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ENHANCEMENT OF POULTRY WASTE COMPOST BY ADDING BIOCHAR

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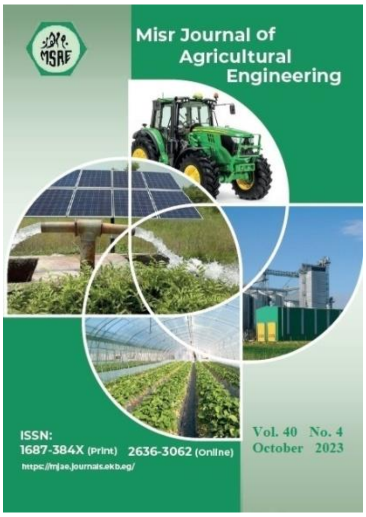

Keywords:
Composting; poultry litter; biochar; maturity and stability; germination index.

ABSTRACT

The process of converting poultry waste into organic fertilizer is the best option, but the challenge in treating nitrogenous waste is the easy loss of nitrogen and the increase in methane emissions. Thus, the aim of this study was to determine the best mixing ratio of biochar (BC) for the production of organic fertilizer and to test the degree of maturity and stability of the produced fertilizer through maturity and stability tests. Addition of BC to the poultry litter (PL) was very beneficial, as it gave several initial indications of the possibility of producing good organic fertilizer. BC was added to the PL in proportions of 0%, 5%, 10%, and 20% by weight to produce compost using cylindrical bioreactors. The results showed that the addition of 10-20% of biochar to poultry litter achieved the highest average temperature (62.2, and 67.5 °C, respectively) after 48 hours from the start of operation. The decrease of percentage of organic matter, volatile solids, and ash during the the active stage are indicators of increased microbial activity and analysis of organic matter. The maturity and stability tests (Solvita index and Dewar's test) as well as the phytotoxicity test (germination index) proved that the compost contains 10-20% biochar, is mature, and stable compost with low ammonia. Therefore, adding biochar to the poultry litter leads to improve the homogeneity and building the mixture and stimulating the microbial activity in the compost mixture, and this has good economic effects in terms of accelerating the process of compost production.

1. INTRODUCTION

Date palm is planted over an area of 1.381 million hectares (FAO, 2023), primarily in North Africa and the Middle East, with an estimated production of 9.66 million metric tonnes of dates in 2021 (Shahbandeh, 2023). Egypt, Iran, Saudi Arabia, and the United Arab Emirate (UAE) are the major producing countries, contributing to 57% of the global production (Shahbandeh, 2023). The annual global production of date palm residues is about 3 million tons, resulting in a significant amount of waste in the form of fibrous materials, dried fruits, and seeds (Faiad et al., 2022). This poses a major problem for farmers and has a negative impact on the surrounding environment. Some of these residues are utilized in construction, homes, the paper industry, or as animal feed. However, due to a lack of awareness among palm farmers about the potential benefits of using these residues, a large part of them becomes burdens on the fields and farms. Consequently, many palm farmers dispose of these unused wastes within the farm using primitive methods, leading to environmental pollution. This poses a real environmental problem in the countries that produce date palm crops. In recent years, there has indeed been an increase in demand for recycling materials in agriculture. This demand is driven by the recognition of the numerous benefits it offers, such as reducing natural resource consumption, allowing nutrient recycling, and increasing organic matter levels in the soil. These factors collectively contribute in improving the physical, chemical, and biological properties of the soil, which is crucial for sustainable and productive agricultural practices. (Westerman and Bicudo, 2005), which in turn have a significant effect on soil fertility and productivity (Saha et al., 2008 and Francioli et al., 2016). Recently, carbon-rich biomass carbonization products, also known as biochar, have become increasingly the subject of scientific and public interest. It is claimed that biochar can improve soil properties and agronomic performance (Glaser and Birk, 2012). Biochars (BC) are carbon-rich solids obtained from thermochemistry decomposition of organic biomass in limited oxygen environment (Lehmann and Joseph, 2015; Kumar et al., 2021). BC typically has an alkaline pH, higher carbon (C) content, and higher aromaticity; However, it has low ash content and nutrients content such as N, P, K and Ca (Domingues et al., 2017). BC is a fine-grained, hard, carbon-rich biochemical material obtained through the charring of biomass under limited oxygen conditions. It can be added directly to soil to improve soil functions and reduce biomass emissions, the loss of amonia (NH_3) by volatilization, and is a good tool for agricultural and environmental management (Adel et al., 2015). In addition, to improve the soil's water-holding capacity, adjusting pH, and increases microbial activity (Atkinson et al., 2010; Glaser et al., 2002), and increased nutrient uptake by plants (Lehmann et al., 2003). It has been proven that the addition of BC produced from date palm residues to the poultry litter (PL) mixture will reduce composting time, reduce the loss of the initial mixture of nitrogen, and is accompanied by an increase in biological activity, a decrease in methane emissions, and an improvement in the texture of the initial mixture (PBBC, 2020). Plant-derived BC have high C content due to the greater amount of lignin and cellulose present, which gives the BC high stability and resistance to microbial decomposition (Lehmann and Joseph, 2009). High nutrient concentrations in the biomass can generate BC with more ash content and alkalizing capacity (Deenik et al., 2011). Thus, BC can be used in soils to correct acidity (Wan et al., 2014), increase soil cationex change capacity (CEC), retain water (Singh et al., 2010; Wan et al., 2014), and regulate C and N dynamics (Shenbagavalli and Mahimairaja, 2012). In addition, researchers have pointed out positive effects of BC on soil remediation due to its adsorption of pesticides or metals (Beesley et al., 2010; Paz-Ferreiro et al., 2014). Composting is one of the most widely accepted technologies for the recycling of organic wastes in agriculture, avoiding the drawbacks of direct land application of raw wastes or poorly stabilised materials, such as plant nutrient immobilisation and phytotoxicity (Butler et al., 2001). Composting is the transformation of organic materials into a well-stabilized product by the rapid succession of microbial populations under aerobic circumstances. During this process, some organic matter is mineralised to CO2, while others are converted into humic compounds, which serve as a useful indicator of organic matter stabilisation (Senesi and Plaza, 2007). Thus, the current study aims to determine the best mixing ratio of biochar for the production of organic fertilizer from poultry litter and to validate the degree of maturity and stability of the produced fertilizer.

2. MATERIALS AND METHODS

Biochar, with its high specific surface area and porosity, as well as the presence of diverse functional groups, can be a great matrix for developing fertilisers that release nutrients gradually (slow-release fertilisers and controlled-release fertilisers). Co-composting, co-pyrolysis, or co-application of biochar with synthetic fertilisers enable for biomass use while also protecting the environment.

1- Collection of poultry litter and palm waste and biochar production

Palm tree pruning waste like fronds and green leaves, which are characterized by containing many nutrients and organic materials, was collected from the outskirts of the Riyadh region. The waste was chopped into small pieces using a gas motor–powered shredder (model FYS-76 Shredder, Mainland, Zhejiang, China). The biochar (BC) was prepared from the fronds and burned leaves of date palm. Date palm was selected based on its widespread availability in Riyadh City. BC was produced by collecting date palm fronds and green leaves and exposing them to direct sunlight to dry, and then cutting them into small pieces (2–3 cm). The pieces were subjected to a high temperature of 400–450 °C ± 10 °C in a burning furnace. BC pieces were manually crushed and ground using an electrical grinder. The BC materials were then strained through a 2-mm sieve before being mixed with the poultry litter. Details of date palm preparation can be found in (Al-Wabel et al., 2019; Usman et al., 2015). Poultry litter (PL) was collected from some sheds scattered in the city of Riyadh, and mixed with a little chopped dry palm waste to reduce its moisture content (An adequate quantity of dry palm waste was added to adjust moisture content to be 60%).

2- The fixed cylindrical bioreactors used in the experiment

The system consists of four identical fixed bioreactors, a ventilation unit, and a temperature measurement unit for each reactor. The bioreactor (Fig. 1) is a cylindrical shape (60 liters), made of galvanized iron with a perforated tin base at the bottom to distribute the air supplied from the outside. The bioreactor is surrounded by 2 cm insulation (rockwool) to keep heat loss from the bioreactor wall to a minimum. Air flow at a rate of 10 L/min for 12 h/day was supplied to the bottom of each bioreactor. A thermal thermostat (Type T) was placed near the center of each bioreactor to measure the temperature. All thermostats are connected to a data logger (testo 177-T4 V01.02. Germany).

3- Compost production and parameters monitoring

Biochar (BC) was added to the Poultry litter (PL) in proportions of 0%, 5%, 10%, and 20% by weight. Four cylindrical bioreactors were used to produce composting. Each bioreactor (Bio) contains a fixed amount of mixture (20 kg).

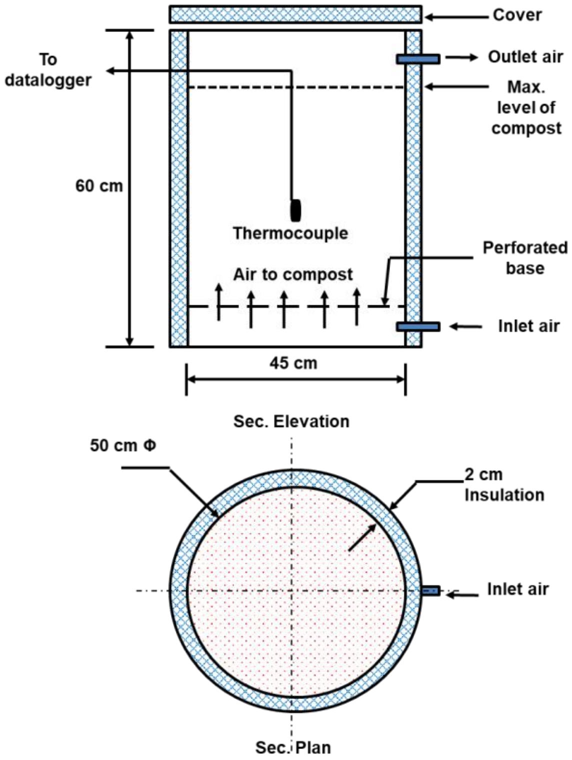

Fig. (1): Schematic diagram of the experimental fixed cylindrical bioreactor

The quantity of BC is a proportion of the total weight as follows: Bio1 (20 kg of PL without any BC, as a control), Bio2 (19 kg PL and 1 kg BC, represents 5%), Bio3 (18 kg PL and 2 kg BC, represents 10%), and Bio4 (16 kg PL and 4 kg BC, represents 20%). The initial mixture had an appropriate moisture content (60-65%), as well as a carbon to nitrogen ratio around 30:1. The bioreactors were filled with the mixture and the internal temperature (Ti), and the external temperature (To) were monitored every one hour by means of thermal wires and a data collector. Other parameters such as pH, volatile solids (VS, %), moisture content (MC, %), carbon to nitrogen ratio (C:N ratio) and amount of ash (Ash) were also monitored during the experiment. The bioreactors were operated for a period of 7 days (168 hours), depending on the maximum temperature reached by the waste, and represent the active stage in compost production. After that, the compost is removed from the bioreactors into the air, where the stage of maturity and stability begins, in which the compost is sprayed with water and stirred at least once a week until compost maturity. Completion of compost maturity and stability is confirmid by conducting a series of maturity and stability tests.

4- Composting parameters determination

At the beginning of the experiment, three samples were taken from each bioreactor as replicates, and the physical and chemical properties were evaluated as in Table (1). Also, a sample was taken every day throughout the active stage in order to monitor the MC, pH, EC, organic matter (OM), C/N ratio. Temperatures are measured around the clock by placing a thermostat (Type T) near the center of each bioreactor. All thermostats are connected to a data collection unit (Multiscan 1200). The American Society for Testing and Materials (ASTM, 2016) techniques were employed to determine the moisture content (MC), volatile solids (VS), and ash in the compost samples. MC was assessed by placing representative compost samples in an air oven at 105 °C until a constant weight was achieved. The organic matter (OM) content was determined by subjecting the dried samples to a muffle furnace at 550 °C for 2 hours. The ash content was measured by weighing the residue after combustion, and the organic matter content was obtained by subtracting the ash weight from the initial dry weight. According to Haug (1993), the total organic carbon (TOC, %) content was determined by assuming it to be equal to 55% of the organic matter (OM) as follows:

$$\boldsymbol{OM}(\%) = \mathbf{100} - \boldsymbol{Ash}\ (\%) \qquad (\mathbf{1})$$

$$\boldsymbol{TOC}\ (\%) = \boldsymbol{OM}\ (\%) \times \mathbf{0.55} \qquad (\mathbf{2})$$

A Foss-Kjeltec analyzer (Model: 8100, Denmark) was utilized to determine total nitrogen (TN, %) based on Total Kjeldahl-N (TKN). The TKN analysis measures the total organic nitrogen, as well as nitrogen in the forms of ammonia (NH3-N) and ammonium (NH4-N), which represent acceptable microbial nitrogen forms during the active stage of composting (Ganguly and Chakraborty, 2018; Abdul Kadir et al., 2016). Consequently, the C/N ratio was calculated by dividing the TOC value by the TN value. The C/N ratios were determined both at the beginning of the composting process (day 0) and upon reaching composting maturity.

EC is measured daily by shaking 5 g of sample in 50 mL of distilled water (1:10, w/v), then filtering the mixture after passing through Whatman No. 42 filter paper and then using a digital conductivity meter (Model EC Meter 19060-Series-Cole-Parmer Instrument Co.). The pH was also determined daily by shaking 5 g of the sample in 50 mL of distilled water (1:10, w/v) using a digital pH meter (Jenway 3510 - UK).

5- Maturity and stability parameters

5-1- Solvita maturity test

The samples were gently poured into the Solvita jar after its squeeze until they reached the fill line. Following the manufacturer's recommendations, the samples were incubated in 200 ml containers with a Solvita reactor for a 4-hour period, at 20-25°C (WERL-2018, Guide to Solvita Testing for Compost Maturity Index). The maturity index (MI) was derived by analyzing the interrelationship of the two indications obtained from reading both probes, following the manufacturer's methodology (WERL, 2018, and Buchanan et al., 2001).

5-2- Dewar (self-heating) test

The Dewar or self-heating test is a useful tool for determining compost maturity (Estevez-Schwarz et al., 2012). Each sample was stored in a flask for six days. Afterward, the highest temperature and the corresponding ambient temperature were recorded, and the temperature difference was determined for each sample (WEL, 2009).

5-3- Germination percentage and germination index

Germination index (GI) serves as a sensitive parameter to assess compost toxicity and maturity levels (Zucconi et al., 1981b). The method used to determine GI, according to Zucconi et al. (1981b), involved mechanically shaking ten grams of the sample under examination with 100 ml of distilled water for one hour in an incubator shaker (IKAR KS 4000i control, Germany/Deutschland). After a 15-minute mixing at 3000 rpm, the supernatant was filtered through a Whatman FP No. 6 filter paper. Subsequently, ten seeds of white radish (Raphanus sativus) were placed on a Whatman FP No. 1 filter paper in sterile Petri dishes.

The compost extract, approximately 4.0 ml (divided into two intervals), was pipetted into one Petri dish, while 4 ml of distilled water (added in two intervals) was used as the control. The Petri dishes were then covered and kept inside a Binder incubator (USA) at 25°C in the dark for 5 days. After the 5th day, the percentage of seed germination (SG) in the compost extract was compared to that of the distilled water control. For germination assessment, any protrusion through the seed coat was considered germination (Bazrafshan et al., 2016). The treatments were evaluated by counting the number of germinated seeds and measuring the length of the roots (Gao et al., 2010). The percentage of GI, used to evaluate phytotoxicity, was calculated based on the relative seed germination (SG), and the root elongation (RE) was determined following the method described by Zucconi et al. (1981b) as follows:

$$\mathbf{RE}\ (\%) = \frac{\mathbf{No.\ of\ seeds\ germinated\ in\ compost\ extract}}{\mathbf{No.\ of\ seeds\ germinated\ in\ control}} \times \mathbf{100} \qquad (\mathbf{3})$$

$$\mathbf{SG}\ (\%) = \frac{\mathbf{Mean\ root\ length\ in\ compost\ extract}}{\mathbf{Mean\ root\ length\ in\ control}} \times \mathbf{100} \qquad (\mathbf{4})$$

$$\mathbf{GI}\ (\%) = \mathbf{SG}\ \times \mathbf{RE}\ /\mathbf{100} \qquad (\mathbf{5})$$

6- Statistical analyses

SAS ver. 9.0 (SAS Institute, Cary, NC, USA) was utilized for statistical analysis to examine changes in compost qualities. The data are presented as means (SEM) and were analyzed using one-way ANOVA with the least significant difference (LSD) test at a significance level of $p < 0.05$.

3. RESULTS AND DISCUSSION

1- Initial physical and chemical properties of the mixtures

The most important elements that were measured at the start of experiment were the moisture content and the C/N ratio because they are of great importance in ensuring compost formation and adjusting each of them if they were not in the required range. Table (1) shows the most important physical and chemical properties of the compost mixture in the bioreactors at the begining of the experiment.

Table (1): Physical and chemical caracterestics of compost mixture at the begining of the experiment (mean±SD, n=3).

Parameter	Bio (1) 0% BC	Bio (2) 5% BC	Bio (3) 10% BC	Bio (4) 20% BC
Moisture content, %	58.11 ± 0.49	56.16 ± 0.7	52.16 ± 0.6	58.90 ± 0.5
pH	7.47 ± 0.02	8.4 ± 0.05	8.1 ± 0.02	8.8 ± 0.02
EC, dS/m	1.81 ± 1.0	2.36 ± 0.99	3.25 ± 2.2	3.43 ± 1.5
Organic matter, %	77.15 ± 1.2	78.42 ± 2.1	81.14 ± 2.5	85.17 ± 1.8
Total Carbone, %	35.08 ± 0.06	32.2 ± 2.1	33.1 ± 1.5	31.6 ± 1.6
Total nitrogen, %	1.63 ± 0.49	1.28 ± 0.8	1.21 ± 0.09	1.01 ± 0.52
C/N ratio	21.5	25.2	27.3	31.2
Ash, %	66.80 ± 1.68	67.12 ± 1.42	66.06 ± 1.64	64.88 ± 2.1
Bulk density, gm/cm^3	0.672 ± 18.03	0.632 ± 15.6	0.566 ± 11.2	0.592 ± 14.1

2- Composting stages and temperatures

Composting is an exothermic chemical process that generates heat due to aerobic metabolic reactions in the composting materials (Alkoaik et al., 2020). During the active phase, the compost temperature (Fig. 2) began to gradually increase after the first six hours from the start of the experiment, then a sharp rise in the compost temperature occurred in all bioreactors after about 48 hours. The maximum temperatures achieved were 47.5, 48.5, 62.2, and 67.5 °C for bioreactors 1, 2, 3 and 4, respectively and the temperatures over 55 °C continued for 96 hrs in biorectors 3 and 4. This rise in temperature is due to the decomposition of carbohydrates, proteins, and fats. These finings are in allighment with Alkoaik et al., (2020). Afterwords, a gradual decrease in temperature occurred, wich was previously reported by Rashwan et al., (2021), and this stage is known as the cooling stage, during which the decomposition of the existing hard materials that did not decompose in the active stage continues. This decrease may be due to the consumption of the organic matter available for decomposition, as the mixture begins to decompose to the stage of maturity (Biddlestone and Gray, 1985). The temperature of bioreactor 1 and 2 did not rise as much as required and this was due to the fact that PL contains a high percentage of nitrogen with a small amount of carbon, which makes the ratio of C/N is low and below the recommended percentage when composting. The change in temperature is an indication of the progress of the organic fertilizer production process from the beginning to the stage of maturity, and therefore it can be considered that the temperature is a good indicator of the end of the decomposition process and the arrival of the fertilizer to the stage of maturity (Jimenez and Garcia, 1989).

3- Composting parameters

The optimum moisture content (MC) of the compost is a vital factor for the microbial decomposition of organic waste. The moisture content of the four units at the beginning of the experiment ranged from 53% to 60%, which are very suitable percentages for fertilizer production (Elcik et al., 2016).

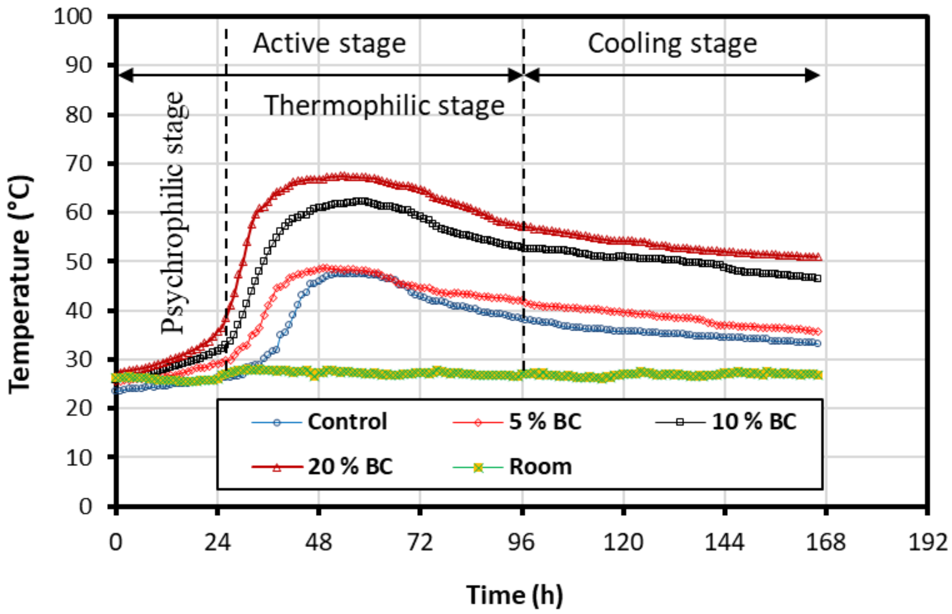

Fig. (2): Average change in the temperature value of the compost during the active phase.

Where, excessive MC, however, leads to a decrease in the rate of oxygenation, which leads to the formation of anaerobic conditions, and thus reduces the rate of decomposition of OM as well as enhances the formation of unpleasant odors due to the release of volatile compounds such as carbon and hydrogen sulfide (Manohara and Belagali, 2014). MC gradually decreased at a small rate with time during the active phase (Fig. 3A).

The pH values at the beginning of the experiment during the active phase ranged between 7.47 and 8.78. Some of these values are considered slightly high due to the high carbon content (Fig. 3B). While the pH value in the control unit (Bio 4) was 7.47, which is very suitable for composting when other factors are available. The pH values of Bio1, Bio2, and Bio3 slightly decrease during the first day due to the activity of aerobic microbes and their decomposition of organic matter, and the high level of carbon dioxide produced from the breakdown of carbohydrates (Estevez Schwarz et al., 2012). After that, the pH started to rise and reached 9.15. This increase is due to the production of ammonia due to the initiation of the proteolysis process and then decrease slowly but steadily as ammonium (NH4 +) is nitrifed to approach neutral values as compost matures (Gao et al., 2010). After that, it decreased slightly in the curing stage reaching between 9 and 7.21 at the end of the active phase due to the formation of ammonia (Bazrafshan et al., 2016) and the formation of mineral nitrogen (Bustamante et al., 2008).

EC is an indicator reflects the level of salinity in the fertilizer product, which suggests the possibility of phytotoxic or plant inhibitory effects (Gao et al., 2010). EC values at the beginning of the experiment (Fig. 3C) were relatively high, may due to the presence of ammonia and its gradual decrease in the following days, and this means that the fertilizer needs another sufficient period of treatment until maturity and stability occur. Therefore, it is very important to measure the EC in the compost because if it is high the seedlings and plants will be more susceptible to infection (Sullivan et al., 2018).

Organic carbon (OC) is one of the most important nutrients that microorganisms need in their diet and structure, as microbes and microorganisms break down organic matter into simple components that they can benefit from. Accordingly, over time, organic carbon depletion occurs and it decreases continuously. This decrease begins during the active phase as shown in Figure (3D) and continues in the cooling and treatment phase until stability occurs in the organic matter, which indicates the arrival of the fertilizer to the stage of maturity. In Figure (3d), the rate of decrease in organic carbon is very low at this stage, and the highest rate of decrease was in the unit containing 20% BC compared to the other units.

Figure (3E) shows the decrease in the percentage of volatile solids (VS) The unit containing 20% BC consumed the most VS, as it decreased from 59.06% to 53.12% during the active stage, followed by units containing 5 and 10% BC. While the control unit is almost stable due to the the weak fermentation and and decomposition process.

Figure (3F) shows a gradual decrease in the proportion of ash in all units. The unit with 20% BC has the lowest ash content, decreasing from 65.88% to 63.82% during the active stage, followed by units with 5 and 10% BC. While the control unit is almost stable due to the lack of fermentation and decomposition, as the ash percentage decreased from 66.8% to 65.61%.

Numerous researches indicated that the ideal C:N ratio with which compost should start is about 25/1 to 35/1 (Guo et al., 2012), while the ideal ratios for the quality of compost after maturity range from 12:1 to 25:1 (Estevez-Schwarz et al., 2012; Tiquia, 2010). There is a variation in the C/N value in the begining of composting process (Table 2) due to the different percentages of BC added to each bioreactor. C/N content are important in the composting process because microorganisms use carbon as a source of energy and nitrogen for cell construction and protein synthesis (Iqbal et al., 2015). The optimal C/N ratio in the composting process is considered to be 30/1. if the C/N ratio is higher than optimal, the composting process is slowed down because the activity of microorganisms is reduced, and at a lower C/N ratio, ammonia and unpleasant odors are generated (Neugebauer et al., 2017).

Table (2): Physical and chemical caracterestics of compost mixture after two months of the active stage end (mean±SD, n=3).

Parameter	Bio (1) 0% BC	Bio (2) 5% BC	Bio (3) 10% BC	Bio (4) 20% BC
pH	7.3 ± 0.02	7.4 ± 0.01	7.7 ± 0.01	8.5 ± 0.04
EC, dS/m	0.94 ± 0.01	2.03 ± 1.01	2.21 ± 1.15	2.03 ± 1.4
Total Carbone, %	40.66 ± 2.16	40.5 ± 1.1	41.3 ± 1.15	39.4 ± 1.3
Total nitrogen, %	1.53 ± 0.04	1.57 ± 1.08	1.87 ± 0.08	1.89 ± 0.02
C/N ratio	26.57	25.79	22.1	20.85

4- Compost Maturity and stability

The findings of the Dewar flask temperature versus time (Stability test) revealed that the compost in Bio1 and Bio2 (Table 3) exhibited considerable temperature variation between the inside and outside of the Dewar flask over the course of 5 days, ranging from 10 to 15°C. These variations suggest that the compost product is immature and requires additional time to mature. Conversely, the compost in Bio 3 and 4 showed a variation of only 10°C, indicating that the compost is fully matured and ready to use (WEL, 2009).

Table (3): Dewar test result of the final compost (mean±SD, n=3).

Day	Net rise temperature (°C) (Flask-Ambient)			
	Bio (1) 0% BC	Bio (2) 5% BC	Bio (3) 10% BC	Bio (4) 20% BC
1	15 ± 1.01	12 ± 0.03	5.3 ± 0.01	1.2 ± 0.01
2	11 ± 0.09	10 ± 0.10	3.2 ± 0.02	1.2 ± 0.02
3	13 ± 1.02	15 ± 0.99	4.2 ± 0.01	1.3 ± 0.02
4	10 ± 1.05	11 ± 0.04	2.4 ± 0.01	0.9 ± 0.03
5	13 ± 1.04	12 ± 0.02	6.3 ± 0.04	0.7 ± 0.01

Solvita test results (Table 4) indicated that, the compost in Bio1 and Bio2 are immature (SI=1 and 2), therefore, they need more time to achieve maturity. While the compost in Bio3 is mature with low ammonia (SI=6) and the compost in Bio4 is very mature (SI=7). This result agrees with the findings of Rashwan et al., (2021).

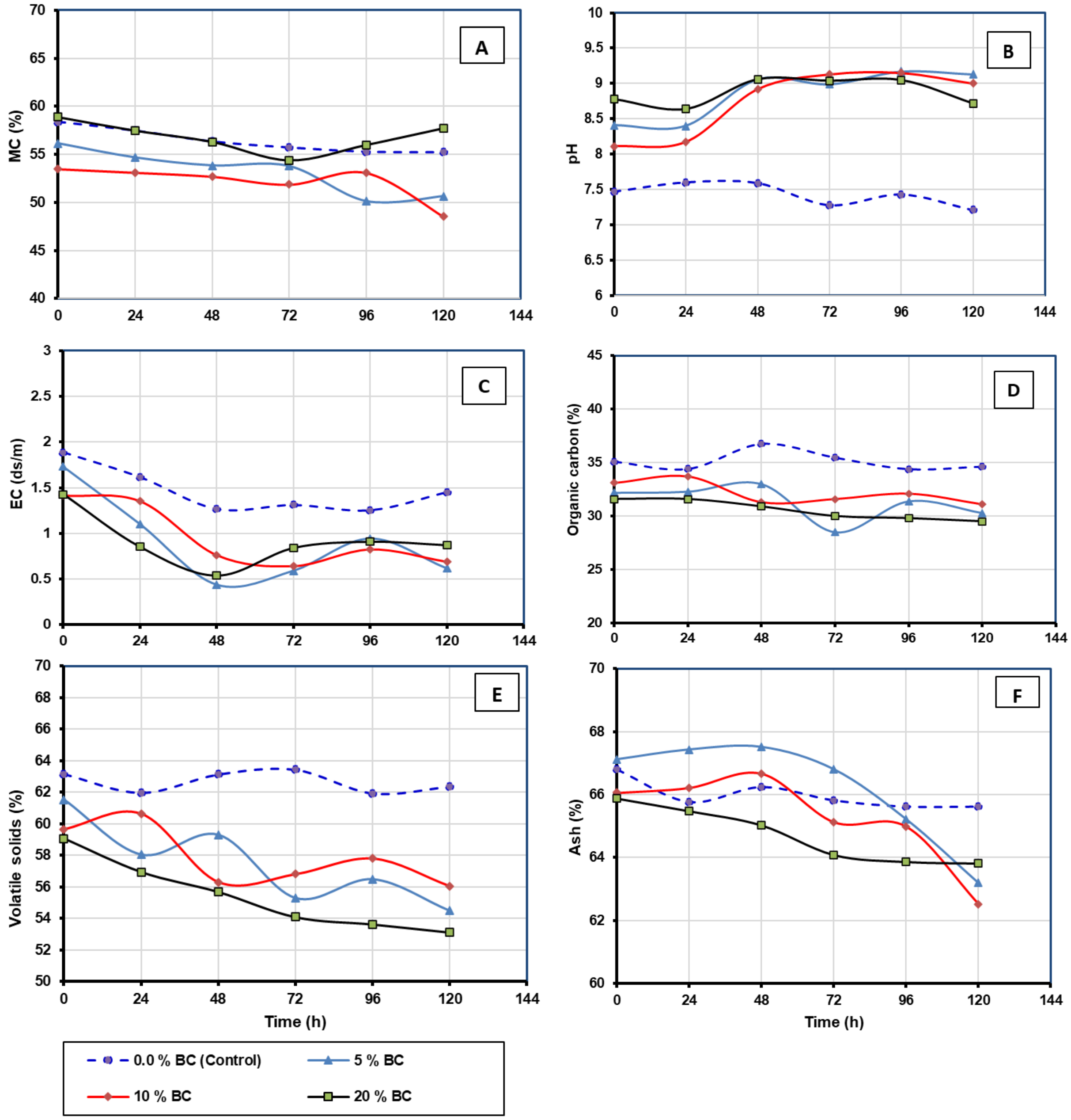

Fig. (3): The average change in the composting parameters during the active phase.

Table (4): Solvita test for maturity

	Bio (1)	Bio (2)	Bio (3)	Bio (4)
Parameter	**0% BC**	**5% BC**	**10% BC**	**20% BC**
Solvita CO_2	**3**	**4**	**6**	**7**
Solvita NH_3	**2**	**2**	**4**	**4**
Solvita Index (SI)	**1**	**2**	**6**	**7**

5- Germination percentage and germination index

Table 5 displays the average germination percentage of white radish seeds in both the control and compost runs after 5 days. Throughout the test period, the majority of the seeds germinated in both the control and compost runs. According to Tiquia et al. (1996), the Germination Index (GI) serves as a sensitive measure of compost maturity and phytotoxicity. GI values below 50% indicate high phytotoxicity, values between 50% and 80% indicate moderate phytotoxicity, and values above 80% indicate no phytotoxicity. Phytotoxicity can occur in stable or mature composts due to the presence of elements that were not eliminated during the composting process, such as heavy metals and persistent pesticides (Research report 2005). The result of GI value of white radish seeds that germinated on the compost at the end of the germination period indicated that the compost in Bio1 and Bio2 are moderately phytotoxic (GI=68.22 and 74.65, respectively). While, the tested sample of the compost in Bio3 is not totally free of phytotoxicity but has low phytotoxicity is present as well (GI=78.25). This result agrees with the earlier findings obtained by the Zucconi research group (Rashwan et al., 2021; Zucconi et al., 1981b; Zucconi et al., 1985) as well as the later findings of Barral and Paradelo (2011) and Estevez-Schwarz et al. (2012). While the compost in Bio4 has no phytotoxicity (GI=81.23). More details are shown in Table (5).

Table (5): Radish seeds germinated during germination period.

Average value of germinated seeds	**Bio (1) 0% BC**	**Bio (2) 5% BC**	**Bio (3) 10% BC**	**Bio (4) 20% BC**
Radicle (mm)	**44.90**	**49.50**	**50.30**	**56.40**
SG (%)	**88.45**	**94.56**	**100.00**	**100.00**
GI	**68.22**	**74.65**	**78.25**	**81.23**
Control	**90.00**	**90.00**	**94.00**	**95.00**

GI: germination index; SG: seed germination.

4. CONCLUSION

The results indicated that the compost containing 10 and 20% biochar achieved the highest temperatures (62.2, and 67.5 °C, respectively) and continued above 55 °C for 96 hours. This is a good indicator of the activity of microbes and microorganisms in the breakdown of carbohydrates, proteins, and fats. The compost stability test (Dewar's test) proved that the compost containing 10 and 20% biochar gave low differences in temperature (<10°C), which means that the compost is finished and matured. The compost maturity test (Solvita Test) also confirmed that the compost containing 10% biochar is mature and low in ammonia (SI = 6) and the compost containing 20% biochar is very mature (SI = 7). The GI result indicated that the tested sample of compost containing 10% biochar had low phytotoxicity (GI = 78.25). While the compost containing 20% biochar is completely free of phytotoxicity (GI = 81.23). Thus, adding biochar in appropriate doses of 10-20% by weight gives mature, and stable compost with low ammonia and leads to accelerate the composting process mainly through improving the homogeneity and building the mixture and stimulating the microbial activity in the compost mixture, and this has good economic effects in terms of accelerating the process of compost production.

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تحسين خصائص السماد العضوى لمخلفات الدواجن بإضافة الفحم الحيوى

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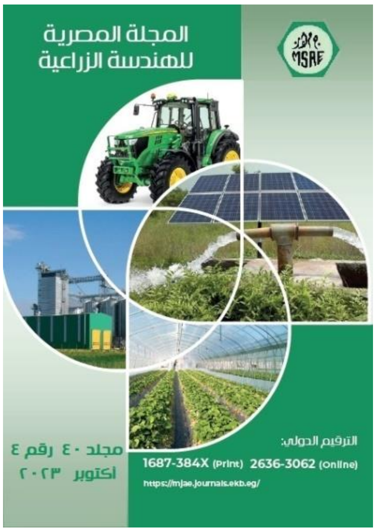

الكلمات المفتاحية:

سماد عضوي؛ مخلفات الدواجن؛ الفحم الحيوي؛ النضج والثبات؛ مؤشر الإنبات.

الملخص العربى

تعتبر عملية تحويل مخلفات الدواجن إلى سماد عضوي الخيار الأفضل، لكن التحدي في معالجة المخلفات النيتروجينية هو سهولة فقد النيتروجين وزيادة انبعاث الميثان. ولذا تهدف هذه الدراسة الى تحديد أفضل نسبة خلط للفحم الحيوي لإنتاج السماد العضوي من فرشة الطيور واختبار درجة نضج وثبات السماد الناتج. تمت إضافة الفحم الحيوي إلى فرشة الدواجن بنسب ٠٪، ٥٪، ١٠٪، و٢٠٪ بالوزن لإنتاج سماد باستخدام مفاعلات حيوية أسطوانية. وقد بينت نتائج هذه الدراسة أن إضافة الفحم الحيوي إلى فرشة الدواجن أعطت عدة مؤشرات أولية (ارتفاع درجة حرارة الكومبوست لأكثر من ٥٥ °م، وانخفاض نسبة المادة العضوية والمادة الصلبة المتطايرة) لإمكانية إنتاج سماد عضوي ذو خصائص مقبولة. أظهرت النتائج أن إضافة ١٠-٢٠٪ من الفحم الحيوي إلى فضلات الدواجن حققت أعلى متوسط درجة حرارة (٦٢,٢ و٦٧,٥ °م على التوالي) بعد ٤٨ ساعة من بدء التشغيل. يعتبر انخفاض النسبة المئوية للمواد العضوية والمواد الصلبة المتطايرة والرماد خلال المرحلة النشطة مؤشرات على زيادة النشاط الميكروبي وتحليل المواد العضوية. أثبتت اختبارات النضج والثبات (مؤشر Solvita واختبار Dewar) وكذلك اختبار السمية النباتية (مؤشر الإنبات) أن السماد الذي يحتوي على ١٠-٢٠ ٪ فحم حيوي، يعتبر سماد ناضج ومستقر مع انخفاض نسبة الأمونيا فيه. لذلك فإن إضافة الفحم الحيوي إلى فرشة الدواجن يؤدي إلى تحسين التجانس وبناء الخليط وتحفيز النشاط الميكروبي في خليط السماد، وهذا له آثار اقتصادية جيدة من حيث تسريع عملية إنتاج السماد.