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Production of Compost Tea from Farm Wastes

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ABSTRACT

The aims of this study were to design and manufacture an innovative unit for producing compost tea, and optimizing some operating parameters affecting the performance of the manufactured unit such as flow rate , temperature, aeration , pH ,nutrient additives and fermentation period . Also, to optimize the fermentation and quality of the produced. The selected factors are: extraction temperature (30°C, 40°C, 50°C and 60°C), water flow rate (270 , 300, 330 and 540 l/h), aeration time (6, 12,18, and 24 h with an aeration rate of 0.18 m³/h) , nutrient addition (25,50,75 and 100 ml) and pH (6 and 6.5) of produced compost tea. The result has shown that the temperature has significant role to play in producing high quality of compost tea. pH is the other factor which may contribute poor in quality of compost tea to the results. Power and specific energy are more sensitive to different factors such as extraction temperature, aeration time and fermentation period. The results showed that the values obtained for the extraction efficiency were 98.3%, the production rate was 2.2 l /h and the energy consumed was 5.74 kWh / l and the cost of the extraction process per liter was 1.72 L.E, at 60 ° C and the flow rate of hot water was 270 l /h and aeration time of 24 hours at 0.18 m3 / h and an nutrients additives rate of 50 mL at pH 6.5 for 24 hours fermentation period.

Keywords : compost ; compost tea ; non-aerated method ; aerated method ; Taguchi method ; Microbial population.

INTRODUCTION

In Egypt, The amount of agricultural residues ranged from 30-35 million tons a year of which only 7 million tons as animal feed and 4 million as organic manure are being used. So, the safe use of agricultural waste in an environmentally friendly method is crucial. Thus, alteration from considering crop wastes as undesired residues, for which some usage should be found, to those of considering such wastes as an integral portion of agricultural system for production. There are many new techniques and methods for using crop wastes that have become encouraging and beneficial such as composting, animal fodder and energy production. These can be performed by compost production through brewing the agricultural residues in the perfect method for recycling. This will aid in organic re-fertilizing for the soil and minimize the production cost (Abou Hussein and Sawan , 2010). Composting is the aerobic fermentation of organic materials by microbial activity under controlled conditions. Agricultural wastes are rich in organic matter. This matter is derived from the soil and the soil requires it back for keeping healthy crops production. As well, composting is one of the best known recycling processes for organic waste to close the natural loop (Geisel , 2001; El-Haggar *et al* , 2004 and Abou Hussein and Sawan ,2010).Compost tea is a fermented extract made by extracting soluble nutrient and useful microorganisms from compost then fermented with a microbial catalyst source (i.e, molasses and yeast). It is easier to manufacture, transport, and apply than compost .Its impact attributed to the varied organisms and soluble nutrients existent in compost tea (Scheuerell , 2003 and Zaki *et al* , 2011) .

Ingham (2003) stated that compost tea contains soluble nutrients that perform two key functions: they feed the microorganisms already within the tea, so they grow faster, and can do their disease repressive role perfectly; they help the plant, making it healthier and capable to produce more nutrients to feed the beneficial microbes that repress disease-causing microorganisms. As well repressing disease, the microorganisms in tea give other important interests on plants: they hold nutrient sources in the soil around the plants, therefore extra fertilizer will not be required; they make nutrient sources obtainable to plants at the rate which plants needed ; they detoxify the soil and water making it easier for plants for growing; and they build soil structure, so air and water can easily reach plant's roots.

Compost tea is made by two brewing methods, non-aerated method and aerated method .Non aerated compost tea produce during 2 weeks. Aerated compost tea (ACT) prepared in a shorter fermenting time ranging from 12 to 48 hrs. In the aerated technique, preparing the mixture of aerated compost tea is needed to aerate deliberately. For both methods of producing compost tea, nutrients of microorganisms may or may not be added. If extra nutrient is not added, microorganisms are not active and less to survive the transfer from blend to soil or applications to plants surface (Scheuerell , 2003 ; Kelley, 2004 and Ingham , 2005). Also, Mistry and Mukherjee , (2015) reported that the predominant compost tea production method practiced in the United States is commonly termed actively aerated compost tea, which is the product of the following common process. Usually compost is filled into a permeable vessel which is then submerged in water. Continuous mechanical power input is utilized to supply aeration either by air pump directly into the water or by recirculation of the water, for 12-24 hours. Compost tea additives, such as molasses and yeast extract when added; extraordinarily enhance microorganisms communities in the watery stage from organisms extracted from the compost.

Currently in Egypt compost tea produced from farm wastes is limited. The traditional methods for producing compost tea causing non-aerobic condition during the process which has negative effect on the produced tea in terms of creating different diseases to the soil and the plant. So, the aims of the present study were to design and manufacture an innovative unit for producing compost tea to improve aspects of the soil, and optimizing some operating parameters affecting the performance of the manufactured unit.

MATERIALS AND METHODS

Experiments were carried out through the year of 2016 at Department of Agricultural Engineering, Faculty of Agriculture, Mansoura University to evaluate the performance of manufactured unit for producing compost tea. In this study, the Taguchi quality engineering method was used to optimize the parameter combination and obtain the maximum compost tea production . The aim of the Taguchi method is optimizing the working performance.

The compost tea production unit

The unit was manufactured specially for this work and constructed at a private workshop on Mansoura City. The manufactured unit consists of two parts, the first part is the extraction unit, which includes a stainless steel funnel covered by a stainless steel mesh with a diameter of 50 cm, and 800-micron diameter holes. A vertical tube (196.5 cm high) connected to a shower which was used to spray hot water on the compost which was placed on the stainless steel mesh. The second part is the fermentation unit , which consists of an aerobic tank and air pipe, air compressor , water pump, three water heaters, electric control panel , stainless steel T-valve and metal frame.The unit is moved by three wheels, the unit is shown in Fig. (1).

The compost

The used compost was obtained from Valley of the Kings in Ismailia city and prepared for experiments. The samples were screened through two sieves with diameters of 2 and 1.18 mm . The Chemical and biological characteristics of the used compost are summarized in Table (1).

Table 1. Chemical and biological characteristics of compost :

Chemical analysis	Values
Moisture (%) w.b.	25
pH	7.9
C/N ratio	1:15.32
N (%)	1.6
P (%)	0.55
K (%)	0.63
Total bacterial count (cfu/g)	2.25×10ˆ3

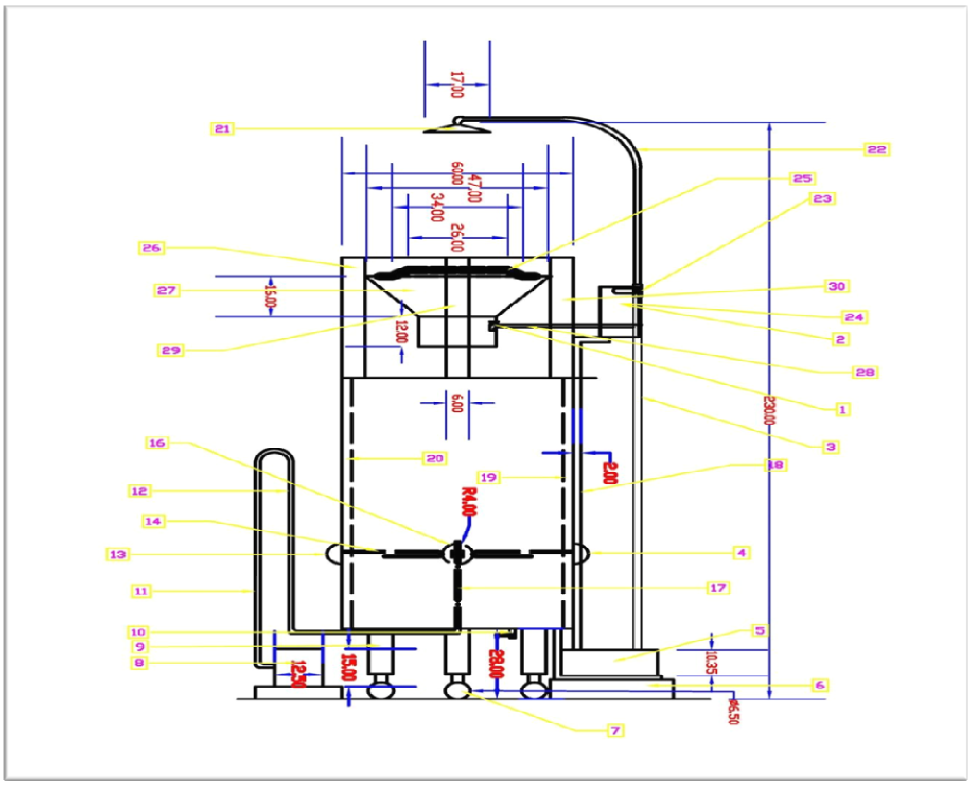

Fig . 1. Schematic diagram of the compost tea production unit . (All dims in cm).

1	Tap	9	Iron stand	20	Thermal wool
2	Electric control panel	10	Intake valve	21	Sprayer
3	Water pipe	11	Flexible hose	22	Water pipe
4,13,16	The heater lid ١	12	Air pipe	23	Valve
5	Water pump	14	Electric heater	24	Electric control panel
6	Fulcrum base	1٧	Air distribution pipe	25	Handle
7	Wheel	18	Electrical wire connection	26,29,30	Iron pillars
8	Air pump	19	Double jacket of stainless steel	27	Extraction cone
				28	Mixing pipe

Additives for compost tea

Humic Acids and Fulvic acids and molasses were used as nutrient additives. Yeast and EM (Effective Bacterial Nutrient Solution) were added as microbial supplements to increase microbial population densities in the compost tea then adjust the acidity of the extraction liquid in the tank as recommended by Mistry and Mukherjee ,(2015).

procedure for Taguchi method

The experiments were conducted with three replications. Since it is aimed to minimize the coefficient of variation, SN values were calculated . The levels of each factor that minimize the SN were optimized. The order of experiments was getten by introducing the parameters into the columns of orthogonal array (OA) , L16, was chosen as experimental way given in Table 2. The validity of this assumption was checked by confirmation experiments conducted at the optimum conditions.

Table 2. Taguchi design of the experimental work.

Run	Temp, (°C)	Water flow rate,(l/h)	Aeration period, (h)	Addition of nutrient, (ml)	pH
1	30	270	6	25	6
2	30	300	12	50	6
3	30	330	18	75	6.5
4	30	540	24	100	6.5
5	40	270	12	75	6.5
6	40	300	6	100	6.5
7	40	330	24	25	6
8	40	540	18	50	6
9	50	270	18	100	6
10	50	300	24	75	6
11	50	330	6	50	6.5
12	50	540	12	25	6.5
13	60	270	24	50	6.5
14	60	300	18	25	6.5
15	60	330	12	100	6
16	60	540	6	75	6

Table 3. The treatments and their levels used for compost tea preparation.

Factors	Level 1	Level 2	Level 3	Level 4
(1) Temperature , °C	30	40	50	60
(2) Flow , l/h	270	300	330	540
(3) Aeration , h	6	12	18	24
(4) addition of nutrients, ml	25	50	75	100
(5) pH	6	6.5		

Note: The aeration rate was 0.18 m³/h.

According to data analysis from Taguchi experiment, the optimum level for each experimental treatment was obtained from signal to noise ratios (SN) after analysis of Taguchi response data by using Minitab 17.

Compost tea production

The simplest method of making tea, and also one of the earliest reported methods involves covering compost with water, stirring the combination and allowing it to soak for a period between 12 to 24 hour .This method produces an acceptable, low cost compost tea. The brewer was filled with 50 L tap water and run for half hour for chlorine reduction. The extraction process was conducted on the basis of 1:10 ratio of compost to water, according to (Pant *et al* ., 2009 and Shrestha *et al* ., 2011). The temperature of circulated water used for the extraction process was at levels of 30°C, 40°C, 50°C and 60°C to dissolve compost particles and extract most of the microorganisms and nutrients of the compost . Water pressure forces the water toward the mesh which separates the leachate from the slurry. The water is re-circulated for one hour until the desired levels of nutrients and micro-organisms are obtained. In the fermentation process, the active additives (molasses , activated EM ,yeast ,citric acid and haobutas) were added to increase microbial population densities in the compost tea then adjust the acidity of the extraction liquid in the tank at (6-6.5) pH as recommended by Mistry and Mukherjee , (2015). Mixing is an important part of the process, assisting the physical extraction of bacteria and fungi from the compost and it was carried out by a mixing pipe , where the liquid was re-circulated from the bottom of the tank and spraying it again in the tank using a mixing pipe. Aeration was carried out by the air pump, (where a vertical aeration tube was placed on the lower third part of the tank. The main point is that maintain the concentration of dissolved oxygen in the liquid at a desirable high level to prevent production of non-aerobic compost tea (running out of Oxygen). The sampling of tea was taken from the fermentation tank at 12, 18 and 24 hours intervals.

Measurements

Physico-chemical analyses of compost teas

A pH meter (AD111 Standard Professional pH-ORP-TEMP Portable Meter) was used for measuring the pH values according to Jodice *et al.* (1982). Dissolved nitrogen was measured using micro-Kjeldahle, and dissolved phosphorus was measured colorimetrically using JENWAY 6305 UV-vis Diode Array Spectrophotometer, by the hydroquinone method according to the methods described by Bremner and Mulvaney (1982) and Olsen and Sommers (1982), respectively. Dissolved potassium was determined using JENWAY flame-photometer with acetylene burn according to the method advocated by Jackson (1973) .

Microbial population density of compost tea:

Total bacterial count (cfu) was measured according to Smith and Dawson, (1944) and Kim *et al* ., (2015).

Performance of the manufactured unit:

Unit productivity :

Unit productivity was determined by using the following equation , as mentioned by Badr,(2013):

$$Up = \frac{Ve}{t}\ ,\ l/h \qquad (1)$$

Where : Up **= Unit productivity ,** l/h **.**

Ve = Volume of extracted sample , l .

t = The time consumed for the fermentation process.

Extraction efficiency:

Extraction efficiency was calculated by using the following equation as determined by Badr,(2013):

$$\text{Extraction efficiency (\%)} = \frac{Ve}{Vi} \times 100 \qquad (2)$$

Where: Ve = Volume of extraction sample , L .

Vi = Volume of input sample , L .

Power requirements:

The consumed power was calculated according to the equation of (Fehér and Puklus, 2007):

$$\text{Consumed power} = \frac{I V \cos\theta}{1000},\quad kW \qquad (3)$$

Where: I = Line current strength in amperes.

V = Potential difference (Voltage) being equal to 220 V.

Cos θ = Power factor (being equal to 0.84).

Energy requirement :

Energy requirement were obtained using the following equation:

$$\text{Energy requirement} = \frac{\text{Consumed power}, k.W}{\text{Unit productivity}, m^3/h}\ ,\ kW.h/m^3 \qquad (4)$$

Operation cost :

The cost analysis was performed according to Zaki,(2014).

Calculation of fixed costs:

Depreciation costs:

$$\text{Deprecation} = \frac{\text{initial price} - \text{salvage value}}{\text{useful life in hours}}$$

Salvage value has been assumed as 0.1 of the initial price

Interest cost

$$\text{Interest} = \frac{(\text{unit price} + \text{salvage value}) * 0.10}{2 * \text{yearly operation hours}}$$

Miscellaneous costs:

Miscellaneous costs = (V + F) x 0.05

Where:

V = Variable costs. F = Fixed costs.

0.05 = Coefficient of miscellaneous costs as a percentage of variable and fixed costs.

Calculation of variable costs:

Labor cost:

The cost of labor varies with location, hence the prevailing wage rate for labor was found to be 5 LE. h^{-1}. The number of labor was one.

Electricity costs:

The cost of electricity was determined according to the following equation as determined by Egyptian electric ministry, (2016):

Electricity consumption = 0.86 LE.kW^{-1}.

Repair and maintenance costs:

Repair and maintenance costs = 90 deprecation .

RESULTS AND DISCUSSION

The experimental data was assigned for testing and analysis using Taguchi method. This method suggested the optimum conditions for producing the compost tea.

Effect of experimental parameters on dissolved NPK concentration for 12,18 and 24 h respectively:

The optimum conditions for NPK concentration in the produced tea at different fermentation time are summarized in table (4).

Figs (2) , (3) and (4) illustrate the optimum conditions for NPK concentration in the produced tea at 24 h. In general ,the result showed that fermentation period of 24 h recorded the most optimum concentration values of NPK.

Table 4. The optimum conditions for NPK concentration in the produced tea at different fermentation time.

Fermentation period	N					P					K				
	Temp, ° C	Water flow rate, l/h	Aeration time, h	addition of nutrients, ml	pH	Temp, ° C	Water flow rate, l/h	Aeration time, h	addition of nutrients, ml	pH	Temp, ° C	Water flow rate, l/h	Aeration time, h	addition of nutrients, ml	pH
12 h	50	540	6	50	6	50	270	12	100	6	50	300	6	75	6.5
18 h	60	300	12	50	6	30	270	18	50	6.5	40	300	12	100	6.5
24 h	30	300	24	100	6.5	40	300	6	50	6	30	270	6	25	6.5

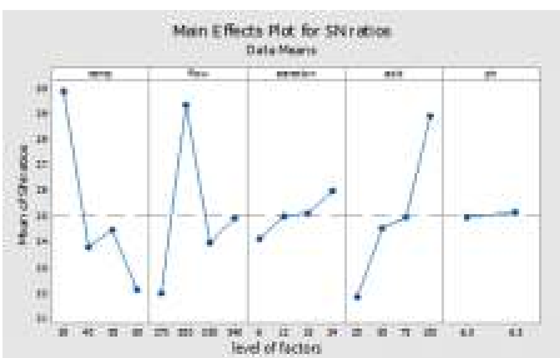

Fig. 2. Main effect plot for SN ratios of nitrogen concentration after 24 h of fermentation.

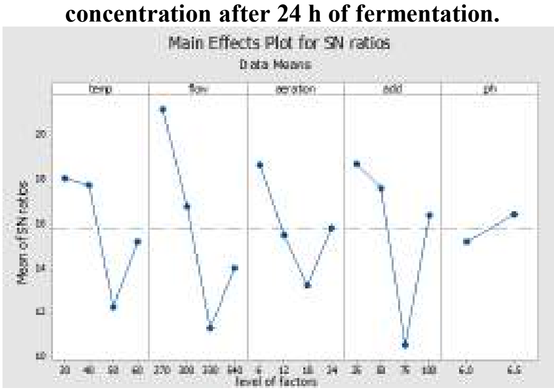

Fig. 3. Main effect plot for SN ratios of Potassium concentration after 24 h of fermentation.

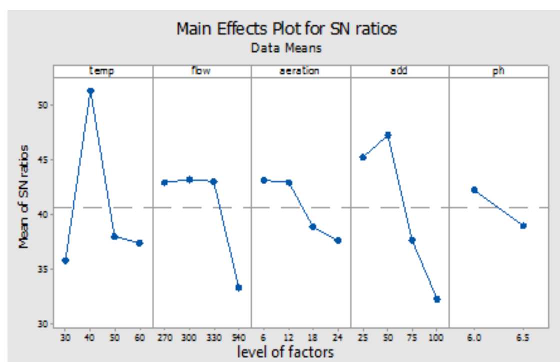

Fig. 4. Main effect plot for SN ratios of Phosphorus concentration after 24 h of fermentation.

Effect of experimental parameters on microbial population density of compost tea for 12,18 and 24 h respectively:

The optimum conditions for microbial population density in the produced tea at different fermentation time are summarized in table (5).

Fig (5) illustrate the optimum conditions for microbial population density in the produced tea at 24 h. In general, the result showed that fermentation period of 24 h recorded the most optimum values of microbial population density.

Table 5. The optimum conditions for microbial population density in the produced tea at different fermentation time.

	microbial population density, cfu				
Fermentation period	**Temp, °C**	**Water flow rate, l/h**	**Aeration time, h**	**addition of nutrients, ml**	**pH**
12 h	50	540	12	75	6
18 h	40	270	12	25	6
24 h	40	300	6	75	6.5

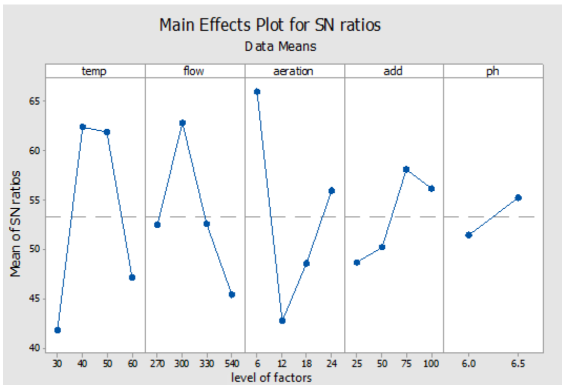

Fig. 5. Main effect plot for SN ratios of microbial population density of compost tea after 24 h fermentation .

Unit productivity for 12,18 and 24 h respectively:

The unit productivity and extraction efficiency are affected by the extraction temperature and the addition of nutrients and the fermentation periods . Concerning the effect of the extraction temperature and addition of nutrients, results show that increasing temperature from 30 to 60° C as well as decreasing addition of nutrients from 100 to 25 ml, for 12,18 and 24 h respectively of 12, 18 and 24, decreased unit productivity from 4.45 to 4.39, from 2.97 to 2.92 and from 2.23 to 2.19 1/h. Also, it has decreased extraction efficiency from 99 to 98.3 % , respectively . Higher values of temperature more than the optimum value tend to decrease both of unit productivity and extraction efficiency because high temperature increased the amount of evaporated water thus reduce the volume of compost tea. Lower values of temperature less than the optimum value also decrease both of unit productivity and extraction efficiency. As to the effect of fermentation periods , results show that increasing fermentation period from 12 to 24 h , decreased unit productivity from 4.45 to 4.39 ,from 2.97 to 2.92 and from 2.22 to 2.19 1/h for 12,18and 24 h, respectively. While increased the extraction efficiency from 98.3 to 99% for 12 and 24 h , respectively . Higher of fermentation periods decrease the unit productivity due to the higher periods and oxygen becomes limited and the microbial populations will increase under this anaerobic conditions.

Figs (6) and (7) present the unit productivity at the minimum and maximum fermentation period.

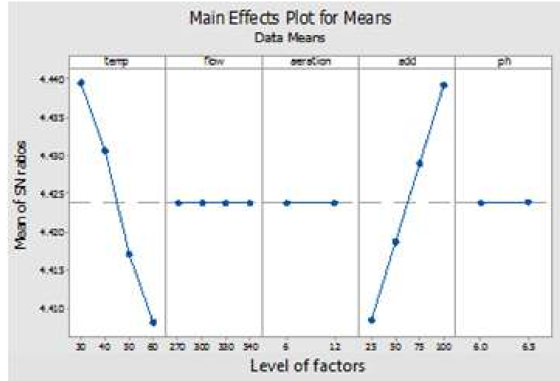

Fig. 6. Main effect plot for means ratios of unit productivity of compost tea production after 12 h fermentation .

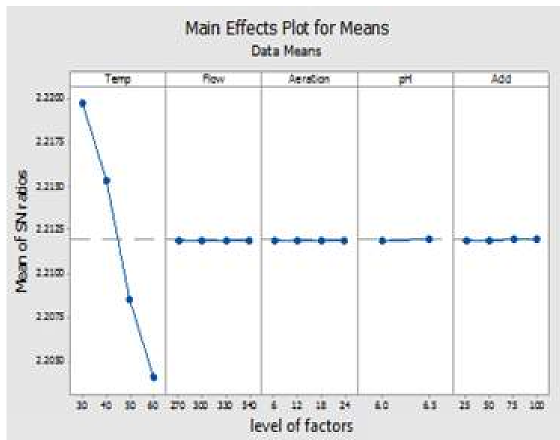

Fig. 7. Main effect plot for means ratios of unit productivity of compost tea production after 24 h fermentation .

Effect of experimental parameters on power and energy requirements :

Power and energy requirements are more sensitive to different factors such as extraction temperature , aeration period and fermentation period. Results show that increasing aeration period from 6 to 24 h, at different fermentation period, increased the required power from 5.77 to 7.14, from 7.96 to 9.88 and from 10.16 to 12.63 kW for 12,18 and 24 h , respectively. Also, the specific energy increased from 1.3 to 1.62 , from 2.7 to 3.37and from 4.59 to 5.74 kW.h/l for 12,18 and 24 h, respectively. Meanwhile, the required power as well as specific energy increased by increasing aeration period because of the increase of ampere consumption required for operating the air pump. Also, increasing temperature from 30 to 60° C, at different fermentation period, increased required power from 5.77 to 7.14 , from 7.96 to 9.88 and from 10.16 to 12.63 kW for 12,18 and 24 h , respectively. Specific energy increased from 1.3 to 1.62 , from 2.7 to 3.37and from 4.59 to 5.74 kW.h/l , for 12,18 and 24 h , respectively. However, increasing fermentation period from 12 to 24 h, measured at different extraction temperature of 30, 40, 50 and 60 ° C as well at different aeration period of 6, 12 ,18 and 24 h, increased the required power from 5.76 to 7.14 , from 7.96 to 9.88

and from 10.16 to 12.63 kW, also increased specific energy from 1.3 to 1.62 , from 2.7 to 3.37and from 4.59 to 5.74 kW.h/l, respectively .

The power and energy requirements at the minimum and maximum fermentation period presented in figs (8) and (9).

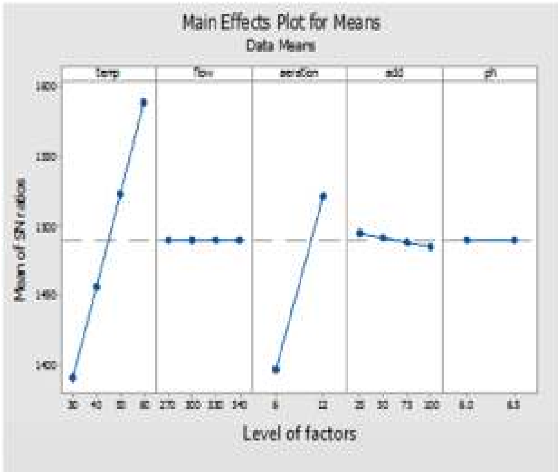

Fig. 8. Main effect plot for means ratios of energy requirements of compost tea production after 12 h fermentation.

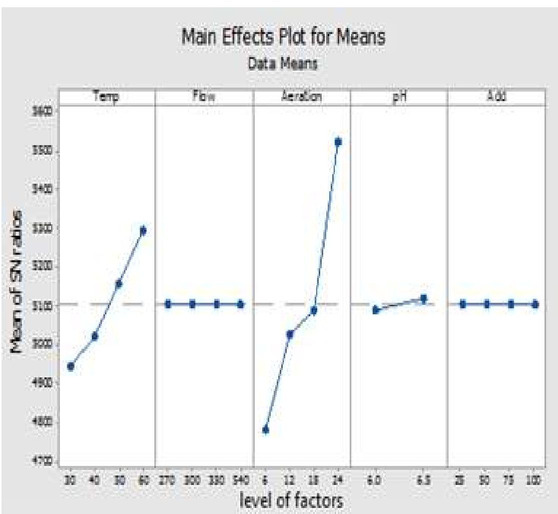

Fig. 9. Main effect plot for means ratios of energy requirements of compost tea production after 24 h fermentation.

Effect of experimental parameters on operational cost of compost tea production:

The results showed that the highest values obtained for the operational cost of the extraction process per liter is 1.72 L.E , at water temperature of 60 ° C, the water flow rate of 270 l / h and the aeration period 24 hours (the aeration rate at 0.18 m3 / h) and the rate of addition of additives of 50 ml at pH 6.5 for 24 hours fermentation period. Fig (10) showed the maximum value of the operational cost at 24 hours fermentation period

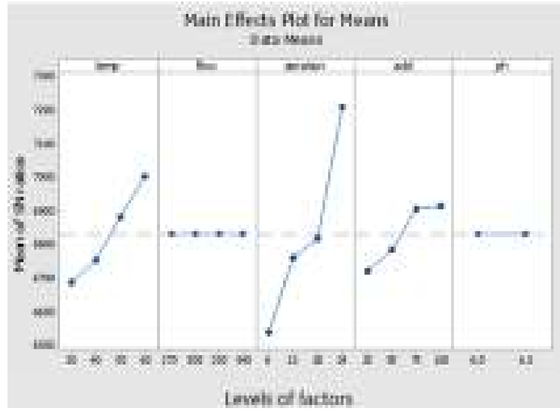

Fig. 10. Main effect plot for means ratios of operational cost of compost tea production after 24 h fermentation.

A complete cost analysis was made at different operating conditions and related with unit productivity. The resulting operating cost was found to be affected significantly by extraction temperature, addition of nutrients , aeration period and fermentation period. The operational cost was based on unit productivity, power and energy requirements. Therefore, minimization of operational cost in relation to both extraction temperature, addition of nutrients, aeration period and fermentation period are required to perform the aeration and extraction operations in lower cost. In general, the operational cost per liter of the manufactured unit ranged from 1.583 (at water temperature of 60 º C , water flow rate 330 l/h ,aeration period of 12 h, addition of nutrients of 100 ml and pH 6) , to 1.736 L.E (at water temperature of 30 º C , water flow rate 270 l/h , aeration period of 6 h, addition of nutrients of 25 ml and pH 6). Operational cost increased by increasing period due to the increase of brewing time resulting in increase of required power.

CONCLUSION

Based on the results obtained in this research work, the following conclusions:

- Temperature is the most important factor affecting the microbial density and concentration of nitrogen, potassium and phosphorus when producing compost tea.
- The optimum operation parameters for the fermentation unit are 24 hour fermentation period and aeration time of 6 hour. other parameters such water temperature, pH, flow rate and additives should be selected based on the aim of the compost application.
- Power and energy requirements are more sensitive to different factors such as extraction temperature , aeration period and fermentation period. Required power as well as specific energy increased by increasing aeration period, temperature and fermentation period .
- The unit productivity and extraction efficiency are affected by the extraction temperature , the addition of nutrients and fermentation periods .
- Elongated anaerobic conditions inactivated the beneficial microorganisms or kill them, accordingly decrease the producing compost extraction efficiency.

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انتاج شاى الكمبوست من مخلفات المزرعة

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يهدف هذا البحث إلى انتاج شاى الكمبوست من مخلفات المزرعة بواسطة آلة تم تصميمها و تصنيعها بقسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة . ولدراسة أداء الآلة المصنعة تم دراسة بعض المعاملات التجريبية التالية: درجات حرارة ماء الإستخلاص (٣٠-٤٠-٥٠-٦٠ °م), معدلات تدفق الماء الساخن (٢٧٠-٣٠٠-٣٣٠- ٥٤٠لتر /ساعة) و فترات تهوية (٦-١٢-١٨-٢٤ ساعة) عند معدل تهوية ٠.١٨ متر مكعب / ساعة ومعدل إضافة للمغذيات (٢٥- ٥٠- ٧٥- ١٠٠مللى لتر) من الهيوميك , الخميرة, المولاس , المخصب البكتيرى EM عند درجة pH (٦- ٦.٥) و أوقات تخمير مختلفة (١٢ , ١٨, ٢٤ساعة) . ولتقييم أداء الوحدة تم إجراء القياسات التالية : ١- القياسات الكيميائية وهى قياس مستوى وتركيز ذائبية النيتروجين و البوتاسيوم و الفوسفور (NPK).٢- القياسات الميكروبية وهى إستخدام طريقة العد البكتيرى للكائنات الحية الدقيقة الموجودة فى الشاى المنتج.٣- القياسات الحسابية أو الهندسية التالية : معدل الإنتاجية – كفاءة الإستخلاص – القدرة المستهلكة – الطاقة النوعية- حساب تكاليف التشغيل . وقد أظهرت أهم النتائج أن درجة الحرارة لها دور كبير في إنتاج شاي الكمبوست والذى يتميز بنسبة عالية لذائبية النيتروجين و البوتاسيوم و الفوسفور وكذلك كثافة عالية من الكائنات الحية الدقيقة خاصة عند المستويات الأعلى من درجات الحرارة. بينما رقم الايون الآيدروجينى لا يؤثر بنسبة كبيرة في نوعية الشاي حيث يعتبر العامل الأقل أهمية من بين العوامل الأخرى. وكذلك أظهرت النتائج أن القيم المتحصل عليها بالنسبة لكفاءة الإستخلاص ٩٨.٣% , معدل إنتاجية ٢.٢ لتر /ساعة وكانت الطاقة المستهلكة ٥.٧٤ كيلووات.ساعه/لتر وتكلفة عملية الإستخلاص لكل لتر ١.٧٢ جنية بعد تخفيف الشاى وذلك عند درجة حرارة ٦٠°م ومعدل تدفق للماء الساخن ٢٧٠ لتر / ساعة وفترة تهوية ٢٤ ساعة عند معدل تهوية ٠.١٨ متر مكعب / ساعة ومعدل إضافة للإضافات الغذائية مقداره ٥٠ ملل من الهيوميك , المولاس , الخميرة والمخصب البكتيرى EM وذلك عند درجة pH ٦.٥ لفترة تخمير مقدارها ٢٤ ساعة .