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Effects of Aeration Pattern in Force-Aerated Static Pile Composting Methods for Rose Oil Processing Solid Wastes

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ABSTRACT

Three trapezoidal piles of the mixtures consisting of rose oil processing solid wastes, separated dairy and poultry manure, and straw as bulking agents were composted to determine the effects of aeration pattern employing forced aeration on various physical and chemical properties and energy consumption by aeration. Temperature feedback control of aeration fans was performed with Rutgers strategies in the positive mode. Aeration patterns with on/off cycles (minute/minute) of 5/30, 7.5/30, and 12.5/30 were performed for Pile-1, Pile-2, and Pile 3, respectively. The control group was set to 5/30 (on/off time) and the experimental groups were set to 7.5/30 and 12.5/30 (on/off time). The results showed that although composting performance parameters of temperature and O_2 as a function of time showed some differences, the similar end-product quality in terms of pH, EC contents and total phosphorus was achieved. The highest energy consumed by fans per Organic Matter Loss (OML, %) of composting (1.044 kWh/OML) was obtained when the fan on/off cycles of 5/30 was applied. When the fan on-time increased to 12.5 min, the energy consumed by the fan was reduced by 12.55% (0.913 kWh/OML). It was concluded that operating the composting process at the higher fan on-time (Pile-3) within acceptable limits appears to be economically convenient in conjunction with energy consumption by aeration fans.

Keywords: Aeration pattern, Composting, Forced aeration, Rose oil, Rose oil processing solid wastes.

INTRODUCTION

Rose oil producing industry produces a fair amount of Rose Oil Processing Solid Wastes (ROPSW), which should be disposed of. In Turkey, 14,770 tons of roses were produced in 2018, which generated 31,700 tons of solid waste from the ROPSW (TURKSAT, 2018). At the other side, huge amounts of Separated Dairy Manure (SDM) and Poultry Manure (PM) existing during the production lead to serious problems for the preservation of environmental resources. Inappropriate handling and the usage of manure can be extremely harmful to public health (Ekinci *et al*., 2010). However, manure is a valuable by-product of both industries and they have important utilization area in agriculture. Forge *et al*. (2014) highlighted that as fertilizer prices continue to rise and public interest in organic food production systems continues to increase, the need to produce compost will increase to improve soil health and efficiency.

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Composting is a biological process that occurs under aerobic conditions (presence of oxygen) with adequate moisture and temperature (Azim *et al*., 2018). Air is forced into the composting medium using a ventilation system. Insufficient aeration or excess aeration can reduce the temperature and lead to oxygen limitations that lead to poor biodegradation rates (Jiang *et al*., 2015). Control of both composting temperature and oxygen level can be accomplished by forced aeration (Ekinci *et al*., 2006, Avidov *et al*., 2018). Furthermore, the selection of an appropriate type of aeration system and aeration cycles are important for composting process operators (Smith and Aber, 2018).

Efficient composting requires the proper design and operation of composting systems. Since many composting facilities employ forced aeration, the selection of aeration fan should be performed in terms of the power and air requirement for efficient composting (Keener *et al*., 1993). Therefore, numerous studies on composting focused on the design and operation of composting aeration systems to minimize the cost of producing compost (Keener *et al*., 2007). Keener *et al*. (1993) stated that composting design can be optimized mathematically or experimentally considering the fixed and operational cost, energy utilization, and pollution levels. Experimental data can be gathered from the field work of real composting systems. Evaluation of how system design and management affects time to reach compost stability is critical to optimizing the process. Ekinci (2005) stated that it is equally important to determine the desired airflow rate and application pattern simultaneously for the composting process. Finstein *et al*. (1986) stated that any data on blower demand would aid decision-making.

Although numerous researches have been conducted on the influence of aeration rate on the composting (Avidov *et al*., 2018., Yuan *et al*., 2016., Mejias *et al*., 2017), much less is known about how aeration pattern in force-aeration affects the composting parameters and energy consumption of the system. Therefore, this research aimed to assess the impacts of aeration pattern on various physical and chemical composting parameters and energy consumption by aeration on the force-aerated pile composting of rose oil processing solid wastes and Separated Dairy (SDM) and Poultry (PM) Manure with straw.

MATERIALS AND METHODS

This study involved (dry weight basis) 20% ROPSW, 61.83% SDM, 8.17% PM, and 10% straw for composting. The main characteristics of the four raw materials and mixture (dry weight basis) are reported in Table 1. Approximately 13,800 kg of the mixture on a dry weight basis with an initial C/N ratio of 28.56 was prepared and equally divided into three piles.

Three trapezoidal piles (each of which was 4,600 kg) with the width of 2.10 m, the length of 6.20 m and the height of 1.03 m were formed with ROPSW, SDM, PM, and straw. These piles were named as Pile-1, Pile-2, and Pile 3. Each of the three aerated static piles was centered over two aeration lines consisting of perforated pipes installed in a concrete floor (Figure 1). The pipes were covered with unchopped straw at the height of 10 cm and packed with shade net to equally distribute air in the pipes. The outer part of the piles was not covered.

Thermocouples (average of three readings of K type) inserted into each pile generated a control signal used to modulate aeration fans. The aeration was provided by a fan (model YB4T-1/2 hp, Bahcıvan, Turkey) connected to PVC pipes having a diameter of 5 cm. Aeration based on feedback control of temperature employing Rutgers strategies (Şevik *et al*., 2018) was performed by a fan operated in the positive mode (forced aeration) (Figure 2).

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Table 1. Initial physical and chemical properties of feedstocks and composting mix used in the experiment.

Parameters	ROPSW	SDM	PM	Straw	Mixture
Moisture content[a] (wb %)	71.58±0.08	73.62±0.50	18.53±0.37	3.48±0.02	71.39±0.94
Organic matter (%)	91.74±0.08	80.69±0.99	87.36±0.26	94.46±0.61	85.86±0.97
EC[b] (dS m^{-1})	0.82±0.03	2.95±0.05	7.37±0.08	1.09±0.03	3.23±0.00
pH	4.75±0.20	8.81±0.33	8.77±0.12	6.4±0.40	9.01±0.00
Total Carbon (C, %)	29.25±0.53	40.51±0.10	41.88±0.04	44.405±1.75	40.55±0.33
Total Nitrogen (N, %)	1.9±0.13	1.22±0.03	5.07±0.45	0.49±0.06	1.42±0.21
C/N	15.39	33.20	8.26	90.62	28.56
Total Phosphorus (P, %)	0.17±0.00	0.17±0.00	0.97±0.01	0.04±0.00	0.21±0.01

[a] Value on a wet weight basis, [b] Electrical Conductivity, ***: level of detection.

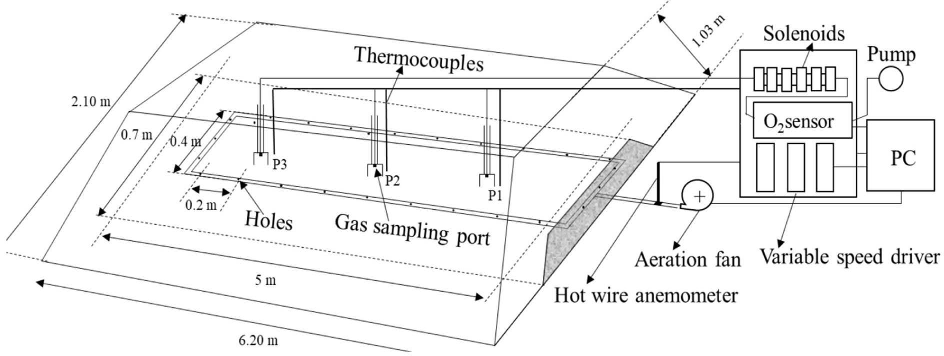

Figure 1. Schematics of the experimental set-up.

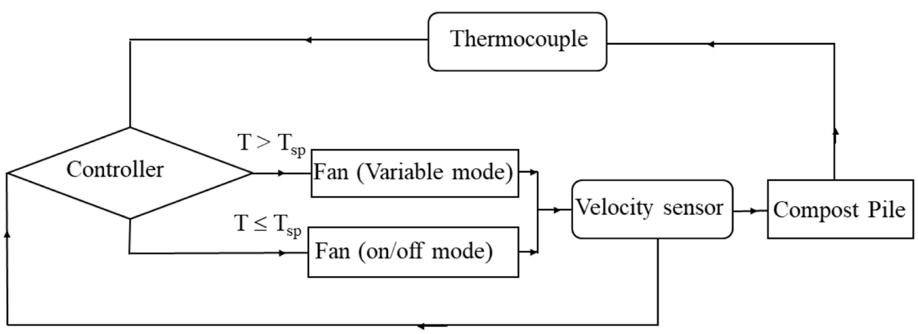

Figure 2. Illustration of aeration system (T is the compost Temperature and T_{sp} is the set-point Temperature).

The aeration control system allowed the fans to be operated on/off mode when compost Temperature (T)≤ set point Temperature (T_{sp}) to maintain the volumetric airflow rate (Q, m^3 h^{-1}) for the temperature development and to satisfy the level of oxygen concentration for microbial activity. Caceres *et al*. (2015) explained that the O_2 concentration in the compost medium influences the growth of microorganisms and is usually sufficient if the aeration is based on a heat management strategy. However, the maximum O_2 consumption at the early stages of the process may lead to a deficiency of O_2 concentration. At this stage, airflow rate supplied by the fans can be manually adjusted to maintain sufficient O_2 level in the compost medium. This operation

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allows independent regulation of O_2 throughout the composting cycle and temperature. On/off aeration pattern cycles for the three piles were 5/30, 7.5/30, and 12.5/30 (on-minute/off-minute) for Pile-1, Pile-2, and Pile 3, respectively. The magnitudes of the volumetric airflow rate were adjusted through the course of the experiment in this stage. Fan-off time should not be more than 30 min (Shen *et al*., 2011).

The fan provided air for cooling when the temperature was above T_{sp} of 65°C with a differential of 1.5°C. Finstein and Miller (1985) reported that aeration system with temperature feedback control should be able to control compost temperature below 60-65°C while maintaining sufficient O_2. The system reduces the volumetric airflow rate when the compost material cooled below T_{sp}. Variable aeration rates based on temperature feedback control were automatically applied by the controller to cool down the pile when $T > T_{sp}$ (Figure 2).

Feedback control of the volumetric airflow rate when $T>T_{sp}$ was achieved through a Proportional-Integral-Derivative (PID) control program written in Visual basic™ on a Personal Computer (PC). The volumetric airflow rate was evaluated by multiplying air velocity measured by (QVM62.1 Siemens) by pipe area. Volumetric airflow rates and temperature readings were recorded every one minute for the three piles. Three thermocouples per pile were positioned along the length of each pile: At the beginning (P_1), middle (P_2) and end (P_3) of compost piles (0.5 m down from the top of the pile). Online measurement of O_2 concentration was performed with sensors (Polytron 7000 Draeger) thrice a day, drawing the compost air by internal pump passing through a trap containing drierite as a desiccant. Air samples for O_2 determination were drawn for one minute after the fan was shut off. Energy consumed by aeration fans was measured by single-phase electricity meters (VEM-T580DB2 Viko, Turkey) and measurements were recorded once a day.

Samples were taken from three different points of the heap, from the horizontal and vertical axis (total of 9 points) and homogenized and analyzes with 3 replications were carried out for physical and chemical properties of composting. The moisture content of fresh compost samples was evaluated at 70±5°C in 72 hours, and organic matter content of dry samples was analyzed by loss on ignition at 550°C based on USCC (USCC, 2002). Organic Matter (OM) was calculated based on Equation (1) (USCC, 2002)

$$OM = [1 - (AshW/dw)] \times 100 \quad (1)$$

Where; OM= Loss-On-Ignition organic matter, (%) AshW= Sample net Weight after ignition at 550°C (g) and dw= Sample net weight after drying at 70±5°C before ignition (g).

pH and EC of the fresh compost samples were determined using pH and EC meters (Models WTW pH 720 and WTW Multi 340i) extracting at 180 rpm for 20 minutes at a solid: water ratio of 1:10 (dry weight/volume) (USCC, 2002). Total C and N content were determined using the elemental analyzer (Vario MACRO CN Elemental Analyzer). Total phosphorus was analyzed by the stannous chloride method (APHA, 1998) on a spectrophotometer (Model DR 5000) after nitric acid-perchloric acid digestion.

Organic Matter Loss (OML) was determined based on the ash content at the beginning (X_1) and end (X_2) of composting (Fornes *et al*., 2012):

$$OML\ (\%) = 100 - 100\frac{[X_1(100-X_2)]}{[X_2(100-X_1)]} \quad (2)$$

Statistical evaluations of the data were made using Minitab (Minitab Inc., USA). All the reported data are the arithmetic means of three replicates with standard deviation. One-way Analysis Of Variance (ANOVA) and Tukey test were performed to determine any significant difference among the parameters analyzed at 0.01% level of significance. The composting piles were prepared of one control group and two experimental groups. The aeration time of 5/30 (on-minute/off-minute) was set to

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control group, 7.5/30 and 12.5/30 (on-minute/off-minute) were set to the two experimental groups for Pile-1, Pile-2, and Pile-3, respectively. Similarly, in the study of Ma *et al*. (2020), 10-10 minutes (on-off time) was chosen as the control group and 10-30 minutes (on-off time) was selected as the experimental group.

RESULTS AND DISCUSSION

Temperature Profiles and Aeration

The temperature profiles of three piles changing with time are shown in Figure 3. The temperature was the average of three readings of thermocouple positioned at each pile. Temperature stories provided information for composting in succession over time, which is three consecutive phases (mesophilic, thermophilic and maturation) (Zhang *et al*., 2019). In this study, SDM had the highest rate with 61.83% among compost materials. Due to the high ambient temperature in summer condition and the long transfer time from the farm where SDM was maintained to the application area, decomposition process had already begun. Once the piles were built, the temperature reached 43.5, 48.5, and 53.5°C in the piles within two hours, respectively. Since compost temperature was less than T_{sp} (65°C) at this stage, volumetric airflow rate was supplied with on/off cycle modes. Until 0.54 days of composting, the piles were aerated with the total airflow rate of 8.33 m^3 h^{-1} with 5/30, 7.5/30, and 12.5/30, in the order, on/off cycle modes corresponding to volumetric airflow rate of 50, 33.33, and 20 m^3 h^{-1} to fulfill the level of O_2 for microbial activity (Table 2). However, due to a continued rapid increase of temperature at this stage, the total airflow rate was adjusted to 13.33 m^3 h^{-1} to avoid oxygen limitation in the process between 0.54-0.84 days of composting (Table 2). When the compost temperature exceeded T_{sp}, temperature feedback control of aeration fans was kicked in to cool the process temperature. Nevertheless, the amount of air supplied by the fans was not enough for evaporative cooling of the piles, then, the temperature peaked in the piles (70.8, 72.7, and 70.9°C, in order) at 1.08, 0.86, and at 0.88 days composting for piles. An aeration system was able to control the temperature at 65 °C approximately at 1.60 days of composting for all piles. Volumetric airflow rate changing with time for Pile-1 is presented in Figure 4. During the PID control of the volumetric airflow rate, an overshoot was observed and the data acquisition system registered this fluctuation (Figure 4). The thermophilic phase lasted for 13 weeks in static pile composting reported by Rasapoor

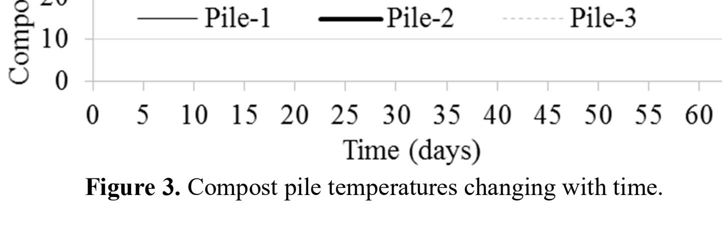

Figure 3. Compost pile temperatures changing with time.

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Table 2. Volumetric airflow rates supplied when T≤ T_{sp}.

	Volumetric airflow rates with aeration pattern (m^3 h^{-1})			
Time (days)	Pile-1 (5/30)[a]	Pile-2 (7.5/30)	Pile-3 (12.5/30)	Total supplied airflow rate (m^3 h^{-1})
0.00-0.54	50.00	33.33	20.00	8.33
0.54-0.84	80.00	53.33	32.00	13.33
14.79-32.00	20.00	13.33	8.00	3.33
32.00-53.10	10.00	6.67	4.00	1.67
53.10-62.70	5.00	3.33	2.00	0.83

[a] 5-min on/30-min off cycle.

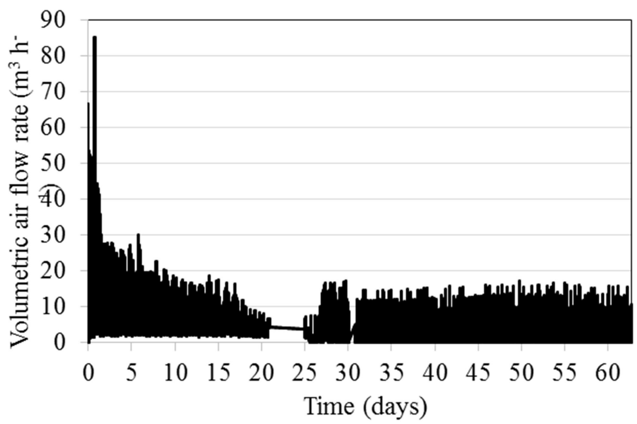

Figure 4. Volumetric airflow rate changing time for Pile-1.

et al. (2009). In the current study, the thermophilic phase of composting lasted for 52, 47, and 42 days, respectively. The reason for elongation of the thermophilic phase could be due to the controlled temperature feedback control of large composting mass and high initial OM content of the mixture.

Data (Temperature, O_2/CO_2 concentration, volumetric air flow, energy consumption by fans) was not registered due to a problem with data acquisition occurred at 21 days of composting. This problem lasted for almost 4 days and ventilation fans kept working at this period. Since the easily degradable organic matter was utilized by microorganisms at the thermophilic phase, thereafter, the compost temperature declined (Chen *et al*., 2019). The drop in temperature was monitored slowly and continuously until the ambient level and the process was completed when it reached the same level as the ambient temperature. This suggested that the bio-oxidative phase of the organic material reached the end (Montemurro *et al*., 2009). High temperatures resulting from composting ensured that animal and plant pathogens in the piles were eliminated. The time for compost temperature stayed at 55°C or higher temperatures were reported as 29.3, 27.8 and 27.9 days for Pile 1, 2, and 3, respectively. Likewise, Liu *et al*. (2017) reported that compost temperatures of 55°C for 3 consecutive days are sufficient to maximize sanitation and destroy the pathogens in compost.

O_2 Concentrations

Figure 5 shows the change of the O_2 concentration as a function of time during composting. The lowest oxygen concentrations were measured approximately 6% at 0.43, 0.77, and 0.14 days of composting for Pile 1, 2, and 3, respectively, which was above the minimum

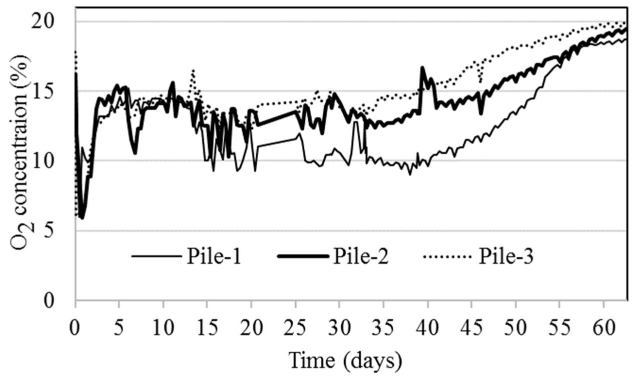

Figure 5. The change of O_2 concentrations with time for all piles

O_2 concentration level of 5% (He *et al*., 2017) in the compost matrix because of high respiration rate of the microorganisms (Villaseñor *et al*. 2011). The level of O_2 concentrations for the rest of composting in all piles was above the level of 9% indicating abundance of the O_2 composting matrix. These results showed that all piles were aerated well. Towards the end of composting, the O_2 concentration in all the piles showed an increase to the ambient air oxygen level, which is a possible consequence of decrease in microbial activity (Petric *et al*. 2012).

Moisture Content

The change of moisture content of piles is given in Figure 6. The moisture content of piles at the beginning of the process was 71.39±0.94%. It should be noted that no water was added to the initial mixture and compost moisture was not controlled during composting. The composting study was carried out considering the wastes generated at regional and local scale. A compost pile was created by considering the mixing ratios and the amount of waste generated. Therefore, initial moisture contents of piles were higher than that of reasonable limits (40-65%) due to the initial moisture contents of feedstocks (ROPSW and SDM) (Table 1). As composting proceeded, the moisture contents of all piles dropped to 43.57, 39.15, and 42.32%, respectively, continuously until the end of composting. Since compost piles had a high initial moisture content, water was not added during composting. It can be stated that aeration patterns had no significant effects on the final moisture content of composting.

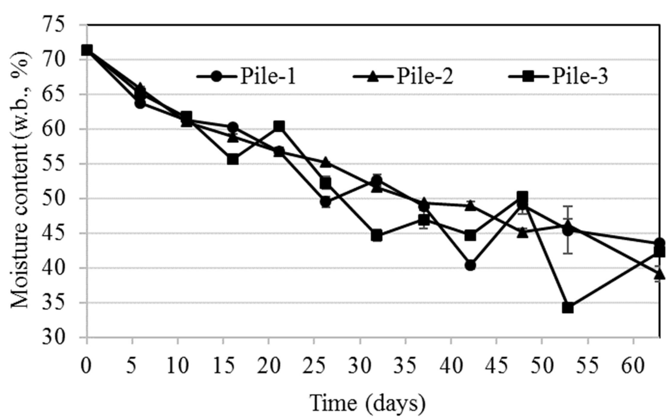

Figure 6. Change of moisture content of composting process with a standard deviation.

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Organic Matter and OML

The organic matter content of piles decreased from 85.86% to 75.75, 73.87, and 75.26%, respectively, during the biodegradation process in all the three piles (Figure 7). Furthermore, studies showed that as labile fractions of organic matter were mineralized into the stable compounds by microbial activities, the organic matter content decreased in piles throughout the composting (Fourti, 2013) and the maximum organic matter decomposition existed during the thermophilic phase because of microbial activity (Wang *et al*., 2015). These findings are in accordance with the temperature development of the piles. Aeration patterns had significant effects on the final organic matter of composting ($P< 0.01$). OML of piles was 48.54±3.86, 53.4±4.28, and 49.9±3.73 in Piles 1, 2, and 3, respectively. The decline in an organic matter clearly indicates that an effective organic matter decomposition occurred during composting. Composting is a process that takes place with the help of microorganisms, and the existing organic matter is consumed by microorganisms and CO_2 gas is released. This process is a clear indication of the decomposition of organic matter (Zhu *et al*., 2020). The rate of organic matter degradation slows as composting progresses due to reduction in available carbon resources, and during the maturation phase, synthesis reactions of new complex and polymerized organic compounds (humification) take precedence over mineralization (Bernal *et al*., 2009). Aeration patterns had no significant effects on OML of composting.

C/N Ratio

Initial CN value of piles was 28.56, which is within the range of preferred C/N values of between 20 and 30 reported as being the most favorable for an effective composting (Wang *et al*., 2019, Onwosi *et al*., 2017). As composting proceeded, because of the change in C and N, the ratio decreased in all the piles (Ekinci *et al*., 2019). The C/N ratio was nearly fixed at the end of thermophilic stages in all piles (Figure 8). The initial C/N of piles decreased to 17.52, 16.76, and 16.4 at the final of the composting for Pile-1, Pile-2, and Pile-3, respectively. Mathur *et al*. (1993) highlighted that final C/N should be < 20:1 but preferably<10:1. Iglesias-Jiménez and Pérez-García (1991) suggested a ratio of less than 20 and even 15 for mature composts. The final C/N ratio of composting was affected significantly by aeration patterns ($P< 0.01$).

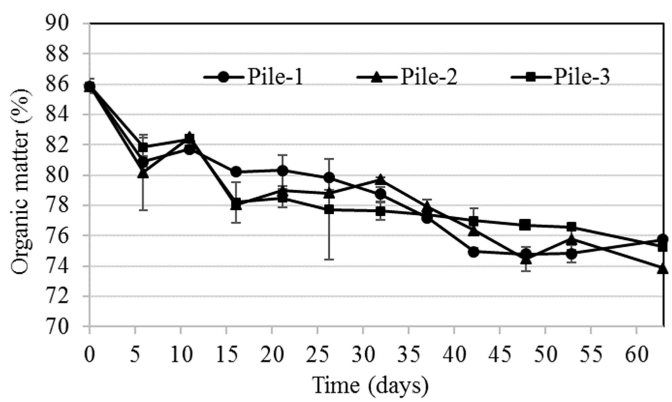

Figure 7. Change of organic matter content as a function of time.

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EC

Figure 9 shows changes in EC for the three piles. The EC of all piles, increased from an initial value of 3.23 dS m^{-1} to final of 4.02, 4.03, and 4.29 dS m^{-1}, respectively, which is similar to the findings of Gigliotti *et al*. (2012). Probably, this could be because of the increase in ion concentration caused by the weight reduction of the compost piles (Gigliotti *et al*., 2012). Compost with the low EC values can be utilized directly in agriculture, while composts with high EC values should be mixed to soil or low EC materials before application. (Onwosi *et al*., 2017; Makan *et al*., 2019). The EC values of the compost obtained are evaluated in the "low-salinity" class by Turkish national legislation and are suitable for use in agriculture (OG, 2005). Aeration patterns had no significant effects on the final EC content among the three piles during the composting process. Although the final EC's of composting was higher than the limit of 3 dS m^{-1} in the three piles on day 62.7 days (Sülük *et al*., 2016) the final EC of all the piles were 4.02, 4.03, and 4.29, dS m^{-1}, respectively, which is defined as low-salinity soils (OG, 2005).

pH

Figure 10 shows the change in pH of the tree piles during the aerobic decomposition process. The initial value of 9.01 decreased to 8.20-8.40 in all the piles around the 11 days of composting. This may be due to the production of organic acids from the degradation of readily available carbon present (Sharma *et al*. 1997; Lim *et al*. 2011). Then, a rise in pH was observed between 10.96 and 16.04th day in all the piles as a result of the biodegradation of acids (Meng *et al*., 2020). At the end of the experiment, the final pH value ranged from 8.5 to 8.7 for all the piles. The final pH values were slightly higher in the piles, possibly because of the evolution of

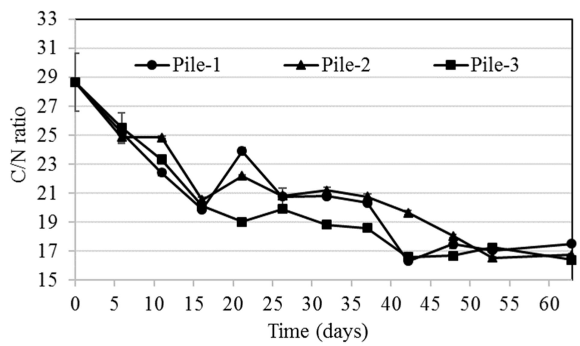

Figure 8.The change of C/N ratio during composting.

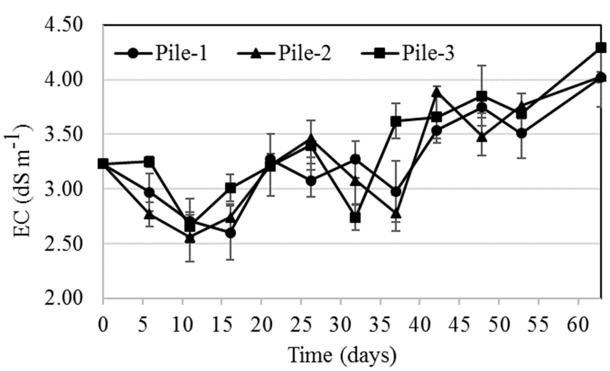

Figure 9. EC histories for three piles during composting.

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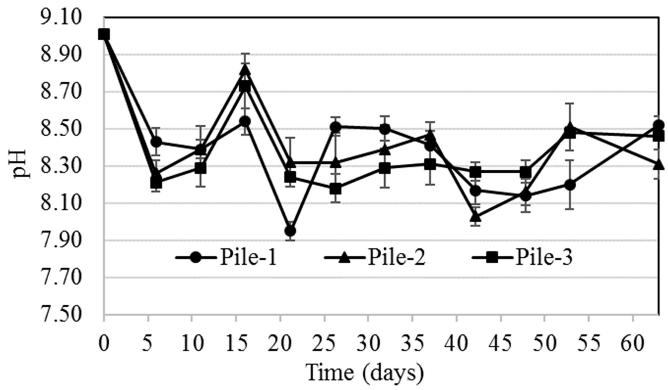

Figure 10. Change of pH with time for three piles during the composting process.

ammonium and N loss (Spencer *et al*., 2013). Analysis showed that aeration pattern had no effect on the final pH values significantly.

Total Phosphorus

Figure 11 presents total phosphorus as a function of time for all piles. Total phosphorus content showed a rise from 0.21% to 0.5, 0.53, and 0.49% at the end of experiment, respectively. Alfano *et al*. (2008) found that total phosphorus increased from 0.3-0.4% to 0.4-0.6% for composting of two-phase olive oil processing solid waste. Similarly, Rasapoor *et al*. (2009) reported that initial content of phosphorus of 0.3-0.32% resulted in 0.35-0.5% at the end of composting of municipal solid wastes. In this study, the analysis showed that aeration pattern had no significant effect on the final total phosphorus content.

Energy Consumption by Aeration

Electric energy consumed (kWh) by aeration fans were measured by electric meters during composting for all piles and presented as a function of time in Figure 12. The steepest slope occurred within the first day of composting due to required airflow rate. The aeration pattern affected histories of energy consumed by fans. The fan in Pile-3 with 12.5 min-on /30 min-off cycle consumed less energy all the time. Fans in Pile-1 and 2 followed a similar pathway during composting. End of composting, energy consumed by fans were measured as 50.66, 52.92, and 45.56 kWh, respectively. At the other side, OML of piles were calculated as 48.54, 53.4, and 49.9 %, respectively, for piles. Based on these parameters, a ratio can be defined as Energy consumed by Fan per unit

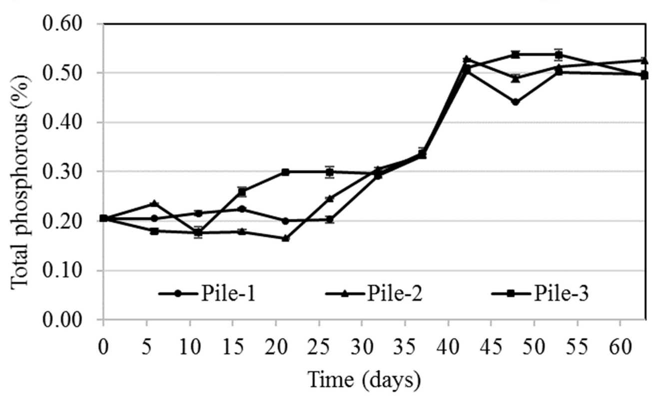

Figure 11. Change of total phosphorus as a function of time.

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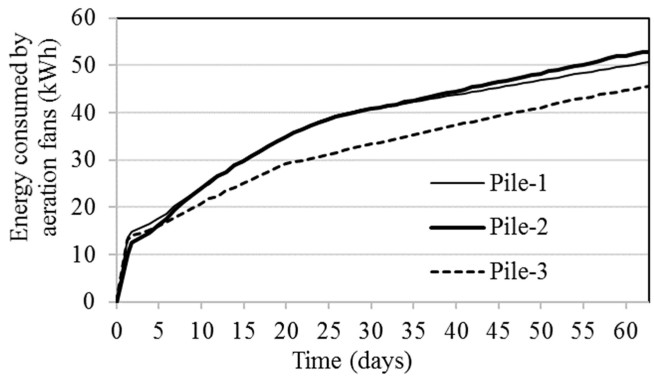

Figure 12. Energy consumed by aeration fans during composting for three piles.

OML of composting (EF). EF was calculated for piles as 1.044, 0.991, and 0.913 kWh/% corresponding on/off cycles of 5/30, 7.5/30, and 12.5/30, respectively. This ratio is a normalization of energy consumed by fan considering OML of composting and could be used for intra-comparison of different treatments at the same composting experiment. This result indicates that, when fan on-time increased with the same airflow rate, the energy consumption by fan decreased per OML. Furthermore, there was no significant difference in OML among the three composting piles (P> 0.05) (Table 3). However, it was observed that there was a decrease in EF from Pile-1 to Pile-3 (Table 3). Considering the operating conditions, it was determined that Pile-3 (12.5/30 on-off time) was the most economical aeration method in terms of energy consumption.

CONCLUSIONS

Co-composting of rose oil processing solid waste, separated dairy, and poultry manure with straw were conducted to determine the effects of aeration pattern using forced aeration. All piles yielded minor differences in temperature and O_2 concentration as a function of time. Even though the aeration pattern did not have a significant impact on the final moisture, electrical conductivity, pH, and total phosphorus, it had a significant effect on final organic matter and C/N ratios. Energy consumed by fans per OML of composting was calculated for piles as 1.044, 0.991, and 0.913 kWh/% corresponding on/off cycles of 5/30, 7.5/30, and 12.5/30, respectively. This result pointed out that when fan on-time increased with the same airflow rate, the energy consumption by fan decreased per OML. Therefore, operating the composting process at the higher fan on-time appears to be economically convenient in conjunction with energy consumption by aeration fans. This clearly showed that energy efficiency of the composting system strictly relies on operational strategies developed for specified OML. Convenient assessment of the management of the system is, therefore, required if a composting system is run

Table 3. Energy consumed by Fan per unit OML of composting (EF).

Pile	OML (%)	EF (kWh/%)
Pile-1 (5/30)[a]	48.54 A	1.044 A
Pile-2 (7.5/30)	53.40 A	0.991 A
Pile-3 (12.5/30)	49.90 A	0.913 A

[a] 5-min on/30-min off cycle.was control group

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within an acceptable range and the system efficiency is to be maximized.

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اثرات الگوی هوادهی اجباری در کمپوست سازی از ضایعات موادجامد فرآوری روغن گل رز به روش‌های هوادهی توده‌ای ایستا

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چکیده

در این پژوهش، برای تعیین اثرات الگوی هوادهی اجباری بر خواص فیزیکی و شیمیایی مختلف و مصرف انرژی توسط هوادهی در تهیه کمپوست، از سه توده ذوزنقه ای شکل از مخلوط های متشکل از ضایعات جامد پردازش روغن گل رز، کودهای گاوی و مرغی جدا شده، و کاه (به عنوان عامل حجیم سازی) استفاده شد. کنترل بازخورد دمایی پنکه (فن)های هوادهی با استراتژی راتگرز(Rutgers strategies) در حالت مثبت انجام شد. الگوهای هوادهی با چرخه خاموش/روشن (دقیقه/دقیقه) ۵/۳۰، ۷.۵/۳۰ و۳۰/ ۱۲.۵ به ترتیب برای توده‌های Pile-1، Pile-2 و Pile 3 انجام شد. گروه شاهد روی ۵/۳۰ (زمان روشن/خاموش) و گروه های آزمایش ۷.۵/۳۰ و۳۰/ ۱۲.۵ (زمان خاموش/ روشن) تنظیم شدند. نتایج نشان داد که اگرچه پارامترهای عملکرد کمپوست دما و O_2 به عنوان تابعی از زمان تفاوت هایی را نشان داد، کیفیت محصول نهایی از نظر pH، محتوای EC و فسفر کل مشابه به دست آمد. بیشترین انرژی مصرف شده توسط پنکه‌ها به ازای از دست دادن ماده آلی (OML، درصد) در کمپوست سازی(OML /۱.۰۴۴ کیلووات ساعت) زمانی به دست آمد که چرخه روشن/خاموش پنکه ۵/۳۰ اعمال شد. هنگامی که زمان روشن بودن پنکه به ۱۲.۵ دقیقه افزایش یافت، انرژی مصرف شده توسط پنکه به میزان ۱۲.۵۵ درصد کاهش یافت (OML/کیلووات ساعت۰.۹۱۳). نتیجه گیری چنین شد که در ارتباط با مصرف انرژی توسط پنکه‌ها، هوادهی با اجرای فرآیند کمپوست سازی در زمان بیشتر روشن بودن پنکه (در Pile-3) در محدوده‌ای قابل قبول، از نظر اقتصادی راحت باشد.

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