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DESIGN AND MANUFACTURE OF COMPOST STIRRING MACHINE AND EVALUATION OF ITS OPERATION

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Abstract:

Several experiments were conducted to evaluate the mechanical performance and the quality indicators of the compost manufactured for the machine using three rotational speeds (750, 1500, and 2250) min^{-1} cycle. Three times the compost is turned over a month, which is once, twice, and three times. The results showed that the rotational speed of 2250 rpm^{-1} had the lowest compost density and compost maturity time and the highest rate of disintegration, fuel consumption and productivity of the machine compared to the rest of the speeds. Also, treatment of three times of stirring per month gave less compost density and compost maturation time and the highest rate of disintegration, fuel consumption and productivity of the machine compared to stirring once and stirring twice.

Keywords: Compost Stirring Machine, Compost density, Fuel consumption.

INTRODUCTION:

The process of treating agricultural waste and converting it into organic fertilizer (compost) is important in conditions of intensive agriculture, especially in the southern regions that contain many orchards, agricultural fields and greenhouses, which result in large quantities of waste annually, As they are burned or thrown on the outskirts of the fields, which helps to spread fungal diseases, insects and rodents, Which causes a huge waste of organic matter. Therefore, it is possible to benefit from this agricultural waste and recycle its use in the compost industry, relying on organic agriculture, and expanding the production of organic fertilizers, which Contributes to increasing the areas planted with Crops that adopt this method, the development of the spread of organic agriculture and the use of compost in agriculture depends on several factors, including spreading awareness of the advantages of this method, providing specialized machines for the compost industry, and supporting the state for organic agriculture through the establishment of specialized organic farms in each governorate to benefit from agricultural waste, the quality of the manufactured compost depends on the process of stirring and aerating, as this process is one of the most important processes in the compost industry, as it leads to the exposure of all materials to the air on the surface equally, as well as high temperatures inside the heap. Given the importance of this process, which was based on primitive methods in the compost industry, which is manual stirring, especially in Iraq, this machine was manufactured and designed from simple materials and evaluated its performance with manual stirring. In Egypt, they found that increasing the rotational speed and number of times of stirring of the compost-stirring machine led to a decrease in the density of the compost and the maturation time. While others have noticed the ratio between the rotational speed of the engine and the forward speed of the hauler is one of the most important factors that affect the process of turning the compost through the decrease in the density of the fertilizer produced by increasing this percentage. The most important factors in evaluating the performance of the compost stirrer are the ripening time, the density of the fertilizer produced, and the quality of the fertilizer. The degree of maturity and stability of compost depends on a number of physical and chemical properties, including the degree of reactivity, electrical conductivity, and the percentage of water-soluble organic carbon. Several studies indicated that the minimum acceptable limits for the properties of compost are pH (6.3 - 8.5). Organic matter (20% < O.M) carbon to nitrogen ratio (20 C/N < 20) Electrical conductivity (EC < 5 mmhos cm-1) and total nitrogen (0.8% < N-Total).

MATERIALS, METHODS, AND LABORATORY EXPERIMENTS:

A laboratory experiment was conducted to determine the maturity of compost. Three different speeds were chosen for the shaft rotation mechanism, namely 750, 1500 and 2250 rpm^{-1} and three composting times per month once, twice and three times. The compost was mixed from different wastes with a length of 10 m and a height of 75 cm of the compost heap. A random design was used with a factorial experiment with two factors (3 x 3 x 3), so the number of experimental units was 27 lines (experimental unit) and the results obtained from the machine were compared with manual permutation.

COMPOST PREPARATION:

The compost components were collected from sawdust and palm leaves at a rate of 1000 kg, animal manure (cow waste) 150 kg, urea fertilizer 15 kg, agricultural soil 50 kg, and high-phosphorous compound fertilizer (DAP) 10 kg, and the treatments were mixed and placed at a height of 100 cm and a width of 75 cm. The process of stirring and fermentation continued for a period 20 weeks. Table (1) shows the properties of compost after a week of the experiment.

Table (1) some properties of compost at the beginning of the experiment.

O.M (%)	**C** (%)	**EC** (mmohs cm^{-1})	**pH**
8.32	30.76	1.32	**6.2**
Water Holding Capacity (%)	**C/N**	**CEC** (meq $100g^{-1}$)	**SI**
19.23	15.29	34.12	1.10

Manufacture of compost stirring machine:

The compost-stirring machine was manufactured in one of the private workshops in Al-Gharraf district of Dhi Qar governorate, under the supervision of a group of specialists, beside machines, agricultural and soil machinery, and technical engineers who were consulted in the field of mechanical engineering to arrive at the perfect design for the machine.

Compost density (ρ):

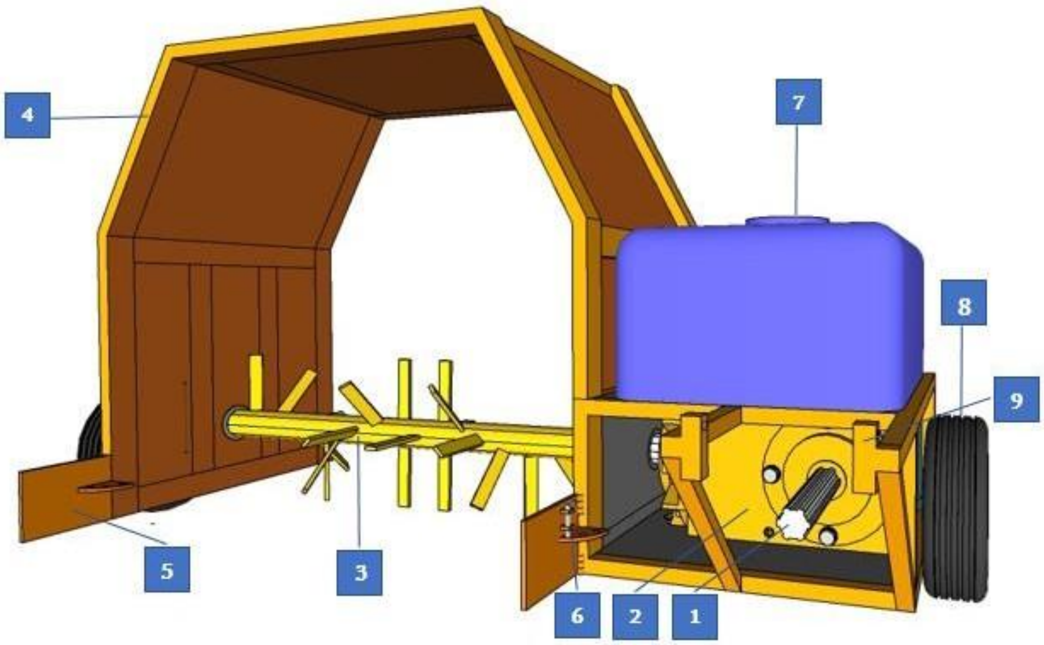
Calculate the Compost density from the aftertaste (Equation 1):

$\rho = \frac{M}{v}$ **............... (1)**

ρ = Compost density (g cm^{-3}) M= Compost sample mass (gm) V= Compost sample size (cm^{-3})

Composting time:

It was calculated from the beginning of the stirring process until recording the full maturity of the compost and reaching the final stage of maturity.



1- Connecting rod with power take-off shaft. 2- Gearbox. 3- Stir shaft. 4- Cabin. 5- The gate. 6- Gate control. 7- Tank. 8- Tires. 9- The point of attaching the machine to the pull arm of the puller.

Figure (1) Components of the developed subsurface composting machine.

FUEL CONSUMPTION:

The fuel consumption was measured by the method of adding using the graduated cylinder. If the tug tank was completely filled, then the tug was turned on and started working directly to the end of the compost stirring line. The tug is turned off immediately, and then fuel is added to the tug using the inserted cylinder. The amount of addition is the consumed fuel (Al-Hashem et al., 2000) and according to the equivalent (2):

$$QF = \frac{Qd \times 10000}{Wp \times D \times 1000} \dots\dots\dots\dots\dots\dots (2)$$

QF = the amount of fuel consumed in hectares (liters ha-1). Qd = the amount of fuel consumed during the treatment (ml). Wp = Actual working width of the compost stirrer (m). D = the distance traveled (the length of the compost turning line m).

COMPOST BREAKAGE RATE: (%)

It was calculated through the relationship between the weight of the blocks less than 25 mm to the total sample weight and according to the following equation (3):

$$\text{Compost breakage rate} = \frac{(\text{25 mm of minimum masses weight})}{(\text{Total sample weight})} \times 100 \dots (3)$$

Machine productivity:

The theme of the accounts according to the equation: Machine productivity (hectares^{-1}) = working speed of the machine (km h^{-1}) x working width of scattered compost (m) x field efficiency (%) / unit area (10000 m^2).

Statistical analysis:

The data obtained for all the results of the studied traits were statistically analyzed according to the method of analysis of variance using a complete random design (Al-Mashhadani and Al-Qassab, 2017) with three replications with (9) coefficients for each replicate, so the number of experimental units becomes (27) experimental units (3 x 3 x 3) to calculate machine and compost evaluation indicators: The data were statistically analyzed using the statistical program (Gens tat). The averages of the transactions were also compared using the least significant difference (L.S.D.) test at the (0.05) probability level.

RESULTS AND DISCUSSION:

Compost density:

The results of the statistical analysis of the F test in Table 7 show that there is a significant effect of the rotational speed factor and the number of times of permutation on the density of compost. When comparing the averages of the treatments, significant differences appeared between all the rotational speed treatments (Table 2), as the rotational speed 750 rpm^{-1} gave the highest values at 0.460 g cm^{-3}, while the lowest values were when the treatment was 2250 rpm^{-1}. As from Table 2, there are significant differences for the number of permutation times, as the values were 0.481, 0.427, 0.365 g cm^{-3} for the treatments once, twice and three times per month, respectively.

As for the effect of the interference, we notice from Table 2 that the change in the values of compost density at the rotational speed coefficients varies according to the change in the number of times of stirring. The interaction treatment between the rotational speed of 750 revolutions min^{-1} and flipping once a month gave the highest values of 0.523 g cm^{-3}, Whereas, the lowest Value was 0.341 g cm^{-3} when the interaction was treated with a rotational speed of 2250 rpm^{-1} and stirring three times a month. The reason for the decrease in the density of the compost is due to the increase in the rotational speed and the number of times of stirring to the common role between them through the high impact on the compost manufacturing materials by increasing the shredding and mixing by weapons, which led to an increase in the unit volume of the compost and thus a decrease in the density of the compost (Morad *et al.*, 2008), All values were within the appropriate range for the agricultural environment between (0.15-0.5) g cm^{-3} (Joiner, 1981)

Table (2) the effect of rotational speed (one minute cycle) and number of times of stirring (one month^{-1}) on the fertilizer density (g/cm^{-3})

the average	Frequency of stirring (once 1 month)			Rotational speed (rpm^{-1})
	three times	twice	Once	
0.460	0.392	0.465	0.523	750
0.428	0.363	0.439	0.482	1500
0.385	0.341	0.376	0.439	2250
	0.365	0.427	0.481	the average
rpm = 0.0054 nt = 0.0054 nt * rpm = 0.0094				L.S.D

Compost ripening time:

The results of the statistical analysis of the F test in Table 7 show that there is a significant effect of the rotational speed factor and the number of times of stirring at the time of compost maturity. When comparing the averages of the treatments, significant differences appeared between all the rotational speed treatments (Table 3). The rotational speed 750 rpm^{-1} gave the highest values at 17.11 months, while the lowest values were 13.56 months when the treatment 2250 rpm^{-1}.

As we note from Table 2, there are significant differences in the number of times of stirring at the time of compost maturity, as the values were 17.44, 15.44, 12.89 months for transactions once, twice and three times per month, respectively. The reason for the decrease in the compost maturity time by increasing the rotational speed and the number of times of stirring is due to the common role between them by increasing the compost volatility and destroying the building of organic matter and increasing the size of its component parts, thus increasing the decomposition process, which leads to accelerating the compost ripening process (Naylor, 1996). As for the effect of interference, the film has a spiritual effect.

Table (3) the effect of rotational speed (one-minute cycle) and number of times of stirring (once one month) on the time of compost maturity (month)

the average	equency of stirring (once 1 month)			Rotational speed (rpm^{-1})
	three times	twice	Once	
17.11	14.00	17.33	20.00	750
15.11	12.67	15.33	17.33	1500
13.56	12.00	13.67	15.00	2250
	12.89	15.44	17.44	the average
rpm = 0.406 nt = 0.406 nt * rpm = 0.703				L.S.D

Fuel consumption: (liter ha^{-1}):

The results of the statistical analysis of the F-test in Table 7 show that there is a significant effect of the rotational speed factor and the number of permutations on fuel consumption. When comparing the averages of the treatments, significant differences appeared between all the rotational speed treatments (Table 4). The rotational speed of 2250 rpm^{-1} gave the highest values at 10.815 liters ha-1, while the lowest values were 7.339 liters ha-1 when the treatment was 750 cycles. 1 minute

As we note from Table 4, there are significant differences in the number of times of flipping in fuel consumption, as the values were 6.368, 8.724, 12.203 liters ha^{-1} for the treatments once, twice and three times a month, respectively. The reason for the increase in fuel consumption by increasing the rotational speed and the number of times of flipping is due to the Common role between them in order to increase the distance traveled during the increase in the number of times of flipping as well as the increase in the load on the engine during the increase in the rotational speed of the engine and thus increase the fuel consumption. As for the interference effect, it had no significant effect.

Table (4) Effect of rotational speed (min-1 cycle) and number of stirring times (1 month) on fuel consumption (liter ha^{-1})

the average	Frequency of stirring (once 1 month)			Rotational speed (rpm^{-1})
	three times	twice	Once	
7.339	10.579	6.619	4.817	750
9.142	12.585	8.401	6.441	1500
10.815	13.445	11.152	7.847	2250
	12.203	8.724	6.368	the average
rpm = 0.4509 nt = 0.4509 nt * rpm = 0.7810				L.S.D

Compost breakage rate: (%)

The results of the statistical analysis of the F test in Table 7 show that there is a significant effect of the rotational speed factor and the number of times of stirring on the compost rate. When comparing the averages of the treatments, significant differences appeared between all the rotational speed treatments (Table 5), as the rotational speed 2250 rpm^{-1} gave the highest values at 28.630%, while the lowest values were 19.296% at 750 rpm^{-1}.

We also notice from Table 5 that there are significant differences in the number of times of flipping in fuel consumption, as the values were 16.690, 23.310, and 31.629% for the transactions once, twice and three times per month, respectively. The reason for the rate of compost fragmentation by increasing the rotational speed and number of times of stirring is due to the common role between them by increasing the number of times of stirring and the high speed, which leads to the fragmentation and destruction of compost aggregates and thus increasing the proportion of compost particles with a size of less than 25 mm. As for the effect of interference, as for the effect of interference, we note from Table 5 that the change in the values of the compost break-down ratio at the rotational speed coefficients varies according to the change in the number of times of stirring. The interaction treatment between the rotational speed of 2250 revolutions min^{-1} and the flipping three times a month gave the highest values by 37.517%, while the lowest value was 12,000 when the interference treatment was the rotational speed of 750 rpm^{-1} and stirring once a month.

Table (5) Effect of rotational speed (one-minute cycle) and number of times of stirring (once one month) on the compost rate (%)

the average	Frequency of stirring (once 1 month)			Rotational speed (rpm^{-1})
	three times	twice	Once	
19.296	27.277	8.610	12.000	750
23.703	30.093	3.360	17.657	1500
28.630	37.517	7.960	20.413	2250
	31.629	3.310	16.690	the average
rpm = 1.2265 nt = 1.2265 nt * rpm = 2.1244				L.S.D

Machine productivity: (hectare $hour^{-1}$)

The results of the statistical analysis of the F test in Table 7 show that there is a significant effect of the rotational speed factor and the number of times of permutation on the productivity of the machine. When comparing the averages of the treatments, significant differences appeared between all the rotational speed treatments (Table 6). The rotational speed of 2250 rpm^{-1} gave the highest values at 2.234 hectares per $hour^{-1}$, while the lowest values were 1.640 hectares per $hour^{-1}$ when the treatment was 750 rpm^{-1}.

As we note from Table 6, there are significant differences for the number of times of stirring in the productivity of the machine, as the values were 1.768, 1.869, 2.092 hectares $hour^{-1}$ for the treatments once, twice and three times a month, respectively. The reason for increasing the productivity of the machine by increasing the rotational speed and the number of times of stirring is due to the common role between them due to the increase in the working width during the stirring operations and the increase in the rotational speed. As for the interference effect, it had no significant effect.

Table (6) Effect of rotational speed (one-minute cycle) and number of times of stirring (once one month) on the compost rate (%)

the average	Frequency of stirring (once 1 month)			Rotational speed (rpm^{-1})
	three times	twice	Once	
1.640	1.847	1.600	1.473	750
1.881	2.073	1.893	1.677	1500
2.234	2.357	2.193	2.153	2250
	2.092	1.896	1.768	the average
rpm = 0.0418 nt = 0.0418 nt * rpm = 0.0725				L.S.D

Table (7) Statistical analysis of F-test for some indicators of performance evaluation of compost stirrer

Source	d.f	Compost density	Compost ripening time	fuel consumption	Compost breakage rate	Machine productivity
rpm	2	94.51**	38.60**	29.73**	28.99**	102.17**
nt	2	227.53**	63.35**	84.76**	74.49**	30.53**
rpm* nt	4	3.56**	2.30 N.S	1.00 N.S	2.63*	1.33 N.S
. The number of flips per month :nt ، Rotational speed (rpm^{-1}:Rpm)						

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