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Study on conversion of some chemical compounds of wood sawdust waste in bio-composting process

Nghiên cứu sự biến đổi một số thành phần hóa học của mùn vụn gỗ phế thải trong quá trình tạo phân bón hữu cơ vi sinh

Research article

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This paper presents the research results of treatment solution of wood waste of Acacia and Eucalyptus in making of bioorganic fertilizers for the effective utilization of plant biomass resources and minimization of environmental pollution. The conversion cycles of the basic chemical compounds of wood waste in composting process were established by two biological products: Biomix and Compost Maker. Research results have shown that, under the action of microorganisms, all basic chemical compounds were modified (among them cellulose was most powerfully modified) whereas lignin, extractives dissolved in ethanol were less destructed. Within about first 75 days of composting, the conversion of the above mentioned compounds is negligible. With the time of composting from 105 days to 120 days, in total over of 70% of cellulose was conversed into compounds dissolved in water and in 1% NaOH solution. The optimal composting time was about 105 days. In this case, the fertilizer obtained was humified, had dark colour and could be used for planting and soil improvement purposes.

Bài báo này trình bày các kết quả nghiên cứu giải pháp xử lý mùn vụn gỗ phế thải của gỗ Keo và Bạch đàn thành phân bón hữu cơ vi sinh, nhằm tận dụng hiệu quả nguồn sinh khối thực vật và giảm thiểu ô nhiễm môi trường. Đã xác lập được một số quy luật biến đổi của các thành phần hóa học cơ bản của mùn vụn gỗ trong quá trình ủ compost bằng hai chế phẩm vi sinh Biomix và Compost Maker, để tạo phân bón hữu cơ vi sinh. Kết quả nghiên cứu đã cho thấy, dưới tác dụng của vi sinh vật, tất cả các thành phần hóa học cơ bản của mùn vụn gỗ đều bị biến đổi, trong đó xenluloza bị biến đổi mạnh nhất, lignin và các chất trích ly bằng etanol ít bị phân hủy hơn. Trong vòng khoảng 75 ngày ủ đầu tiên, sự biến đổi của các thành phần nêu trên là không đáng kể. Với thời gian ủ từ 105 ngày đến 120 ngày, tổng cộng có trên 70% xenluloza bị phân hủy thành các hợp chất dễ tan trong nước và dung dịch NaOH 1%. Thời gian ủ thích hợp là khoảng 105 ngày. Trong trường hợp này, phân bón thu được đã bị mùn hóa, có mầu sẫm và có thể sử dụng cho mục đích trồng trọt và cải tạo đất.

Keywords: biomass resources, bioorganic fertilizer, cellulose, extractive, lignin

1. Introduction

In 2011, production of wood pieces of paper processing materials reached over 4 million tons, of which over 90% was exported. By processing this amount of materials, a large amount of waste was produced such as mulch wood chips, accounting for above 2% by weight of wood pieces. Besides, the wood processing industry, distributed throughout the country, with diversified product categories and impressive revenue also generated a large amount of wood wastes in form of sawdust, chip, particle debris, scrap, etc. The current method of utilization of these types of wastes is as fuel for combustion.

Failure to properly take advantage of these scrap and residue generates a huge amount of waste. In addition, they are a threat for the environment, fire safety, forest protection and public health. Therefore, the study on taking advantage of these kinds of residues is an urgent

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and necessary issue worldwide (Faaij, 2006; UNIDO, 2007).

In terms of the nature and economic value as well as needs, the most feasible solution is the use of the above types of wastes as organic fertilizer (micro-organic fertilizer), in addition to the purpose of utilizing biomass plant source, this solution also contributes to soil improvement and environmental protection.

The application of biotechnology in research on producing various forms of organic fertilizer and micro-organic fertilizer has also been noted (UNIDO, 2007). However, the organic-microorganism fertilizers are mainly produced from raw natural material (peat) and easily biodegradable waste.

2. Materials and methods

The raw materials used to produce micro-organic fertilizer were wood scraps and chips (pieces of wood shavings, sawdust) of acacia and eucalyptus, formed during processing pieces of raw materials for pulp cooking in Bai Bang paper mill and some facilities of wood processing. These wood scraps and chips had a storage period not exceeding three months. The materials are selected by using a sieve with the mesh size $\Phi < 2$ mm. The rest is crushed and continuously screened (sawdust was not crushed and screening selected). Then the selected materials were incubated with effective microorganisms.

Two types of effective microorganisms have been selected for the study: Compost Maker and Biomix. Their compositions include microorganisms that are capable of decomposing cellulose and other components of the plant materials (Figures 1 and 2).

Figure 1. Effective microorganisms Compost Maker

Figure 2. Effective microorganisms Biomix

The process of producing fertilizer is described in the following diagram:

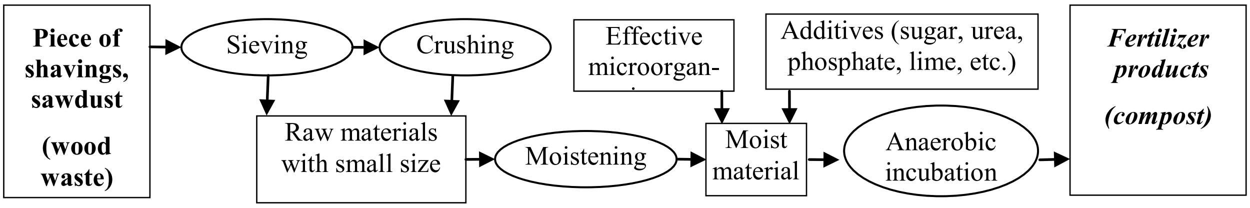

Figure 3. Diagram of producing micro-organic fertilizer from waste wood chips mulch

Composting was processed with microorganisms and additives according to the following formula: 1,000 kg raw materials + 3 kg effective microorganisms + 3 kg sugars or molasses + 40 kg phosphates +10 kg urea + 15 kg limes. Incubation process was carried out in sealed Styrofoam boxes. Ingredients are moistened before mixing (Figures 4 and 5). The incubated samples were monitored; temperature and water content were measured regularly to keep certain humidity. After different periods of time: 75, 90, 105, 120 days, incubated samples were taken representatively to analyse the chemical compositions.

For analysing the chemical composition, 200 g of each sample was collected in five different locations in the pile of material before and after incubation, air-dried, crushed and screened in order to select the particles having standard size (0.25 mm - 0.5 mm). The selected materials were mixed, kept in conditions of saturated humidity for 48 hours, and stored in sealed vials for analysis.

Figure 4. Styrofoam box for composting

Figure 5. Wood waste after 120 days of incubation

The analysis of the chemical composition of the wood waste chips was performed according to the standard method TAPPI (Technical Association of Pulp and Paper Industry), GOST about analysis of the chemical composition of wood and non-wood material (Smook, 2002; Obolenskaya et al., 1991).

3. Results and discussion

Before treatment with effective microorganisms, the contents of some chemical components of wood wastes were different between the samples. This difference was mainly due to the sampling location. The concentrations of the solutes in 1% NaOH solution were relatively high, because the materials underwent the long retention time at the place of production (about three months, Table 1).

The results observed showed that only three-four weeks after treatment with effective microorganisms, wood wastes changed gradually to dark brown and the temperature increased rapidly. After 75 days, the change of the composition of the input material was not significant (Figure 6). As the incubation time was not enough for biological metabolism, so there was no difference in the effect of both the effective microorganisms.

Table 1. Content of the basic chemical compositions of raw materials before treatment with effective microorganisms (SD: standard error)

Content (%)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average	SD
Cellulose	43.26	44.63	43.82	44.15	45.17	44.21	0.73
Lignin	23.52	25.81	23.84	24.12	24.37	24.33	0.88
Solute in 1% NaOH solution	18.71	19.03	18.83	18.81	19.25	18.93	0.22
Extractives in ethanol	2.33	2.46	2.02	3.12	2.56	2.50	0.40
Total nitrogen	0.12	0.18	0.24	0.28	0.28	0.22	0.07

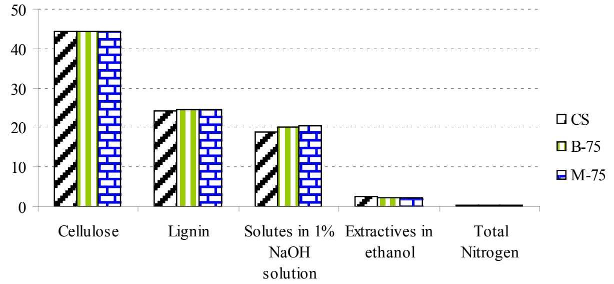

Figure 6. Content of the basic chemical compositions of materials after composting 75 days
(CS: Control sample; B-75: Sample treated with Biomix in 75 days; M-75: Sample treated with Compost Maker in 75 days)

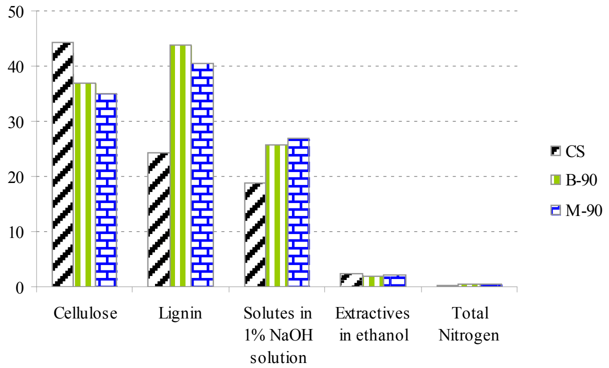

Figure 7. Content of the basic chemical compositions of materials after composting 90 days
(CS: Control sample; B-90: Sample treated with Biomix in 90 days; M-90: Sample treated with Compost Maker in 90 days)

After the anaerobic incubation period of 90 days, the transformation of ingredients was more obvious (Figure 7). For both effective microorganisms, the variation of ingredients took place according to the same rules. The content of all soluble substances in 1% NaOH solution increased (approximately 8%) and these compounds were most susceptible to biological changes. The cellulose content decreased, however lignin concentration was high suggesting that lignin is the component being least changed. The effect of two types of effective microorganisms showed differences: in this period, the Compost Maker had a stronger ability to decompose cellulose and lignin. The content of nitrogen in the 90 day-incubated material was expected to be equivalent, although higher than that of raw material.

In the 4th month, the process of decomposition of material ingredients continued under the influence of both types of the effective microorganisms (Figure 8).

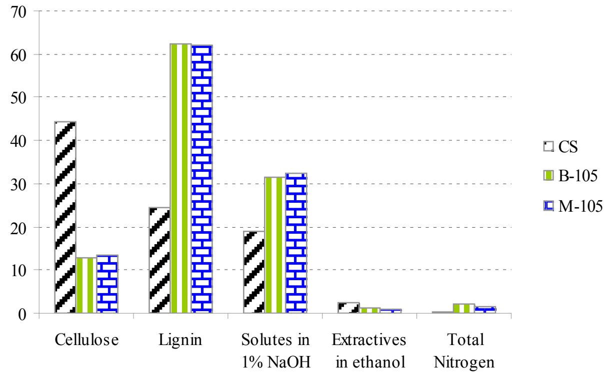

Figure 8. Content of the basic chemical compositions of materials after composting 105 days
(CS: Control sample, B-105: Sample treated with Biomix in 105 days; M-105: Sample treated with Compost Maker in 105 days)

Observation showed that material turned to dark black while the volume of material at this time was only half of the initial volume. However, it can be observed that the extractives compounds (especially cellulose), drastically decomposed, explained by its low concentration in the compost fertilizer. Whereas lignin was less decomposed, the concentration of this component in compost fertilizer was relatively high. At this time, we can say that lignin in the compost did not maintain its initial structure and properties. Instead, it was transformed into humus form, as evidenced by the humus substances that were harder dissolved in a mixture of HNO_3 and C_2H_5OH (solution used for the analysis of cellulose).

The rules of transformation of these components continue to be maintained and extended to the end of the 4th month of incubation (Figure 9), when the cellulose content remained only above 10%, which means that more than 70% of original cellulose was decomposed.

The influences of the two types of effective microorganisms Biomix and Compost Maker can be observed on changing the chemical composition contents of wood wastes to values almost equivalent to those in the three months incubation time. The total nitrogen content after 105 days of incubation reached 2.5% in average, accounting for more than 10 times compared to the original material.

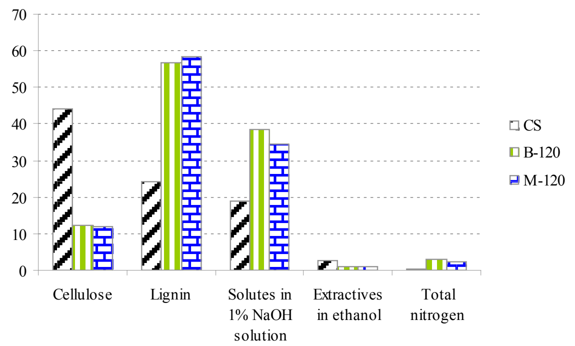

Figure 9. Content of the basic chemical composition of materials after composting 120 days

(CS: Control sample, B-120: Sample treated with Biomix in 120 days; M-120: Sample treated with Compost Maker in 120 days)

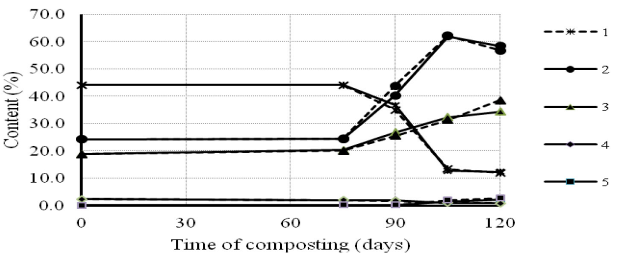

Figure 10. Change in contents of the chemical compositions of wood sawdust waste during composting with Compost Maker and Biomax

(1-Cellulose; 2-Lignin; 3- 1% NaOH solution 4- Extractives in ethanol; 5- Total nitrogen)

Overall, there was almost no difference between the influences of two types of effective microorganisms on the change of the main components of the input materials (Figure 10). Decomposition (humus formation) of the major components, such as cellulose and lignin reached the "threshold" after about 105 days of composting. In parallel, the total nitrogen concentration reached maximum value, this amount could increase depending on the ratio of mixing urea with original wood waste before incubation. Thus it can be concluded, for the purpose of humus formation and improvement of the quality of microorganic fertilizers, composting time for wood waste material is most appropriate about three and a half months to four months.

The compost fertilizer-wood chips after being decomposed were used as growing medium for mixing with soils to nurse young acacias. The results showed that the growing medium functioned very well for acacia trees; the white leaf disease, which is common in young acacias, was remedied. The stems were high, big and the leaves were green and larger than the acacias growing in the substrate without compost fertilizer.

Figure 11. Acacia growing in a) non-mixed substrate (soil); b) mixed substrate (compost + soil)

4. Conclusion

In the process of composting shavings and sawdust debris with effective microorganisms Biomix and Compost Maker in appropriate conditions, all of the major chemical components of the material began to change after about 75 days of incubation, revealed strong variation between 75-105 days of incubation and became stable after 120 days of incubation.

Within the incubation period of 120 days, up to over 70% cellulose was decomposed into compounds soluble in water and in NaOH solution. Lignin and other extracted substances were less transformed.

The most suitable composting period for wood waste was about 3.5 months. The fertilizers produced had the total nitrogen content from 2.3 to 2.8%, which is suitable for plants, especially when they were used as growing medium for nursing acacia and eucalyptus trees.

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