, amino acids and others in the added molasses into compost piles. Whereas, decreasing trend in temperature levels near to the incubation end may be due to decreasing the microbial activity and the greater resistance to decomposition of remaining carbon compounds (Palm and Sanchez, 1991).Thus, temperature is one of the standard parameters for evaluating the effectiveness of composting process.

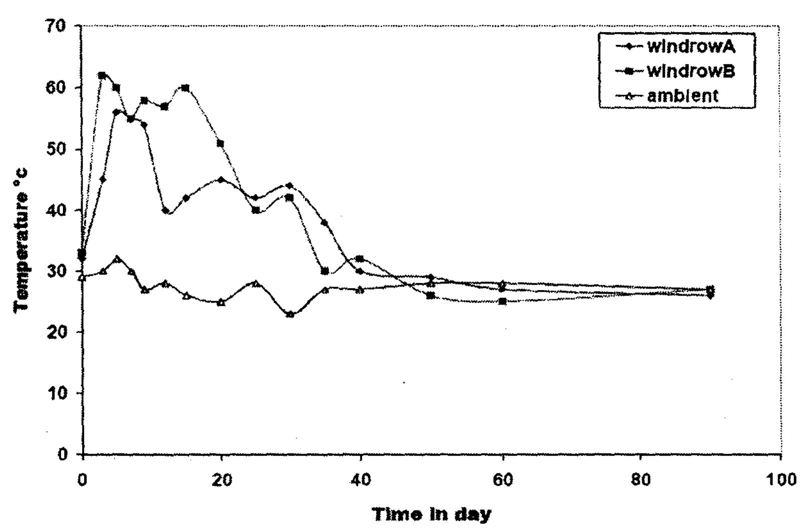

Fig. (1) Changes in temperature during composting processes

1.2. pH

At the first stage of composting processes, pH was around 6.3 and 6.5 for windrows A and B, respectively, and this parameter underwent considerable change from an initial pH of 7.5 for windows A and B to 6.3 and 6.5, respectively in the first stage due to the formation of carbon dioxide and organic acids resulting the decomposition of simple carbohydrate in molasses by the indigenous microorganisms of raw materials, then the pH frequently rises, as ammonia is liberated during protein degradation (Rynk *et al* 1992). The final pH of composting processes was 7.7 and 7.3, respectively (Fig 2).

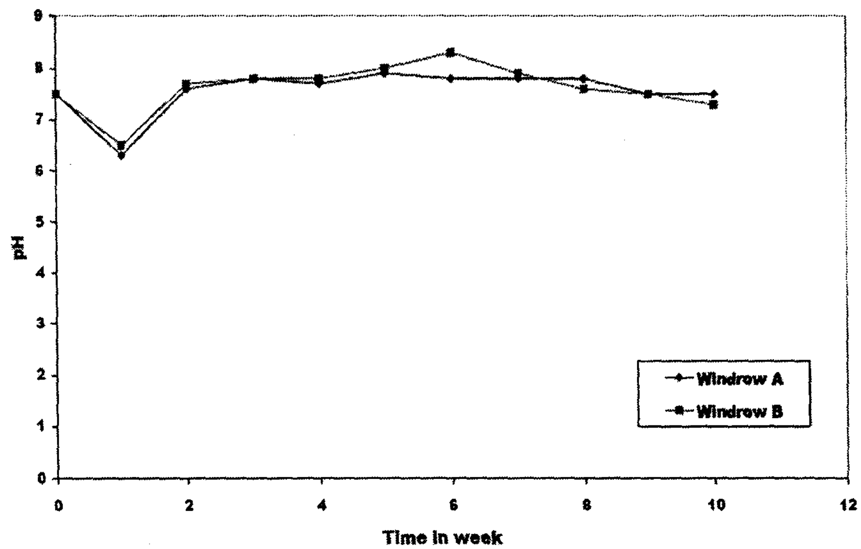

Fig. (2) Changes in pH during composting processes

1.3. EC

Data illustrated by Fig (3) show that the initial EC value for windrow A was higher than windrow B. During composting processes EC values were decreased gradually to reach the minimum values after 2 weeks and still up to 5 weeks constant, then increased gradually to reach the maximum values after ten weeks being 2.4 and 2.3 dS/m for windrows A and B, respectively. Loss of organic matter due to microbial degradation and concentration of salts might be the reason for this decrease and followed an increase. Different treatments mixtures showed different in EC during composting time, but at the end of processes the winderows had the same value of EC. This data was similar with obtained by Guerra-Rodriguez et al (2003). They studied co-composting of barley with liquid poultry manure and found that elcterical conductivity increased with composting time. The observed EC values are comparable with the values reported with Tiquia and Tam, (2002); Abdelhamid *et al* (2004) and Kumar *et al* (2007).

1.4. C : N ratio

Carbon to nitrogen ratio is one of the parameters used as an index of compost maturity. The initial C: N ratio of two piles was 30:1. During the composting processes, The released nitrogen gradually increased due to the mineralization of organic matter and simultaneously the total organic carbon of wastes were decreased due to the humification through the degradability of the organic matter. These processes minimize the difference between C and N and finally the C: N ratio decreased. At the end of composting processes, C: N ratio reached values of 15.8 and 11 for windrows A and B, respectively (Fig 4).From the aforementioned data, it was observed that windrow B had suitable C: N ratio, where Jimenez and Garcia (1992) considered that a C: N ratios lower than 12 for compost indicates a good degree of maturity. On the other hand, Adediran *et al* (2004) found that all final composts produced had C: N ratios < 17 and so were considered conductive to N mineralization and thus suitable for horticultural use.

Generally, it could be noticed that the changes in pH, EC and C: N ratio of organic wastes during composting processes were consistent with those observed with other composting systems and the parameters were influenced by the source of manure used.

The trends observed showed that temperature, pH, EC and C: N ratio was reliable for monitoring the co-composting of rice straw amended with animal manure or chicken manure.

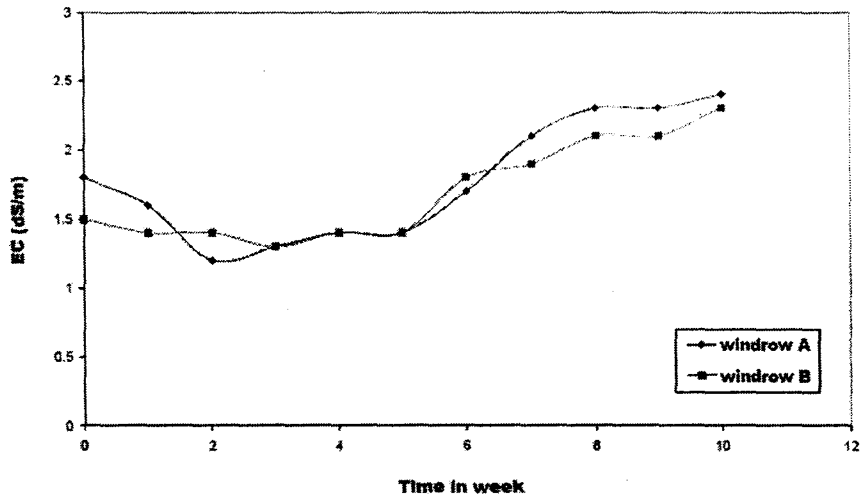

Figure (3) Changes in electrical conductivity (EC) during composting processes

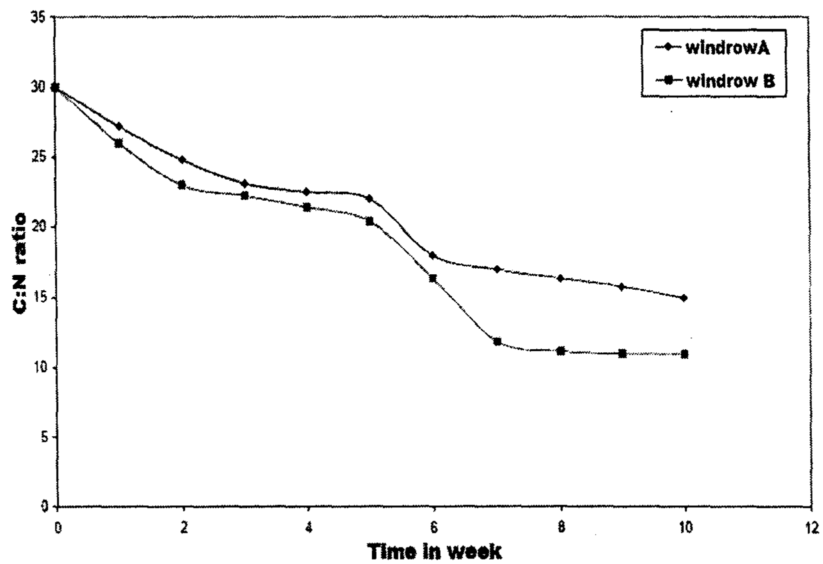

Fig. (4) Changes in C: N ratio during composting processes

2-Growth dynamics of microorganisms

The peak total aerobic heterotrophic bacteria (THB) counts of 12.3 and 13.7 $\log_{10}$ CFU g^{-1} dry wt for windrow A and windrow B, respectively, was evident during the first stage of composting processes (Fig 5) . Their population was still constant until day 35 when the tended to decrease along with the drop in the temperature of compost piles (Fig 1). However, the THB of windrow B sustained a higher population at varying durations suggesting efficacy of the additive, i.e., chicken manure. The microbial counts in this study were accordance with results obtained by Hellal (2007).

On the other hand, the number of actinomycetes increased as the temperature began to peak in the composting piles. At day 20, windrow B maintained the highest level in the number of actinomycetes was 8.3 $\log_{10}$ CFU g^{-1} dry wt, as compared to the windrow A which recorded the value of 7.5 $\log_{10}$ g^{-1} dry wt (Fig6). Actinomycetes are decomposers common in different stages of composting. They prefer woody material and can survive a range of temperature. It is interesting, therefore, to note that these observations were substantiated in this work when the population of actinomycetes was evenly spread out throughout the composting period (Fig 6) despite the fluctuating decreasing temperature profiles in the composting processes (Fig 1). Moreover, the population of actinomycetes of windrow B was higher than windrow A, especially during the later stage of the composting period. This suggested that the chicken manure enhanced the active growth of the actinomycetes during composting process. In addition to; it could be observed that the hyphal actinomycetes strands contributed immensely to the grayish color of the compost surface and whitish appearance during the cooling stage. This finding is related to the work of Epstein (1997).

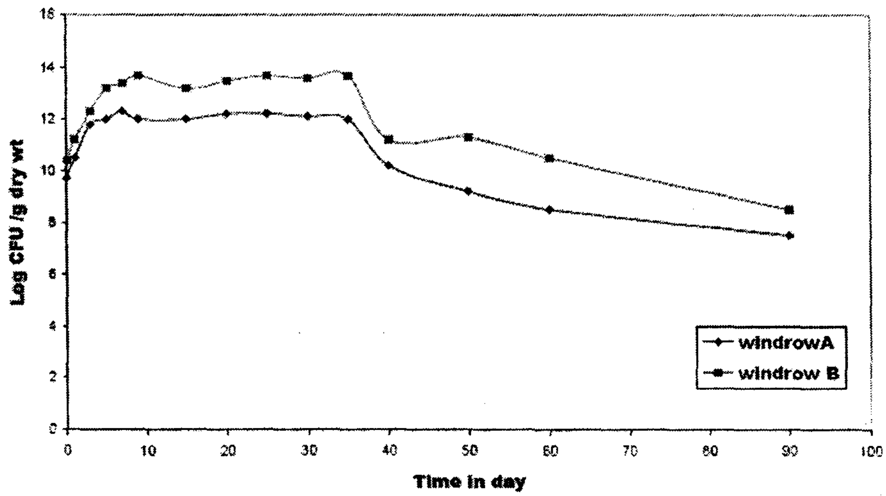

Fig. (5) Total counts of aerobic heterotrophic bacteria (THB) during composting processes

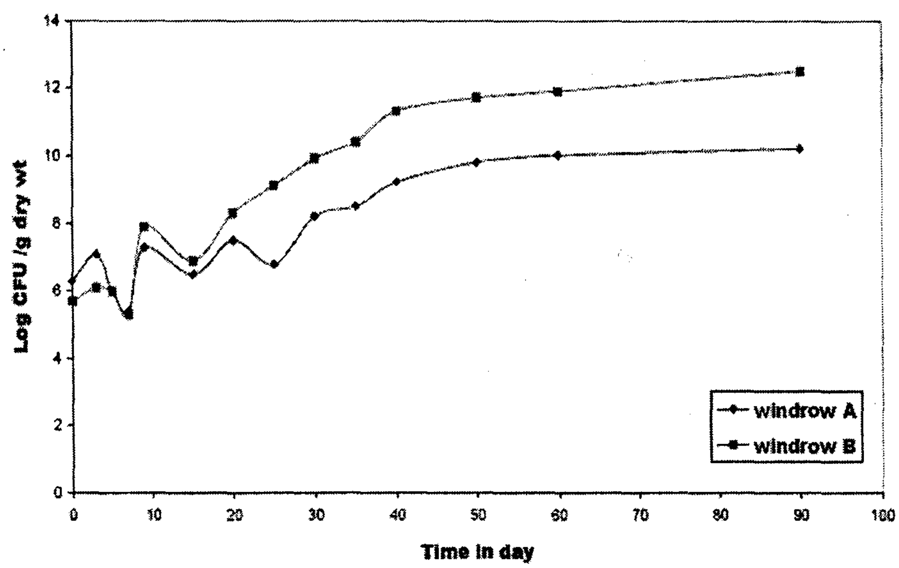

Fig. (6) Total counts of actinomycetes during composting processes

Fungal species are effective decomposing agents. A rapid decline of most fungi was observed at temperature 60 ° C at day 30 in both windrows (5 and 6 log_{10} CFU g^{-1} dry wt for windrow A and windrow B, respectively (Fig 7). This result was in accordance with the extensive molding study done by Eckinci et al (2004).However, it is interesting to note in this study that regrowth of fungi was recorded with windrow B having higher fungal concentration than windrow A. The value of 6 $\log_{10}$ CFU g^{-1} dry wt at day 30 was recorded in windrow B and gradually increased to 7.9 $\log_{10}$ CFU g^{-1} dry wt as compared to 6.2 $\log_{10}$ CFU g^{-1} dry wt in the windrow A (Fig 7).

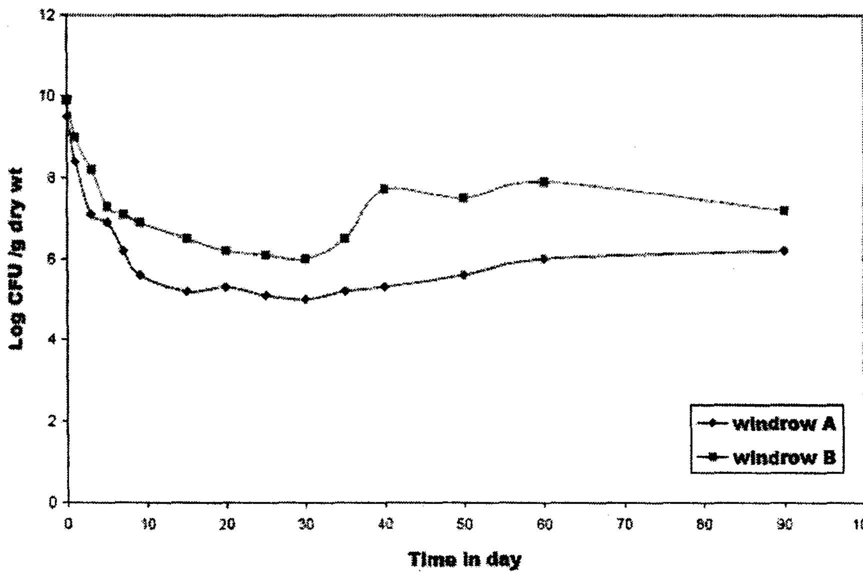

Fig. (7) Total counts of fungi during composting processes

The rapid increase in fungal population towards the end of composting period might be due to the addition of fungal medication the presence of cellulose and lignin .De Bertold *et al* (1983) and Davis *et al* (1992) reported that during the cooling process of compost, active growth of fungi is usually evident if the remaining substrates are predominantly cellulose and lignin. Ryckeboer *et al* (2003) pointed that fungi are believed to be involved in the decomposition of cellulose and lignocellulosic compounds of the compost.

Yeasts population increased slightly at day 15 of composting processes and after the thermophilic phase , reaching the peak of 6.5 and 7.7 $\log_{10}$ CFU g^{-1} dry wt for windrows A and B, respectively, but declined again after about one month of composting processes , possibly due to the pH increase (Fig 8) . This results is accordance with the data which obtained by Choi and Park, (1998). Fungi and yeasts can survive during the thermophilic phase as spores or are re-inoculated into the compost from the environment or the cooler material at the edges of pile.

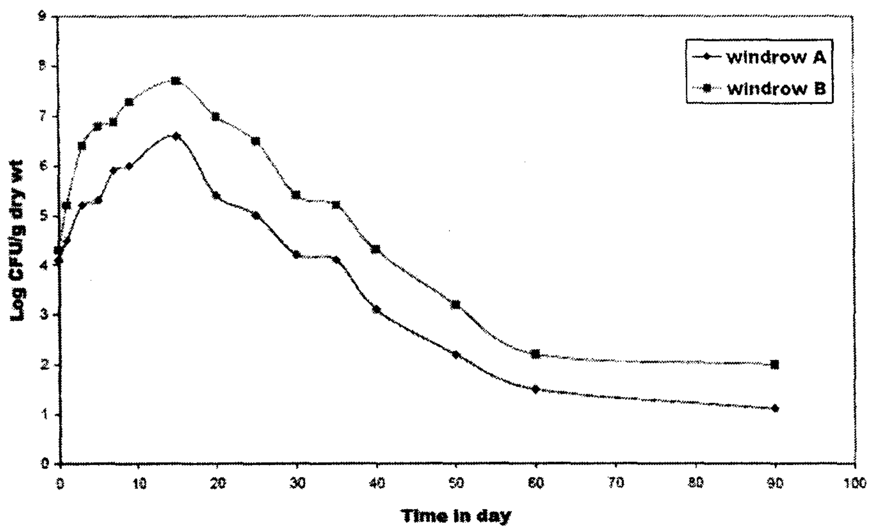

Fig. (8) Total counts of yeasts during composting processes

Spore-forming bacteria were detected throughout the entire processes but their population in both two windrows increased from 6.2 and 6.4 $\log_{10}$ CFU g^{-1} dry wt in the raw materials to 9.2 and 9.8 $\log_{10}$ CFU g^{-1} dry wt at day 15 for windrows A and B, respectively (as shown in fig 9), through the selective period that high temperature exercise to the microbial population, and remained high, thereafter, it was agreement with similar studies of Blanc *et al* (1999). Gazi *et al* (2007) found that spore forming bacteria, in green waste composting, were detected throughout the process time and their population increased from 3.0 x 10^6 CFU g^{-1} dw in the raw material to 3.4x 10^8 CFU g^{-1} dw on day 63.

As high temperature favor cellulose degradation, cellulolytic bacteria demonstrated a high count at the end of the thermophilic phase (8.1 and 8.6 $\log_{10}$ CFU g^{-1} dry wt for windrows A and B, respectively (Fig 10), and their numbers slightly declining during curing and it was because the cellulose may become inaccessible to enzymatic attack due to the association with protective substances such as lignin (Ryckeboer *et al* 2003).

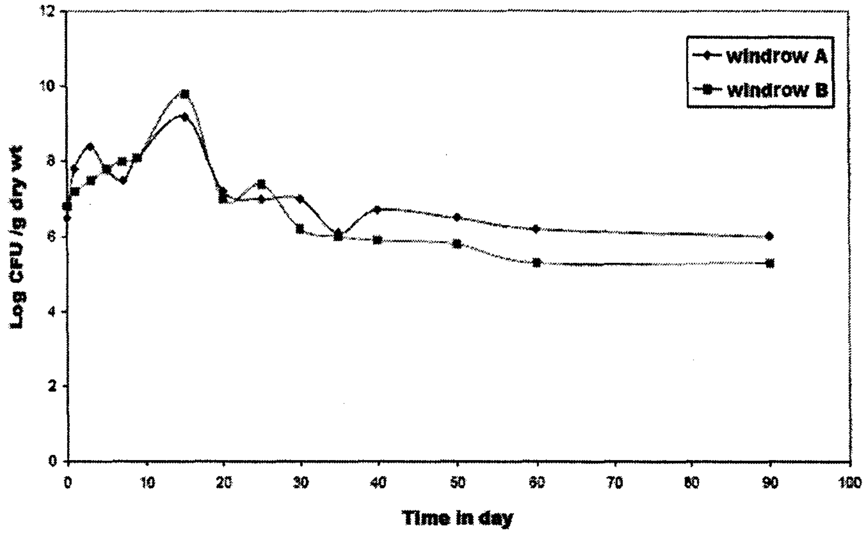

Fig. (9) Total counts of sporforming bacteria during composting processes

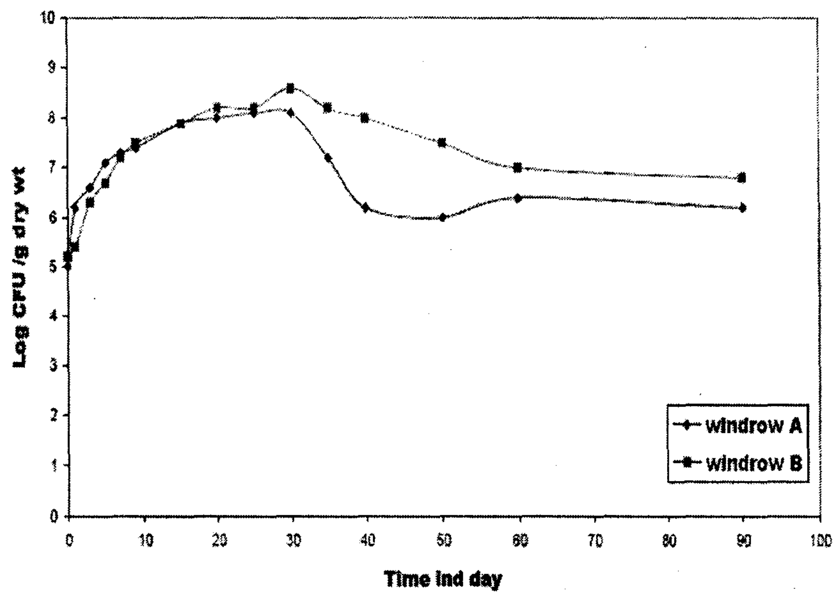

Fig. (10) Total counts of cellulolytic bacteria profile during composting processes

From the aforementioned results, it could be noticed that the population size of different microbial groups was a limiting factor in rice straw amended with animal or chicken manure plus molasses composting processes. Moreover, the numbers of most microbial groups increased throughout the thermophilic phase, although for some groups population counts declined again towards the end of the maturation period, possibly indicating the exhaustion of specific substrates. Overall microbial community succession reflected well the changes during the composting process.

Conclusion

The purpose of this study was to investigate aerobic windrow composting of mixed animal manure or chicken manure with rice straw systems, as well as, using the molasses as a source of available carbohydrates to increase the growth of indigenous microorganisms.

The results of the study are as follows:

1-The temperature within aerobic windrow compost pile of mixed chicken manure with rice straw (windrow B), was the highest values at earlier stage of composting process.

2-Turning one every 2 to 7 days and adding water to maintain optimum moisture content at 60% would be the desirable technique for too hot pile during composting.

3-The number of most microbial groups increased throughout the thermophilic phase, especially in windrow B.

4-Windrow B had the final pH, EC and C: N ratio of 7.3, 2.3 dS/m and 11, respectively. This means that composting of rice straw with chicken manure plus molasses produce good compost with high level of maturity.

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انتاج سماد عضوى من قش الارز بالطريقة السريعة

احمد عبيد عبد الحافظ
قسم الميكروبيولوجيا الزراعية - كلية الزراعة - جامعة عين شمس القاهرة - مصر

في الدراسة الاولي من هذا البحث ، تم خلط قش الارز مع روث الحيوانات و المولاس (كومة ا) بنسبة ١: ٠,٠٤: ٠,٨٨ على التوالى، اما الدراسة الثانية كان قش الارز مخلوط بسبلة الدواجن و المولاس(كومة ب) بنسبة ١ : ٠,٨٥ : ٠,٠٢ علي التوالي . تم دراسة وتقدير التغيرات الفيزوكيميائية و التتابع الميكروبي خلال فترة انتاج السماد العضوي.

اوضحت النتائج ان الكومة (ب) سجلت اعلي قيم لدرجة الحرارة في المراحل الاولي من عملية انتاج السماد ولم يكن هناك فرق في درجة الحموضةpH و نسبة الكربون الي النتروجين خلال فترة انتاج السماد العضوى، كما كانت قيم درجة الحموضةpH و نسبة الكربون الي النتروجين في الناتج النهائي لكلا من الكومة (ا) و الكومة (ب) (٧,٧ ، ٧,٣) و (١٥,٨ ، ١١) علي التوالي.

سجلت النتائج زيادة فى اجمالي النشاط الميكروبي خلال مرحلة ارتفاع درجة الحرارة ثم انخفض بعد ذلك خلا ل مرحلة النضج في كلا من الكومة (ا) و الكومة (ب).

لوحظ سيطرة النشاط البكتري علي مرحلة ارتفاع درجة الحرارة بينما كانت الفطريات و الاكتينوميستات و الخمائر اقل من الحد المسجل ، و مع ذلك هذة المجموعات من الميكروبات نمت مرة اخري في المرحلة الاخيرة (مرحلة النضج) .سجات النتائج ايضا تواجد البكتريا المتجرثمة طوال فترة الانتاج و بلغت اقصي تركيز ٩,٢ , ٩,٨ لو ١٠ وحدة خلايا لكل جرام وزن جاف لكل من كومة (ا) و كومة (ب) علي التوالي ،كما سجل اعلي نشاط للبكتريا المحللة لسليلولوز خلال مرحلة ارتفاع درجة الحرارة ثم انخفضت في مرحلة النضج.

و اذا ما اخذ فى الاعتبار مقارنة السماد الناتج من قش الارز المخلوط بسبلة الدواجن و الاخر الناتج من قش الارز المخلوط مع روث الحيوانات ، نجد ان المخلوط الاول اعطي افضل اداء لتحلل المادة العضوية واعلي قيمة للنشاط و الحمل الميكروبي.