Composting Fish Waste Combined with Cow and Poultry Manure to Produce an Environmentally Friendly Organic Fertilizer

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ABSTRACT

The fishing sector produces substantial waste. The primary goal of this work was to obtain organic fertilizers for use in agriculture by composting fish waste. Four waste mixtures were used in the experiment: cow waste only (C), cow waste combined with dried fish waste previously collected (CF) with a mixing ratio of 1:3, poultry waste (P), and poultry waste combined with fish waste (PF) at the same mixing ratio. The fish waste treatments (PF2 and CF2) recorded a much lower pH than the untreated treatments with fish waste. The pH values were neutral values after the maturity of fish waste. The highest N percentage was in poultry with fish, followed by cows mixed with fish, poultry, and cows. Over time, the GI increased in all treatments because of the compost maturity, recording values higher than 75%. The results confirmed the compost suitability in all treatments for agricultural use. R^2 values reflect their efficiency in interpreting and predicting the results of GI based on pH, EC, and N. The results showed that the compost physicochemical properties had significant influences on the GI values. The results proved that it is possible to use fish waste mixed with of poultry and cow manure to produce an environmentally safe fertilizer and better than the compost product of poultry and cow manure only

Keywords: Composting; Fish Waste; Germination Index; Phytotoxicity; PCA; Organic Fertilizer.

INTRODUCTION

In recent years, the demand for fish globally has grown because of the increase in population (Brabo *et al.*, 2016) . Annual fish production globally increased at a rate of more than 2% during the period from 2007 and during the following ten years (Aster, 2018). While in 2018, there were about 179 million tons of fish aquaculture (Barange, 2018). Fish production of natural resources and aquaculture is essential to Egypt's food security, life way, GDP, poverty reduction, and employment prospects in rural areas. Egypt produces over 1.9 million tons of fish annually, with 1.6 million coming from aquaculture and roughly 0.3 million from natural resources (Mehanna, 2022). Catching fish and processing leaves behind huge amounts of harmful waste. Every ton of fish has a similar amount of waste, which pollutes the soil and water (Choe *et al.*, 2020). The fish waste term (FW) involves various elements, including whole fish, as well as specific tissues, such as heads and bones (Richardsen *et al.*, 2017). Improper methods of fish waste disposal contribute to environmental degradation due to its large quantity (Valente *et al.*, 2017). Fish Waste is suitable for agricultural use due to the nutrient's high contents (Illera-Vives *et al.*, 2015). Commercially, in organic agriculture, there are many fertilizers manufactured from fish waste (Speiser and Tamm, 2011). Many ancient civilizations such as the Egyptians, and Mayans (Ahuja *et al.*, 2020).

The composting process is a natural and environmental method for managing waste and converting it into a soil-safe fertilizer by a microbial biotransformation process (Carr, 1995; Khalil *et al.*, 2012; Sun *et al.*, 2016; Jara-Samaniego *et al.*, 2017: Pottipati and Kalamdhad, 2023). Compost fertilizer is used to preserve soil fertility from deterioration, in addition to reducing the amounts of manufactured fertilizers used for agriculture (Vandecasteele *et al.*, 2016). Soil applying compost fertilizer increases its carbon storage, reducing greenhouse gas emissions (Cerda *et al.*, 2018 and Mu *et al.*, 2017).

Composting turns fish waste into organic fertilizer, supporting sustainability in fishing societies (López-González *et al.*, 2015). Fish waste is utilized as compost material (Illera-Vives *et al.*, 2015). Fish waste reduces the C: N ratio for materials rich in C, like sawdust, rice straw, and crop residues (Kazemi *et al.*, 2017). The composting fish fertilizers weight is about 45 % of the fish waste weight. It offers property waste management (Ahuja *et al.*, 2020), and contains a significant amount of nutrients and organic matter (Illera-Vives *et al.*, 2013). In several countries, composting fish waste is carried out to convert it into useful agricultural fertilizer (Illera-Vives *et al.*, 2015 and Ahuja *et al.*, 2020).

The major objective of this study was to evaluate the compost consisting of fish waste mixed with cow and poultry waste, describe the changes during the composting process, and test the compost toxicity by a phytotoxicity test. We hypothesized that fish waste compost could be suitable for agricultural use.

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MATERIALS AND METHODS

The experiment was conducted on the farm of the Faculty of Agriculture in Al-Bostan, Damanhour University. Four waste mixtures were used in the experiment: cow waste only (C), cow waste mixed with previously collected dried fish waste (CF) at a mixing ratio of 1:3, poultry waste only (P), and poultry waste mixed with dried fish waste (PF) with the same mixing ratio. The combination was weighed forty kilograms and put into 240-liter plastic boxes with covers. For 30 days, the boxes were incubated. There were three copies of every treatment. The samples were taken every week. Every day, the temperature was measured, and the piles were turned. The waste was analyzed in the laboratory before mixing and use, and the results are shown in Table (1). The daily temperature change was monitored and recorded for the three repetitions of each treatment. Samples were also taken from each replicate at the end of each week until the fourth week.

EC and pH were analyzed in water extracts (1:10, w/v). C, N, P, and K contents were analyzed as described by Jackson (2005). Thornton's media was used to assess bacteria, following the procedure described by Black (1965). The bacterial population was enumerated as described by Weaver and Bezdicek (1994). Seed germination index (GI%) carried out the phytotoxicity test technique as illustrated by Yu *et al.* (2010). Aggelis *et al.* (2002) recommended that if GI < 25, the compost is very phytotoxic, if 26 < GI < 65 it is phytotoxic if 66<GI<100 it is non-phytotoxic.

Table 1. The chemical properties of different wastes

Waste Materials	EC	pH	Total N	Total P	Total K	OM
	dS/m		ppm	ppm	ppm	%
Fish waste	7.7	5.98	4550	1.9	11.1	41.9
cow waste	8.54	8.51	770	5.4	37.8	34.9
poultry waste	11.91	8.67	2800	5.1	78.2	35.2

Statistical Analyses:

The results were statistically assessed by LSD in one-way analysis at a 5% significance level calculated using Costat software. A principal components analysis was carried out to summarize the results obtained by the chemical, biochemical, and microbiological parameters. The two principal components (PC1 and PC2) were used for this analysis. A PCA was by Origin program. The relationships between GI and compost variables were defined by regression analysis. The regression analysis was by Excel. The figures were drawn using the Minitab program.

RESULTS AND DISCUSSION

The temperature change of the different compost treatments was monitored, as shown in Figure (1). From the third day onwards, there was a clear rise in temperature in all treatments. Finstein (1986) declared that composting process releases high heat energy. The boxes treated with fish waste had a greater height than the untreated boxes. All treatments remained high from day three to today fifteen. Which represents the thermal period of the compost because of microbial activity. According to Tiquia (2005), the maximum temperature achieved in composting was due to the thermophilic phase. There was a decrease in all treatment temperatures after 15 days. According to Cooperband (2002), composting heats up and cools down faster after the thermophilic stage. There was a significant reduction in the untreated boxes with fish waste compared to the treated ones. All fish treatments remained higher than 20°C until the end of the composting period.

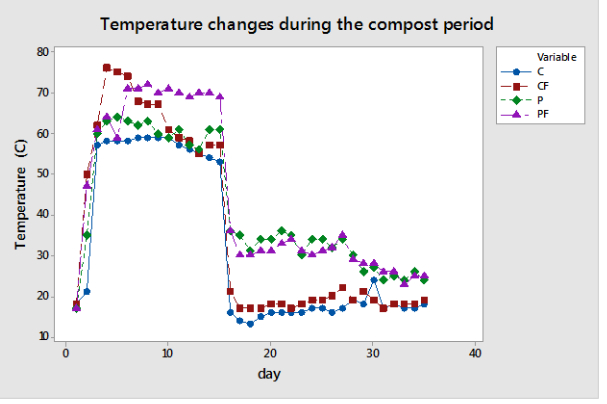

Fig. 1. The temperature change of the different treatments during the composting process

The pH change during the composting period is shown in Table (2). The highest pH was in treatment P1, followed by C1 in the first week. The fish waste treatments (CF1 and CF2) recorded a much lower pH than the untreated treatments with fish waste. The pH decreased due to the mineralization process and organic acid production. The change in the cows' treatments was less compared to the rest. It was 8.51 in the first week and reached 8.27 in the last week. The change in poultry treatments was more noticeable compared to cows' treatments. The CF2 treatment was the lowest for cows, and the PF2 treatment was the lowest for all treatments. In this regard Afifi and Eldin (2020) reported that the

Table 2. The chemical properties change during the composting process

week	Treatments	Abbreviation	pH	EC	O.M	N	P	K	GI
				ms/cm	%	ppm	ppm	ppm	%
1	Poultry	P 1	8.67^{a}	11.91^{e}	35.2^{g}	2800^{g}	5.1^{de}	78.2^{a}	35^{o}
	Poultry with fish	PF 1	7.67^{l}	10.53^{j}	43.6^{a}	5670^{a}	6.7^{ab}	37.8^{j}	30^{p}
	Cow	C 1	8.51^{b}	8.54^{m}	34.9^{h}	1540^{j}	5.4^{cde}	37.8^{j}	71^{h}
	Cow with fish	CF 1	7.88^{i}	10.18^{k}	41.3^{c}	4200^{c}	4^{gh}	29.7^{l}	43^{d}
2	Poultry	P 2	7.73^{j}	11.61^{g}	33.2^{i}	1750^{i}	5.7^{bcd}	78.2^{a}	43^{l}
	Poultry with fish	PF 2	7.44^{n}	11.94^{d}	41.9^{b}	5600^{b}	6.5^{abc}	42.2^{f}	40^{n}
	Cow	C 2	8.45^{c}	7.3^{o}	32.5^{k}	770^{m}	4.4^{ef}	34.5^{k}	84^{d}
	Cow with fish	CF 2	7.72^{k}	12.27^{b}	40.3^{d}	4200^{c}	3^{h}	38.7^{i}	51^{k}
3	Poultry	P 3	8.03^{f}	9.55^{l}	27.8n	980^{k}	6.9^{ab}	56.4^{c}	59^{i}
	Poultry with fish	PF 3	7.57^{m}	12.91^{a}	36.9^{e}	4060^{d}	5.4^{cde}	47.7^{e}	51^{j}
	Cow	C 3	8.28^{d}	6.49^{p}	31.9^{l}	700^{n}	6.16^{bcd}	28.2^{m}	89^{c}
	Cow with fish	CF 3	8.01^{g}	11.53^{h}	35.9^{f}	3500^{f}	6.72^{ab}	40.4^{h}	80^{f}
4	Poultry	P 4	7.72^{k}	10.93^{i}	16.7^{p}	910^{l}	7.7^{a}	77.0^{b}	81^{e}
	Poultry with fish	PF 4	7.67^{l}	11.64^{f}	27.5^{o}	3850^{e}	6.8^{ab}	51.5^{d}	77^{g}
	Cow	C 4	8.27^{e}	8.49^{n}	28.2^{m}	560^{o}	3.6^{fg}	34.5^{k}	100^{a}
	Cow with fish	CF 4	7.93^{h}	11.96^{c}	32.9^{j}	1960^{h}	3.2^{fg}	41.3^{g}	96^{b}

Values having the same alphabetical letter (s), do not significantly differ, using the L.S.D. test at 0.05 level.

pH values decreased from above 8, with a drop in pH below 7 after the thermophilic stage (day 42). The pH values were neutral values after the maturity of fish waste with olive mill composting. Mustin (1987) and Gigliotti *et al.* (2012) stated that organic matter mineralization decreases pH due to the production of organic acids.

The individual cow and poultry samples had the highest EC value recorded in the first week. EC values decreased in the second week, followed by the third week, and then increased in the last week. The highest value for individual cows and poultry samples was in the first week, and the lowest was in the last week. CF treatments increased in the second week, then decreased in the third week, followed by an increase in the last week. The CF and PF treatments were lowest in the first week. In the last week, the increase in EC values was due to the mineralization process as matched with Afifi and Eldin (2020). There was a rise in EC values at the composting end (Baeta-Hall *et al.,* 2005; Gigliotti *et al.,* 2012). After the thermophilic phase, EC increased due to organic matter decomposition (Soumare *et al.,* 2002).

In the first week, the organic matter content was significantly lower in the C and P treatments compared to the mixed treatments, as shown in Table (2). The organic matter content of poultry treatments was higher than that of cows, alone or with fish waste in the first and second week. As the mineralization process occurred, the organic matter percentage consistently decreased across all treatments until the maturity stage. All the above results agree with Afifi and Eldin (2020) who reported that O.M content declined during the composting .In this experiment, about 35–45% of the organic matter would be decreased during poultry composting, while cows' composting decreased 20% due to the C losses. Chefetz *et al.* (1998) report that more than 50% of the organic matter decomposition during the composting process. The change in OM depends on the organic compounds' mineralization during the composting process (Said-Pullicino and Gigliotti, 2007).

Total nitrogen during the first week of the composting process was higher in poultry treatments compared with cows. The results showed that adding fish waste to both poultry and cows waste led to an increase in total nitrogen. The total nitrogen decreases in all treatments because of the mineralization process of organic materials. After the composting process period, the lowest percentage was in cow treatments. The highest content was in poultry with fish, followed by cows mixed with fish, poultry, and cows. The total nitrogen changed during the fish waste and olive mill mixed composting period due to the thermophilic stage (Afifi and Eldin, 2020). Nitrogen decreased was associated with microorganisms activities from the composting process beginning (Bohacz, 2019 and Gigliotti *et al.,* 2012). The fish wastes presence had a positive role in N loss (Dauda *et al.,* 2019) .Temperatures change during the composting process were positively correlated to total N (Grunditz and Dalhammar, 2001). The total N content changed during the composting maturation phase was due to the OM depletion (Said-Pullicino and Gigliotti, 2007).

The change in phosphorus during the composting period does not give a specific pattern for all treatments. In treatment P, the total content of phosphorus increased with time, while in treatment C, it decreased, then increased, and finally decreased. In the PF treatment, the content decreases until the third week, then increases. Finally, in the CF treatment, the phosphorus content decreased, then increased, then decreased in the last week. The different and overlapping changes can explain all phosphorus changes during the composting process. Temperatures change during the composting process were correlated to total P (Grunditz and Dalhammar, 2001). The total P content changed during the composting maturation phase was due to the OM decomposition (Said-Pullicino and Gigliotti, 2007). All treatments had a high P level, these quantities were considered suitable for use as a good fertilizer source as reported by *Hachicha et al.* (2009).

In the P treatment, the K concentration decreased in the third week and then increased again in the last week. The same results were seen in treatment C. In PF and CF treatments, K increased from the first week (the lowest value) until the last week, recording the highest value. All treatments had a high K level, these quantities were considered suitable for use as a good fertilizer source as reported by Hachicha *et al.* (2009). At the mature stage, K levels increased in all treatments. Georgacakis *et al.* (1996) reported that K increases in the final compost, which stands to this study results.

The germination index (GI) in all treatments at the beginning of the compost was less than 50%, except for the C treatment, which was higher than 70%. Over time, the GI increased in all treatments because of the compost maturity, recording values higher than 75%. The results confirmed the compost suitability in all treatments for agricultural use. All of the above agreed with Aggelis *et al.* (2002), who approved that if GI> 66 the compost was characterized as non-phytotoxic and used as agricultural fertilizer. The highest GI was in C, followed by CF, then P, and finally PF in the first week. Adding fish waste to the treatments lowered the GI values compared to the treatments alone. Increasing GI confirmed the compost's maturity and suitability for use. During the composting process generally phytotoxic substances degraded by microorganisms which increased GI .The germination index (GI) is a sensitive parameter for compost maturity (Rashad *et al.*, 2010). The degradation of phytotoxic substances by microorganisms during composting generally causes a reduction in phytotoxicity (Aparna *et al.*, 2008).

The total number of bacteria during the composting process was low as shown in Figure (2). The lowest number was recorded in the P treatment. The total bacteria number order was as follows: CF> PF >C >P. Adding fish waste to the treatments led to an increase in the total number of bacteria. In the third week of compost, all treatments recorded the highest number. It then decreased in the last week (at the end of the thermophilic stage), maintaining the same order as it was in the first week. All the above agreed with (Afifi and Eldin, 2020). Barrena *et al.* (2008) reported that the total bacteria in the beginning were highly correlated to fish waste and then it decreased after the thermophilic phase. Chen and Bejosano-Gloria (2005) affirmed that the total bacteria decreased after the thermophilic phase due to the metabolic activities produced high temperature which destroyed all microorganisms.

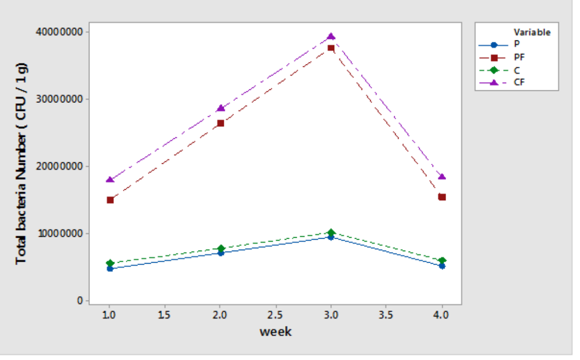

Fig. 2. The total number of bacteria of the different treatments during the composting process

PCA uses a matrix of variances and covariance's to preserve Euclidean distances. The most important findings from the analysis were the first two axes. Figure (3) shows that the PCA correlation indicates a strong correlation between certain variables and the two chosen components. When the variable's component axes are nearest to or further from zero, the maximum and lowest regards are noted. PCA identified tendencies between the variables and their relationship (Peña *et al.*, 2020). The variability appears to consistently indicate the connections between the compost mixtures and the variables pH, EC, N, P, K, O.M, and the total bacteria. PC1 explained 43.53 % of the variance and PC2 27.86 % for a total explained variance of 71 %. The variables modification along PC1 confined EC, OM, N and the total bacteria while the variables adjustment along PC2 contained K and P. All of variables were positively correlated, except pH, P and K. The result showed that pH was negatively correlated as reported by Gómez-Brandón *et al.* (2008). There was a positive correlation between EC, N, total number of bacteria, and OM as reported by Peña *et al.* (2020), while there was a negative correlation between the above and pH, P, and K. There is an inverse relationship between EC and pH.

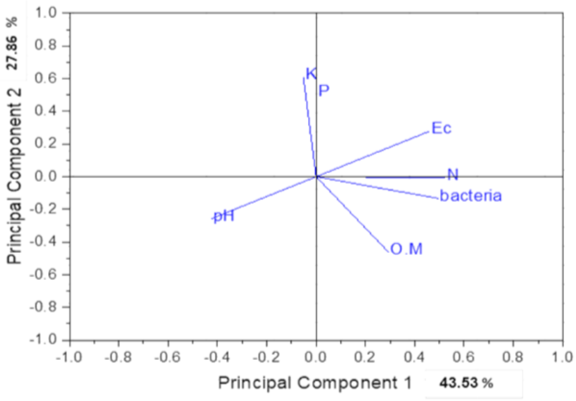

Figure 3. Principal component analysis (PCA) during the composting process

Regression analysis is a statistical method in which the average GI is predicted based on the values and measurements of compost variables (pH, EC, N, P, K and O.M) during the composting process. Regression analysis is the selection of the curve that best fits a given set of data points. In multiple linear regression, there are several independent variables. From the results shown in Table (3), R^2 for all treatments were 1, which reflects their efficiency in interpreting and predicting the results of GI based on the composting variables as reported by Shehata *et al.* (2019). The compost chemical characteristics had an impact on the germination index (GI) (Tiquia, 2010). GI changed according to the changes in pH, EC, and N (Jiang *et al.*, 2018). Tiquia and Tam (1998) established that the GI modifications strongly depended on the compost's chemical properties. In all experimental treatments, N and K were the most influential variables on GI. In C treatment, P had a negative effect on GI, besides the variables mentioned above. In P, PF, and CF treatments, OM as a variable has a negative effect on GI, in addition to N and K. The results showed that the compost physicochemical properties had significant influences on the GI values. This result is stable with what was stated by Pampuro *et al.* (2017).

Table 3. The chemical properties change during the composting process

Treatment	Equation	*R^2
C	GI =197.12-2.5 K-7.26 P +0.01 N	100
CF	GI =262.64+0.53 K+0.002 N-5.88 OM	100
P	GI =369.3-2.96 K+0.03 N - 5.15 OM	100
PF	GI =-45.92+3.26 K-0.01 N-0.47 OM	100

*A regression analysis was performed between GI and all compost parameters, and the equation found the factors that most influence the germination index and that achieve the highest R^2.

CONCLUSION

Composting is an important process for producing environmentally safe fertilizers. Composting fish waste with both poultry and cows led to higher levels of nutrients in it, which benefit the plants and soil when used. The fish waste treatments (CF 1 and CF 2) recorded a much lower pH than the untreated treatments with fish waste. The N content was the highest in pF, followed by CF, P, and C. The variation appears to consistently indicate the connections between the compost mixtures and the varying pH, EC, N, P, K, O.M., and the total bacteria. There was a positive correlation between EC, N, the total number of bacteria, and OM. Regression analysis is a statistical method in which the average GI is predicted based on the values and measurements of compost variables (pH, EC, K, P, K, and O.M.) during the composting process. Furthermore, according to the maturation phase, 30 days was sufficient to produce a stable compost with a low degree of phytotoxicity (high GI %). Finally, using fish waste with cow and poultry manure reduces the environmental impact of these wastes, in addition to producing fertilizer suitable for agricultural use. Fish waste composting reduces fisheries by-products and waste volume.

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الملخص العربي

تحويل مخلفات الأسماك إلى سماد مع روث الابقار والدواجن لإنتاج سماد عضوي صديق للبيئة

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ينتج قطاع صيد الأسماك نفايات كبيرة. وكان الهدف الأساسي من هذا العمل هو الحصول على الأسمدة العضوية لاستخدامها في الزراعة عن طريق تحويل مخلفات الأسماك إلى سماد. تم استخدام أربع مخاليط نفايات في التجربة: مخلفات الابقار فقط (C)، مخلفات الابقار متحدة مع مخلفات الأسماك المجففة المجمعة سابقا (CF) بنسبة خلط ١:٣، مخلفات الدواجن (P)، ومخلفات الدواجن متحدة مع مخلفات الأسماك. (PF) بنفس نسبة الخلط. سجلت معالجات مخلفات الأسماك (PF2 وCF2) درجة حموضة أقل بكثير من المعالجات غير المعالجة بمخلفات الأسماك. كانت قيم الرقم الهيدروجيني قيمًا محايدة بعد نضج مخلفات الأسماك. وكانت أعلى محتوى N في مخلفات الدواجن مع الأسماك، تليها مخلفات الأبقار الممزوجة بالأسماك والدواجن والأبقار. بمرور الوقت، زاد المؤشر الجلايسيمي في جميع العلاجات بسبب نضج السماد ، وسجل قيما أعلى من ٧٥٪. أكدت النتائج ملاءمة السماد في جميع العلاجات للاستخدام الزراعي. تعكس قيم R^2 كفاءتها في تفسير وتوقع نتائج GI بناءً على الرقم الهيدروجيني وEC وN. وأظهرت النتائج أن الخواص الفيزيائية والكيميائية للسماد لها تأثيرات كبيرة على قيم GI. أثبتت النتائج أنه من الممكن استخدام فضلات الأسماك الممزوجة مع روث الدواجن والابقار لإنتاج سماد آمن بيئيا وأفضل من منتج السماد من روث الدواجن والابقار فقط.