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Bioconversion of Rice Husk Plus Wood Waste into Organic Fertilizer Using Sugarcane Molasses and Corn Steep Liquor

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ABSTRACT:

Rice husk is one of the critical agricultural by-products in the rice milling process; it is abundantly produced and often left unused or burned in the environment. In this study, the biotransformation potential of this material into biological organic fertilizer was investigated using a mixture of wood lignocellulolytic microorganisms and natural rice husk compost. Corn steep liquor with 50 ± 5% solid materials in a total ratio of 15% (w/w) and sugar cane molasses (SCM) with 60 ± 5% solids in a total ratio of 15% (w/w) to the treated solids materials were used to supply microorganism's nutrients and optimization of biochemical, organic fertilizer elements. *A rice husk sample and two other rice husks, combined with wood waste, were treated in a mixture of the mentioned additives and microorganisms. Samples at certain intervals were determined to have the amount of nitrogen, organic matter, organic carbon, essential elements, and the C/N ratio as the main parameters to evaluate the quality and maturity of biofertilizer in the conversion period. Based on the results, the biological conversion process converted rice husk into organic biofertilizer. Also, using wood waste along with rice husk, at first, caused a relative decrease in minerals and an increase in the C/N ratio, but this effect decreased with the progress of the process. In addition, during the biotransformation process, with the relative decrease of organic matter and organic carbon, the relative amounts of* K^+, PO_4^{3-}, Ca^{2+} and Mg^{2+} *increased significantly and reached acceptable levels. A rice husk and wood waste mixture can be converted into superior-quality organic fertilizer using low-cost CSL, starch, or sugarcane molasses.*

KEYWORDS: *Rice husk, Molasses, Corn steep liquor, Organic fertilizer, C/N ratio*

INTRODUCTION

Every year, rice mills in the northern provinces of Iran produce a large amount of rice husk (RH) as a vital product, which is left in nature or burned without proper use. This action not only wastes these materials but also causes environmental pollution. According to the available statistics, more than 3 million and 300 thousand tons of rice paddy are produced in the country every year, of which 20-25% (23%) is the outer shell of rice, which amounts to more than 600 thousand tons [1]. This large volume of lignocellulosic raw materials requires special attention for the best use.

RH is one of the lignocellulosic products, and like other lignocellulosic sources, it consists of organic compounds (75-80%), including cellulose, hemicellulose, lignin, and minerals (20-25%). About 95% of this RH mineral (unlike most lignocellulosic sources) consists of silica and siliceous compounds, and less than 5% of the remaining are oxides of calcium, magnesium, potassium, iron, phosphorus, zinc, copper, and sodium elements [2]. Due to the composition of RH, including the high percentage of silica, it supplies unique characteristics, which, while excluding the possibility of using it as animal feed, makes it possible to produce various products. Among the products that can be produced from RH is microbial organic fertilizer. Production of organic fertilizer from RH using microorganisms is the simplest and most economical way to use this by-product in the direction of agricultural prosperity. In the past years, various methods have been used to produce organic fertilizer from RH, including Vermicompost production, bio-microbial organic fertilizer, or vermin-microbial organic fertilizer [3, 4, 5]. Various materials and additives are also used to improve the process and the quality of the manufactured product. Animal manure, chicken manure [6], chicken bone powder [5], fruit waste [3], chicken dung slurry (CDS), chicken feed, and molasses [7] are among the additives that have been used to convert RH into organic fertilizer that can be used for various purposes. It has been used to cultivate rice, sunflower, beans, etc., and meaningful results have been obtained [8,9,10]. Several factors affect the conversion of RH and agricultural waste into organic fertilizer products. Biological factors such as types of earthworms or different microorganisms [11], particle size, nutrient additives, the ratio of nutrients to RH, environmental humidity, transforming materials, initial pH of the transforming environment, aeration, and ambient temperature are important factors that are effective on the conversion process [12]. In addition to the design variables, the size of the container (or bioreactor), the quality of aeration, the humidity, the initial pH of the transformed materials, and the presence of nutrients are essential factors in the growth and development of microorganisms and their stimulation in the digestion and decomposition of RH, as well as the quality of the produced product (in terms of physical properties and chemical composition). The first and final C/N index are the most critical factors in determining the product's maturity and confirmation [13,14,15]. In this research, corn steep liquor (CSL) and sugarcane molasses are new additives for organic fertilizer from RHs. These two additives are used to control pH and as a supplier of nitrogen, phosphorus, potassium, and other nutrients, and the quality of the product is evaluated in comparison with the raw material and past research.

EXPERIMENTAL SECTION

Materials

Microorganisms and collection of organic waste

First, RH was received from a rice mill in Fuman (Guilan-Iran). Iran Pulp and Paper Industry-Choka also supplied wood waste (including wood bark, small chips, and sawdust). CSL was bought from the Qazvin Glucozan Company (Iran), and sugarcane molasses was purchased from the Khuzestan Sugarcane Company. To prepare the inoculum, a mixture of effective microorganisms and fungi in the decomposing of organic matter (such as basidiomycete bacteria and white, brown, and soft rot fungi) present in decaying lignocellulosic materials (wood waste and RH) was used. In this regard, samples of rice husks and rotting wood waste were randomly selected from the environment. Samples were cultured to prepare the suspension from a mixture of microorganisms and then developed in a non-selective environment. Finally, the inoculum was produced by mixing microorganism colonies in distilled water.

Experimental design

This research used transparent polyethylene tanks (35 cm × 25 cm × 20 cm) as bioreactors (for easy viewing inside the tank). The air transmission line was installed under the treated materials. To ease the aeration and prevent the air inlet from being blocked by treated materials, a mesh tray with holes 2 mm in diameter was installed above the air inlet line and 5 cm from the bottom of the tank. The mesh tray supplied uniform air distribution inside the treated materials (Fig. 1). Aeration was planned twice a week. Table 1 shows the experimental plan in this research. These ratios have been chosen based on the literature[16]. All experiments include three different treatments. The first treatment (run 1) had only RH plus nutrient additives, and in treatments 2 and 3, two different mixtures of RH and wood waste were used for the composting process. Assuming that the wood waste is larger than the size of the RH, these ratios can help with aeration in the composting process. All treatments were applied with three replicates for 100 days.

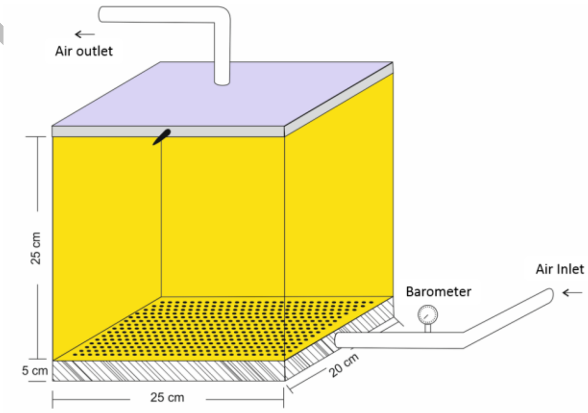

Fig. 1. Laboratory bioreactor for treating a mixture of rice husk and wood waste.

Table 1. Design of rice husk plus wood waste composting experiments.

Run	RH (*w/w* %)	WW (*w/w* %Wood Waste) *
1	100	0
2	85	15
3	70	30

* Wood waste (a mixture of bark, small chips, and sawdust)

To provide the elements and nutrients required for the stimulation, activation, reproduction, and growth of microorganisms and also to optimize the characteristics and composition of the organic fertilizer product in 3 stages, a total of 15% (w/w) compared to solids from sugar cane molasses with 60 ± 5% of solid ingredients and 15% (w/w) of CSL with 50 ± 5% of solids were used for the treatment of compostable materials (in each step 5% of the importance of treated solids were rice husk and wood waste). Also, the humidity of the treated materials was adjusted and controlled by periodically adding water at 60 ± 5%.

The effect of compost on plant growth

To investigate the effect of RH and wood waste organic fertilizer (compost) on plant growth and to evaluate non-toxicity due to the need of rice seeds for silica, the germination and growth of rice seeds were investigated as a sample and model. For this purpose, the plant seeds were treated in distilled water, and seed germination, biomass, and dry weight of the plant were determined. Also, a part of that plant seed was treated in the extract obtained by soaking the organic fertilizer in distilled water at a ratio of 5% w/v. The germination, biomass, and dry weight of the plant were also determined in this case, and the results of the two treatments were compared. Also, their cultivation in pots in sandy soil (as a control) and their cultivation in the desired sandy soil with the addition of 5% (W/W) of the organic fertilizer produced in the experiment (each with three repetitions) were studied comparatively. The growth length was measured every seven days until the 21st day, and the fresh and dry weight of the plants was measured at the end of the 21st day. To calculate the plant's wet and dry weight, the plant was floated in a beaker filled with water to separate the soil attached to it, and the plant was weighed without soil with a digital scale with a sensitivity of 0.001 grams. The height of the plant and the length of its roots were also measured by a ruler with a sensitivity of 0.1 mm.

Sampling and analysis

Anticipated sampling from composting substrates and tests continued every 20 days until the 100th day (Table 3). The temperature inside the treated material (compared to the outside environment) was recorded every two days. To determine the percentage of inorganic materials in the samples, the method of burning in oxygen-free conditions in an electric furnace at a temperature of 550 ± 25 degrees Celsius for two hours was used [18]. This way, the samples' percentage of organic and mineral substances was also determined. Each sampling measured the pH value and electrical conductivity of 10% (W/V) solutions using a HACH digital pH meter and an 8302 digital conductivity meter, respectively. Almost acceptable, the amount of organic carbon in the samples was figured out by dividing the amount of organic matter by 1.82 (Schumacher, 2002) [19]. Total nitrogen was also measured by the Kjeldahl method [20]. Calcium and magnesium were measured by titration with EDTA [21], total potassium was measured by Flame Photometer (JENWAY PFP7) atomic absorption spectroscopy, and phosphorus and iron were also measured by photo spectroscopy with a DR2000 device [22].

Statistical analysis

Using Excel 2016 software, the Figs were drawn, and the corresponding equations and the regression coefficient were obtained in each case. Minitab 2016 software was used to analyze the difference between the experiments' data, find the reliability, and compare the averages.

RESULTS AND DISCUSSION

Characteristics of RH and Wood Waste

Table 2 shows the chemical properties of composting raw materials (RH and untreated wood waste). According to the prediction and information in this Table, RH and wood (Bark and fine wood chips and sawdust) have a high percentage of organic matter waste; in this study, 81 ± 1.5% and 98 ± 1% of organic matter, respectively. Therefore, they have 19 ± 1.5% and 2 ± 1% inorganic matter. The results in Table 2 are comparable to the report as mentioned earlier [2] that more than 95% of the inorganic material of RH is silica (SiO_2), and the remaining less than 5% is calcium, magnesium, potassium, iron, phosphate, and trace elements.

Table 2. Chemical properties of compostable raw materials (rice husk and wood waste) before treatment (compared to solid materials).

Sample	Moisture (%)	pH	*OM. (%)	OC. (%)	EC. (μS.cm^{-1})	Ca^{2+} (%)	K^{+} (%)	$P_{T.}$ (%)	Fe^{2+} (%)
Rice husk	6.5±2	7.4±0.2	81±1.5	44.1±0.8	220±30	0.06±0.001	0.13±0.04	0.11±0.05	0.04±0.01
Wood Waste	10±3	7.1±0.3	98±1	54.4±0.6	110±25	0.01±0.003	0.11±0.03	0.03±0.05	0.03±0.01

*OM: Organic matter, OC: Organic Carbon

RH Composting

The results of Table 3 show the changes in various critical variables during the RH composting process in Experiment 1. This study adjusted the initial pH to 5.5 ± 0.5 by adding CSL and sugarcane molasses [2]. However, this variable shows different pH values for 100 days. These pH changes decreased during the composting of rice husks, during the addition of nutrients (sugarcane molasses and CSL), and during the production of organic acids, and at some point, increased with the production of alkaline substances such as ammonia in other conditions and stages [23, 24]. Also, due to the reduction of the relative percentage of organic matter over time and the mentioned nutrient additives, calcium, magnesium, iron, potassium, and phosphorus increased over 100 days. They reached from 0.09 ± 0.01 to 0.25 ± 0.02, from 0.03 ± 0.01 to 0.24 ± 0.01, from 0.05 ± 0.002 to about 0.12, from 0.1 ± 0.01 to about 0.6, and from 0.11 ± 0.01 to 0.54, respectively. Biological decomposition reduced organic matter during the process and reached the initial value of 81.3 to the final value of 68.4 (15.9% reduction).

In the same way, organic carbon has arrived from the initial value of 45.3 to 35.8 on the 100th day (20.97% reduction). Nitrogen increased from the initial value of 0.3 and reached 1.51 on the 100th day (a 4-fold increase). Due to the growth of phosphorus and nitrogen and the decrease of carbon, the ratios of carbon to phosphorus and carbon to nitrogen have reached from the initial values of 220 and 151 to the final values of 14.1 and 23.4, respectively. These final ratios show the relative maturity of RH organic fertilizer (compost) within 100 days. The final amount of nitrogen and the resulting carbon to nitrogen ratio are comparable to the results obtained by Demir et al. [23]. In the mentioned report, nitrogen has reached from the initial value of 0.376 to the final value of 0.556% after 13 months. The carbon to nitrogen ratio reached 38.3 from the initial 121.146 [23]. The results obtained in the present research are significantly more favorable than the mentioned results. The ratio of carbon to nitrogen in this research is acceptable (20-50) according to Wu et al. (2014) on the biotransformation of solid waste to organic fertilizers [13]. For a better comparison, the carbon to nitrogen ratios in this study is shown in Fig. 2.

Table 3. Variations in chemical parameters of Rice husk plus Wood waste during composting process in run 1.

Time(day)	first*	20^{th}	40^{th}	60^{th}	80^{th}	100^{th}	AVG.	SD.	SE.
Temp. (°C)	25	28	36	38	35	25	32.2	5.84	2.38
PH	5.5	5.8	6.5	5.8	7.1	6.7	6.23	0.625	0.256
Inorg. (%)	18.73	20.35	23.1	25.1	27.2	28.2	23.78	3.76	1.5
OM (%)	81.3	79.2	76.9	75.9	72.1	68.4	62.9	4.81	1.96
OC (%)	44.1	43.8	42.2	41.3	38.1	35.8	40.9	3.297	1.35
Fe^{2+} (%)	0.05	0.08	0.1	0.15	0.18	0.23	0.131	0.067	0.027
Ca^{2+} (%)	0.09	0.17	0.2	0.26	0.28	0.34	0.223	0.089	0.036
PO_4^{3-} (%)	0.2	0.62	0.94	1.48	1.93	2.54	1.161	0.915	0.373
Mg^{2+} (%)	0.09	0.1	0.12	0.14	0.17	0.24	0.143	0.055	0.022
K^{+} (%)	0.3	0.78	0.98	1.28	1.39	1.56	1.048	0.462	0.188
EC (µS.cm^{-1})	180	190	195	201	203	210	196.5	10.597	4.33
N_T (%)	0.292	0.8	1.3	1.44	1.53	1.51	1.141	0.495	0.202
*C/P	220	70	44	27.9	19.7	14.1	65.95	78.1	31.88
C/N	151.3	32.1	29.8	28.2	25.6	23.4	48.4	50.503	20.62

*C/P=OC/PO_4^{3-}, **The sample for a time of 0 (control) is raw materials before treatment. So, temperature is also the ambient temperature of the laboratory.

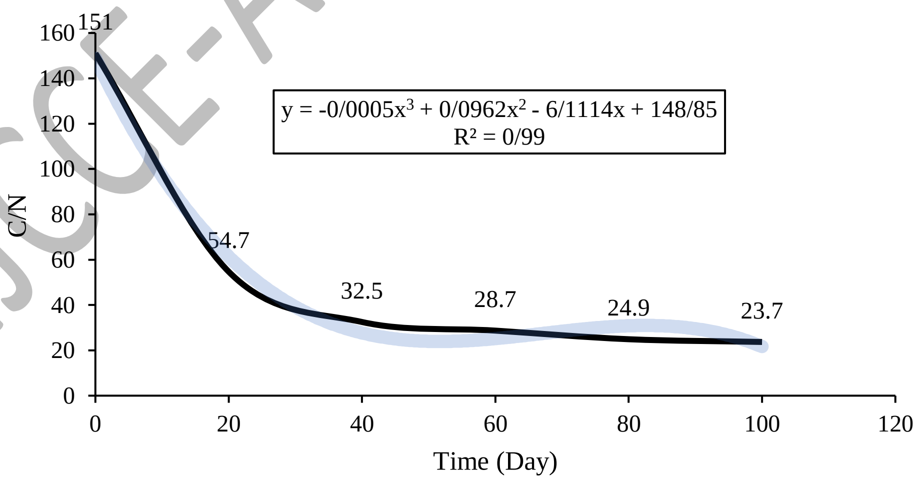

Fig. 2. Changing of C/N ratio with time during the Rice husk composting process.

Changes in the C/N index depend on the nutrient additives, the activity of microorganisms, and the passage of time. This time dependence appears to be non-linear and shows a better fit with a third-order equation than a first-order one (Fig. 2). As can be seen, in this case, the results are more consistent with the curve. According to the initial amount of nitrogen, this index is initially extensive. Then, it decreases sharply due to the abundance of nutrient additives and the activity of microorganisms. Then, its falling slope slows down due to the unlikely possibility of material destruction and the decrease in the performance of microorganisms.

Composting a mixture of rice husks and wood waste

In the next series (second and third run), the biological conversion process to organic fertilizer was investigated for mixtures of rice husks and wood waste with starch liquor from corn and sugarcane molasses. These two additives were added to the composting materials in three stages (first, 40th, and 80th days), each step in 5% (total 15% compared to solid materials).

Table 4. Change of chemical parameters of substrate during composting of rice husk plus wood waste with time.

Sample	Run (2)					
Variable	First (Control)	Day 20th	Day 40th	Day 60th	Day 80th	Day100th
T (ºC)	26±2	36±2	36±2	35±2	28±2	26±2
Moisture (%)	7±1	65±3	63±3	65±3	64±3	55±2
pH	5.5±0.1	5.7±0.3	6.8.0±0.2	6.4±0.1	6.8±0.2	7.2±0.1
EC (µS.cm^{-1})	180±0.1	200±0.1	210±0.1	216±0.1	218±0.1	223±0.1
I.C.s (%)	15.6±0.3	17.8±0.2	19.2±0.2	20.8±0.2	21.9±0.2	23.8
OM (%)	84.4±0.3	82.2±0.2	80.8±0.2	79.2±0.2	78.1±0.2	76.2±0.2
OC (%)	45.2±0.1	42.2±0.1	39.1±0.1	37.2±0.1	36.6±0.1	35.4
Fe^{2+} (%)	0.02±0.003	0.03±0.001	0.033±0.004	0.038±0.002	0.04±0.003	0.042±0.003
Ca^{2+} (%)	0.37±0.01	0.45±0.03	0.52±0.04	0.62±0.02	0.8±0.02	0.84±0.02
PO_4^{3-} (%)	0.36±0.02	1.6±0.04	1.81±0.03	2.6±0.02	2.8±0.03	3.4±0.02
Mg^{2+} (%)	0.11±0.01	0.15±0.01	0.16±0.01	0.18±0.01	0.24±0.01	0.28±0.01
K^+ (%)	0.3±0.03	0.83±0.01	1.2±0.03	1.61±0.02	1.78±0.03	1.87±0.03
N_t (%)	0.287±0.03	0.76±0.02	1.20±0.02	1.44±0.02	1.60±0.02	1.93
C/P	125.6±6	26.4±1.1	21.6±1.1	14.3±1.1	13.0±1.1	10.4±1.1
C/N	157.6±2	55.5±1.2	32.6±1.2	25.8±1.1	22.9±0.9	18.3

*The meaning of control (control) is raw materials before treatment. The control temperature is also the ambient temperature of the laboratory. **percentages are (w/w) and related to the dry weight of the sample.

The continuation of Table 4.

Sample	Run (3)					
Variable	First (Control) *	Day 20th	Day 40th	Day 60th	Day 80th	Day100th
T (ºC)	26±2	37±2	36±2	35±2	29±2	26±2
Moisture (%)	7±1	66±3	65±3	63±3	64±3	55±2
pH	5.5±0.2	5.8±0.1	6.9±0.2	6.6±0.3	6.9±0.1	7.1±0.1
EC (µS.cm^{-1})	170±0.1	190±0.1	195±0.1	205±0.1	215±0.1	221±0.1
I.C.s (%)	14.4±0.3	16.6±0.1	18.4±0.2	20.3±0.2	21.8±0.2	23.2±0.2
OM (%)	85.4±0.3	83.4±0.2	81.6±0.2	79.7±0.2	78.2±0.2	76.8±0.2
OC (%)	46.6±0.1	43.6±0.1	40.0±0.1	38.6±0.1	37.7±0.1	36.4±0.1
Fe^{2+} (%)	0.01±0.002	0.02±0.003	0.03±0.003	0.04±0.001	0.044±0.001	0.046±0.001

Ca^{2+} (%)	0.4±0.01	0.7±0.02	0.83±0.03	1.0±0.01	1.1±0.02	1.2±0.02
PO_4^{3-} (%)	0.35±0.02	1.4±0.02	1.65±0.02	2.4±0.01	2.6±0.03	3.1±0.02
Mg^{2+} (%)	0.15±0.01	0.17±0.01	0.18±0.01	0.20±0.01	0.3±0.01	0.32±0.01
K^+ (%)	0.34±0.03	0.65±0.01	0.98±0.01	1.36±0.01	1.46±0.03	1.91±0.02
N_t (%)	0.273±0.03	1.15±0.02	1.35±0.02	1.68±0.02	1.71±0.02	2.1±0.02
C/P	478.0±2.4	31.1±1.1	24.24±1.1	16.1±1.1	14.5±1.1	11.7±1.1
C/N	167.1±2.0	51.2±1.2	36.4±0.9	27.6±1.1	22.0±0.8	17.3

According to Table 4, the initial pH for both runs is around 5.5. This variable increased to about 5.7 on the 20th day and 6.8 on the 40th day and then decreased to 6.5 and finally reached about 7.2 on the 100th day. It should be noted that pH is an essential variable for the activity of microorganisms in biological transformations. In this study, the value of this variable is initially dependent on additives. Over time, due to the decomposition of organic substances and the possibility of producing organic acids, it decreases and increases in the case of the production of alkaline substances such as ammonia. The changes in the above variables confirm this, and Lim's report (2012) also confirms such changes in the production of organic fertilizer from rice husks [26].

The electrical conductivity variable, which indicates the concentration of dissolved salt and ions in the environment, has increased from 180 and 170 to 223 and 221($\mu S.cm^{-1}$), respectively, in runs 2 and 3. This increase has happened due to the release of phosphate, potassium, calcium, magnesium, iron, and ammonium ions. The content of inorganic materials increased from 15.6 and 14.4 in run 2 and run 3, respectively, and after the 100th day, it reached 23.8 and 23.2%, respectively. The numerical value of the percentage of inorganic materials in these two experiments (compost from a mixture of RH and wood waste) is lower than that of producing fertilizer from RH (without wood waste) in experiment 1. This is due to the relatively low amount of inorganic substance in the RH and waste mixture compared to RH alone. Organic carbon in run two and run 3 decreased from the initial value of 45.7 and 46.8 during composting and reached 35.3 and 36.2 after 100 days, respectively (22.7 and 22.6 percent reduction, respectively). These results are proportional to the primary organic matter in runs two and three and the remaining organic matter in the product. Reports also show that pH regulation effectively regulates the absorption of phosphorus, potassium, iron, and other elements [27].

After 100 days of the conversion process, the amount of nitrogen from the initial value of 0.29 and 0.27% has reached 1.93 and 2.1%, respectively, in runs 2 and 3. After that, the nitrogen/carbon index ratio in experiments 2 and 3 (before the start of conversion) from the initial numbers 157.6 and 167.1, after 100 days, reached 18.3 and 17.3, a decrease of 88.4 and 89.7%, respectively. These numbers are lower than the results of experiment 1. It shows the favorable quality of compost (organic fertilizer) produced in experiments 2 and 3 compared to experiment 1 (RH without wood waste). The slow changes of organic carbon and its high relative amount indicated the difficulty of crushing the cellulose, hemicellulose, and lignin in the structure of the RH [28, 29].

Also, the initial amount of total phosphorus in the raw materials of experiments 2 and 3 is 0.36 and 0.35 percent of the solid weight of the materials; after 100 days, it has reached 3.4 and 3.1, respectively, which is statistically significant. Phosphorus (PO_4^{3-}) is an essential nutrient for making organic matter (biomass) and the primary metabolic pathway in plants [30]. Therefore, its best amount in organic fertilizer indicates the quality of organic fertilizer. Previously, in 2008**,** Anda et al. reported that a significant increase in phosphorus pentoxide (P_2O_5) occurred in an RH composting process after 116 days of the conversion process [31]. The potassium (K^+) level, which was 0.3 and 0.34 in the mixed raw materials of experiments runs 2 and 3, respectively, after the 100th days of the conversion process, reached 1.87 and 1.9, respectively. These results are the same as the report of Anda et al. (2008), who reported a higher level of potassium oxide in RH compost of 3.11% compared to the initial value of 2.8%. This action is also one of the essential elements in plant metabolism, and its optimal amount indicates the quality of organic fertilizer. Changes in the organic carbon index to nitrogen ratio (C/N) in experiments 1, 2, and 3 are shown in Fig. 3. As discussed, except for relatively drastic differences in the content of organic matter, which is caused by the initial composition of the composting materials, for the final product, the ratio of carbon to nitrogen in the three treatments has relatively less difference. The changes of this index with time (according to the operating conditions and the composition used in the experiments) follow a 3rd-degree equation with regression coefficients of about 1.

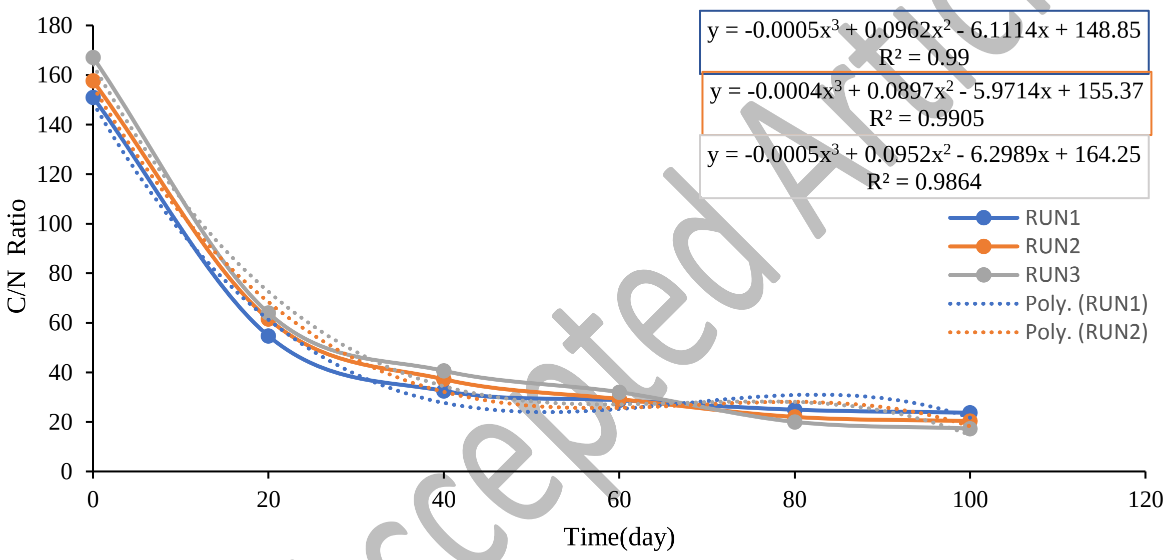

Fig. 3. Changing of organic carbon (C/N ratio) with time in three NO. runs of composting (Run1: Rice husk composting, Run2: Rice husk plus Wood waste (85:15%) composting, Run3: Rice husk plus Wood waste (70:30%) composting).

Compost color evaluation

The initial color of the RH (not composted) is pale yellow (Fig. 4(a), and over time, its color becomes darker as it turns into organic fertilizer (compost) (Fig. 4(b)). This color change in the composting of lignocellulosic materials, in Wu et al. report in 2015, comes from the decomposition of cellulose, hemicellulose, and lignin and the formation of humic compounds [32].

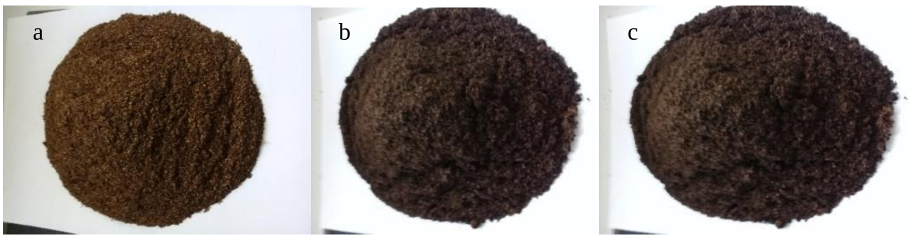

Fig. 4. Rice husk and rice husk plus woody waste compost as organic fertilizer (a: Rice husk compost, b: Rice husk + Woody waste (85:15) compost, c: Rice husk + Woody waste (70:30) compost).

As evident from Fig. 4(b), the product made from RH (without wood waste) still has a lighter color. Still, the product's color obtained from the following two treatments (2 and 3) becomes darker in proportion to the increase in the percentage of wood waste. The result is that raw materials such as wood waste can be used in a suitable balance to improve the appearance of the fertilizer product produced from RH.

The effect of compost on plant growth

Table 5, growth data of 6 samples (6 pots k_1, k_2...k_6) of rice seeds in the presence of 5% (w/w) of RH compost in sandy soil (containing less than 1% organic matter) compared to cultivation 6, shows the control sample (cultivation in sandy soil with less than 1% organic matter without compost). According to the above results, it can be seen that the average height of plant growth in sandy soil without compost (control) on the 7^{th} day was 4 ± 1, on the 14^{th} day, it was 6 ± 0.5, and on the 21^{th} day it was 8 ± 0.5 cm while similar cases in sample cultures were 16.2, 24.7, and 35.8 cm, respectively, and only on the 21^{st} day, the growth height was more than four times that of the control sample. This shows the significant effect of RH fertilizer on the growth of rice seed banks. Also, the fresh and dry weight of the control sample at the end of 21^{th} day was 1.44 ± 0.2 and 0.145 ± 0.01 grams, respectively, while similarly, the average fresh weight and dry weight of the rice plant from the sample were 2.48 and 0.3, respectively. It has been almost twice as much as the control cultures. These cases also show the significant effects of RH fertilizer on the biomass of the rice plant. Variance (S^2) and standard deviation (SD), as well as standard error (SE) of the results compared to six samples and control cultures, are also significant in Table 5.

Table 5. Rice seed growth in sandy soil + 5% rice husk organic fertilizer compared to the control culture (in sandy soil without rice husk organic fertilizer).

Variable	Cultivation in sandy soil (control)						Statistical calculations			
	K_1	K_2	K_3	K_4	K_5	K_6	Avg.	S2	SD	SE
7^{th}-day growth height	3.5	5	6.5	4	6	3.4	4.730	1.3140	1.7270	0.5360
14^{th}-day growth height	4.6	6.5	7	5.5	6	7	6.100	0.9380	0.8800	0.3830
21^{th}-day growth height	6.5	7	10	9.5	9	6.5	8.100	1.5940	2.5140	0.6510
21^{th}-day fresh weight	1.3	1.4	1.45	1.52	1.5	1.35	1.440	0.0074	0.0860	0.0351
21^{th}-day Dry weight	0.13	0.14	0.15	0.16	0.15	0.14	0.145	0.0071	0.0845	0.0345

The continuation of table 5.

Variable	Cultivation in sandy soil +5% organic fertilizer						Statistical calculations			
	K_1	K_2	K_3	K_4	K_5	K_6	Avg.	S2	SD	SE
7^{th}-day growth height	15	16	17	16	18	15	16.2	1.3670	1.1690	0.480
14^{th}-day growth height	19	26	27	28	23	25	24.7	3.2660	10.667	1.3340
21^{th}-day growth height	34	36	37	38	34	36	35.8	2.5670	1.6200	0.6560
21^{th}-day fresh weight	2.3	2.2	2.4	2.5	2.8	2.6	2.48	0.0460	0.2160	0.0882
21^{th}-day Dry weight	0.24	0.34	0.35	0.29	0.32	0.28	0.30	0.00079	0.0280	0.0115

Chemical composition of organic fertilizer product

The changes in the chemical composition of the initial raw materials and the final organic fertilizer product (after 100th days of composting) in the case of three treatments were obtained as described in Table 6. Based on these results, organic matter decreased from 81.3% in RH treatment to 68.4%, and these values fell from 83.1 and 85.4 to 70.6 and 72.4 in the second (RH 85% + Wood waste 15%) and third (RH 70%+Wood waste 30%) treatments, respectively. Therefore, all three runs of composting treatments have reduced the amount of organic matter. The amount of organic carbon decreased from 44.1% in RH treatment to 35.8%, and these values reduced from 45.2 and 46.6 to 37.4 and 38.5 in the second run (RH 85% + Wood waste 15%) and third run (RH 70%+Wood waste 30%) treatments, respectively. So, all three runs of composting treatments have reduced the amount of organic carbon. In general, according to these results, during composting, the percentage of nitrogen has increased, which has caused the ratio of carbon to nitrogen to decrease by the same amount. Also, the increase in the rate of minerals such as potassium and phosphorus has reduced the ratio of organic carbon to phosphorus. All these results indicate the success of the composting process and achieving an environmentally friendly and green procedure for RH composting. In general, according to these results, during composting, the percentage of nitrogen has increased, which has caused the ratio of carbon to nitrogen to decrease by the same amount. Also, the increase in the rate of minerals such as potassium and phosphorus has reduced the ratio of organic carbon to phosphorus. All these results indicate the success of the composting process and achieving an environmentally friendly and green procedure for RH composting to produce organic fertilizer.

Table 6. Chemical composition of initial raw materials and organic fertilizer product after 100th days of composting.

Elements Compound	OM %	OC %	N_t %	C/N	K %	PO_4^{3-} %	C/P
RH	81.3	44.1	0.27	151.3	0.1	0.2	220
RH fertilizer	68.4	35.8	1.51	23.4	1.56	2.54	14.1
RH85% + Wood waste 15%	83.1	45.2	0.29	157.6	0.3	0.36	125.6
RH85% + Wood waste 15% fertilizer	70.6	37.4	1.93	18.3	1.87	3.4	10.4
RH70%+ Wood waste 30%	85.4	46.6	0.3	155.6	0.34	0.37	125.9
RH70%+Wood waste 30% fertilizer	72.4	38.5	2.1	17.3	1.91	3.1	11.7

Zhao et al. reported [33] that the rich nutrition in CSL and sugar cane molasses changed the fungal community structure. They increased the abundance and diversity of fungi and different destructive lignocellulosic substrates microorganisms in the early stage. Still, they decreased the late stage of composting, promoted the conversion and conservation of C and N in composting, and improved the quality of organic fertilizer products. So, as observed in this study, CSL and molasses have the potential to provide energy supply and nutrients and improve the nutritional value of RH organic fertilizer [34].

CONCLUSION

The results show that the fertilizer produced from RH and its combination with wood waste and the mentioned additives had excellent quality and had a significant percentage of elements. Also, they show that combining RH with wood waste decreases the C/N ratio; it increases the compost's potassium, calcium, nitrogen, and phosphorus to some extent and improves the product's color. Adding only 5% (W/W) of the resulting compost to the sandy soil increased the growth of the rice seed sample more than three times and increased its biomass by more than

50%, which is significant. It is necessary to explain that although the factors of the fertilizer produced are acceptable, in the final products of organic fertilizer produced from RH plus wood waste, there are still un-pulverized pieces and crumbs of RH. Therefore, after the 100th day, the processing time can continue by adding nutrients. By continuing the composting process, non-converted materials will decrease again, the quality of the product will be strengthened and even better, and the C/N ratio of the product will decrease again, which can be considered in future research.

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