Recycling of Organic Solid Wastes of Cities to Biofertilizer Using Natural Raw Materials

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Abstract

A pilot composting system was conducted at the factory of recycling of organic solid wastes in Al-Usifia near Baghdad city, to investigate the possibility of the conversion organic fraction of Municipal organic solid waste (OFMSW) to biofertilizer. Results of MSW analysis showed the presence of 64% of biodegradable organic matter and 36% non-biodegradable. The initial composition of OFMSW had a high C/N ratio 37.02, and low availability N content. The additives used in OFMSW composting such as Buffalo, chicken and sewage sludge to the compost pile to treat N deletion and to obtain a desirable C/N ratio in treating piles. Various parameters were determined during the composting process of OFMSW and mixtures, to evaluate their suitability as indicators for the composting process. Results showed that after 6-10 weeks of incubation, the OFMSW turned to black-like substances with earthy smelling compost material. The pH of the mature compost ranged from 7.8 to 7.89; EC in all piles ranged from 3.11 to 5.41 dS/m. The N% increased with time in all piles reaching at the end of maturation to 1.04 to 1.84, the total phosphorous was high in all piles and varied from 1.11 to 1.6% in all piles. However, the results also revealed a higher potassium concentration varied from 1.18 to 3%, compared to initial concentration ranged from 0.6 to 1.6 in all piles. The water holding capacity of compost samples in all piles increased during composting and varied from 69 to 90% compared to initial ratio ranged from 14 to 45%. The windrow system was more effective for heavy metal marinating. The temperature in piles 2, 3 and 4 increased rapidly above 50°C for 4 weeks and reached to the peak recorded value of more than 60°C indicating higher degradation rate, while the temperature in pile 1 and 5 increased slowly relative to the other piles. The biodegradation of organic wastes, as indicated obviously by the reduction of C/N ratio, was rapid and decreased from 27.4 – 37.02 to 9.47 – 15.26 after 6 weeks of composting. Total viable count in all piles showed a marked increase in initial composting process when the temperature increased and a marked decrease at the end of maturation. The total number of bacteria in Piles 2, 3 and 4 was higher than in Piles 1 and 5. Coliform bacteria were found till 6 weeks in piles 2, 3 and 4, while recording up to 10 weeks in piles 1 and 5. *Salmonella* and *Shigella* did not appear throughout the study after 6 weeks of incubation, with exception in piles 1 and 5; these organisms were detected till weeks 10 to 14. Total fungi count decreased in piles 2, 3 and 4 when the temperature increased from 52°C to 60°C, while continued to increase till the end of maturation when the temperature fell to 30°C. Total fungi count recorded at the end of maturation was higher than the initial stage. Physiochemical and microbial characteristics of the final compost product could be recommended that the OFMSW is suitable for composting using the turning windrows system.

Keywords: Organic waste, Physio-chemical characteristics, static piles, C/N ratio, animal manure, nonpathogenic.

Introduction

Rapid increase in population and change in lifestyle has resulted in a dramatic increase in municipal solid waste (MSW). MSW includes both domestic and commercial waste accounts for a relatively small part of the total solid waste stream in developed countries.

Accumulation of a large amount of waste may create several problems to inhabiting populations. It requires the application of some effective strategies for proper disposal of (MSW) (1). The term composting refers is to biological process in which organic fraction of solid waste material is broken down by the activity of microorganisms. The degradation process takes place in the presence of air (aerobic) and results in elevated process temperature and the production of CO_2, water and stabilized organic residue.

The key characteristics of the composting process are the decomposition of the substrate materials by biological activity during the decomposition process and heat generation. By forming the waste into large masses under suitable conditions, they will raise the temperature, resulting in the rapid degradation process. More importantly, these elevations of temperatures have a sanitizing influence upon the waste, reducing the number of pathogenic organism (2).

There are different systems used in the composting process of which the most common methods used for composting include static heaps, passive heaps, windrows and in-vessel composting systems. All the various composting systems can be classified into two systems, according to the mode of aeration: Passive aerated systems, these are given little application; active aerated systems, those that are performance through strong aeration or frequent mechanical turning (3). Various systems would allow dissipation of the heat liberated during the composting process at different rates depending on their design; thus, affluence the dynamics of compost microbial community. For a selection of composting systems for treatment of organic waste, there is a need to consider the systems' effectiveness in reducing pathogens in the final product of compost via temperature development: in order to prevent the penetration of different pathogens into the food chain.

Different factors take into consideration in compost process. One of these factors is carbon: nitrogen ratio (C: N) which, affects the rate of biodegradation activity. Carbon: nitrogen ratios of 15:1 to 35:1 are acceptable. If the C: N ratio is less than 25:1, organisms did not capable to utilize all of the nitrogen available, and nitrogen is then lost as ammonia. This, in turn, results in an unacceptable odor, air pollution, and loss of potential fertilizer value. When the C: N ratio exceeds 30:1, the rate of decomposition of materials decreases. Mixing of Green landscape wastes and animal manure with the carbonaceous material can be lower the C: N ratio of 30:1, or under (4).

The elevation of compost pile temperature is a good indicator of biological activity, and is easily measured. Appropriate moisture content, oxygen availability, and microbial activity all affect temperature. After organic wastes are mixed with raw materials and placed in piles; thermophilic microbes should begin to dominate. These organisms prefer a range of temperature 37.7°C to 65.5°C. As long as a pile temperature is elevated, it is functioning well and should be left alone. As the temperature elevates, and then begins to decrease, the pile should be turned to incorporate aeration into the compost. After turning, the pile should subjected to the mixing and incorporation of oxygen, and temperature should again start to cycle upwards. Ideally, the turning process should be repeated until the reheating response does not take place again; indicating that compost raw material is biologically Table (5).

Keeping in view the large quantity of organic fraction of MSW generated in Baghdad and cities around and required huge cost for its disposal. Most of these wastes are dumped in landfill, and in our knowledge till know any composting system not utilized for converting organic fraction of MSW to compost. The current study aimed to investigate the possibility of bioconversion of organic fraction of solid waste into enriched compost and to evaluate their nutritional quality, using a windrow system.

Materials and Methods

Study area

The study was carried out at Baghdad municipality at factory of recycling of organic solid wastes in Al-Usifia, located at Al-Usifia city about 20 km to the south of Baghdad city. This station was conducted to treat MSW resulted from three or more cities around Baghdad. The study was carried out in January to June 2014 at ambient temperature ranging from 23 to 45°C.

Feedstock used in composting piles

Organic fraction of municipal solid waste

These materials were collected from the mixed municipal solid waste by the cities (Al-Mahmudia, Al- Latifia and Al-Usifia) around

Baghdad after manual separation. The organic fractions of municipal solid wastes (OFMSW) were collected from households and restaurants include, mainly, vegetable, fruit and kitchen waste, etc. was manually separated and exposed to turned windrow composting process.

Compost materials

Compost materials included: organic fraction of MSW; Buffalo and Poultry (Chicken) manure, obtained from farms and households nearby treatment system; sewage sludge, obtained from Al- Rustamia sewage treatment system in Baghdad Municipality. All experiment and pilot scale windrows were used in composting were used OFMSW as base materials and Buffalo, chicken and sewage sludge as bulking agents in the ratio 2:1 and 3:1 (w/w). Table (2) presents some of the physiochemical characteristics of OFMSW and the mixture of OFMSW with different bulking agents. The total weight of introducing organic raw material for composting and the final compost product was calculated by weighing.

Composting methods

For the preparation of compost piles, pilot scale composting took place, mainly by using windrows method. These were formed in the open air or undercover (shelter) and were manually turned. Pilot scale windrows were shaped in piles of 0.90 m high, 1.50 m wide at the base and were 2.5 m long, using more than 3.375 m^3 of feedstock materials in each windrow Fig.(1). In this case, an industrial scale windrow turner was towed by tractor and turns the windrows. Required operation conditions of composting were maintained as per. Temperature in the core of each pile was monitored on a weekly basis. Aeration typically in the heap was provided by manually turning of waste. A heap was moisten regularly to maintain moisture level between 50- 60% and turned manually every 5-7 days for the first eight weeks of composting cycle. From the ninth week, the moisture was allowed to drop when optimum bio-solids decomposition was achieved. The process was completed in about 10-12 weeks. After this period the compost was allowed to cure for additional four weeks without turning. The mature compost was then screened out and weighed.

Sample analysis

Physico-chemical parameters analysis

Temperature in the core of each pile was monitored weekly. Turning was mostly performed periodically (weekly), but temperature fluctuations were also taken into account and turning occurred more frequently when the temperature declined below 45°**C** or increased above 65°C. Sub-samples (250 g) from the raw materials were taken from 4 different points of the compost piles including top, middle and bottom locations in the different piles every two weeks for laboratory study. The samples taken were mixed to obtain a representative sample, packed in a plastic container and transformed to the laboratory. The samples were kept in the refrigerator at a temperature of 4ºC for a day before microbial analysis performed. The mixtures and the mature composts and a range of physiochemical parameters were determined, including:

- pH and electrical conductivity (EC) in water extract, by diluting 1 part of compost by volume, with 5 parts of distilled water (6).
- Moisture content: 10 g of the representative samples from the different piles was weighed and duplicated for moisture content determination using the oven method. The samples were kept in the oven at 105ºC for 24hrs and changing in weight of samples were averaged and used to determine the moisture content of compost mass in each pile (7).
- C% and Volatile solids (VS) by the ignition at 600°C for 4h (7).
- Ash content according to (7).
- Total nitrogen, by the micro-Kjeldahl method, measured by method followed by (8) and total potassium by the flame method using (Flame photometer) according to (7).
- Water holding capacity determined according to the method described by (9).
- Mineral elements: Cu, Zn, Fe, and Fe as well as heavy metal concentrations (Cd and Pb) were determined with an atomic absorption spectrophotometer (10).

2.5.2 Microbial activity of compost piles

The biological analysis of compost samples was analyzed during the composting process. Microbial analysis included total viable bacterial counts (cfu/g) were made on a nutrient agar, molds and yeast counts (cfu/g) were made on Rose Bengal Agar (RBA), total coliform (cfu/g) was made on Violet Red Bile agar (VRB), *salmonella and Shigella* detection (cfu/g) were made on *Salmonella* and *Shigella* agar (SSA). Analysis was done according to (11 and 12).

Ten grams of representative samples taken from each of the piles for the study were weighed into 180 ml of 1% peptone water and incubated at 30ºC for 15minutes.They were well mixed and then 1ml of the supernatant was drawn from each of the bottles and diluted using 10-fold dilution. Different sterilized pipettes were used for each of the dilution. 0.1 ml of the diluents taken from dilution factors: 1:10 to $1{:}10^8$ were transferred into 2 sets of Plate Count Agar (PCA) used for viable count and VRB agar for coliform count. For fungi enumeration, 0.1 ml of each dilution was transferred onto the RBA in labeled Petri-dishes. The whole set of plates were incubated at 30ºC for 24 hours for total viable count and at 30ºC and for 2-7 days for fungi counts. While Total Coliform and *Salmonella* and *Shigella* plates were incubated at 37 ºC for 24h. Cultures showing "between" 30-300 colonies were calculated using the colony counter.

Fig. (1): Pilot scale of the compost piles, including organic fraction of MSW and their treatment with different manure using a windrow system, at the Factory of recycling of organic solid wastes in Al-Usifia City.

Results and Discussion

Recycling of organic matter is a vital for supplementing plant nutrients and increasing soil productivity. The municipal solid wastes containing some reusable materials such as plastics, glass, metals, paper and others, which totally represented about 36%. This was separated and used for recycling for further uses. Vegetable matter and other decomposable were the predominant constituents which are present to an extent of 64% as shown in Table (1). The results clearly indicate that the organic fraction of the municipal waste was highly suitable for composting process. Similar observations have also been made by many earlier workers (1, 13, 14).

Table (1)
The main composition of municipal solid waste understudy.

No.	*components*	*(%) by weight*
1	glass	3.2
2	Paper	4.2
3	Plastic / polythenes	8.0
4	Textile	2
5	Leather and rubber	1.5
6	Metal	5
7	Food waste	64
8	Soil and stones	12
Total		99.9

Chemical composition of organic wastes used in composting

The chemical compositions of different organic materials used for preparing the compost are given in Table (2). Municipal organic waste is one of the important nutrient organic residues, which on recycling produced valuable and nutrient rich product known as compost. The organic waste is found to be neutral in nature (pH 6.8) and was fairly low in N (0.85%). The organic carbon was 31.47% with a C: N ratio of 37.02.

The chemical characteristics of OFSW Table (2) show that the material had a high C/N ratio, and low availability of N would restrict the microbial activity and stabilization of the waste by composting (3). One approach to correct this deficiency is to supply a source of N to adjust the C/N ratio to the optimum range (15). Buffalo manure, Chicken manure and sewage sludge were rich in N (2.8), (2.3) and (2.1)%, respectively, were used to supplement to the piles to treat nitrogen depletion as well as animal manure (Buffalo and Chicken) and sewage sludge as an additive or inoculums for the compost treatment, and served as a starter for composting.

Data from the current study showed that proportioning of mixed wastes in the mixtures Table (2) had resulted to desirable C/N ratio in all piles, ranged from 27.44 to 35.58 as generally agreed by many researchers (16 and 4).

Table (2)
Physiochemical characteristics of raw and mixtures of composted materials.

Raw materials and their mixture / *Unmixed*	*pH*	*EC (ms/cm^{-1})*	*TDS (mg/l)*	*Organic matter (OM)%*	*C (%)*	*N (%)*	*C: N*
P 1: Organic fraction of solid waste (OFSW) (100%)	6.80x	5.8	2900	56.64	31.47	0.85	37.02
Buffalo manure (100%)	-	-	-	87.48	48.6	2.8	26.6
Chicken manure (100%)	-	-	-	67.68	37.6	2.3	16.34
Sewage sludge (100%)	-	-	-	55.44	30.8	2.0	15.4
Mixtures							
P 2: OFSW+ Buffalo manure (66%+ 33% by weight)	6.4	6.0	3100	69.17	38.43	1.28	35.58
P 3: OFSW + Buffalo manure (75%+ 25% by weight)	6.4	6.0	2850	67.77	37.65	1.15	32.74
P 4: OFSW + chicken manure (75%+ 25% by weight)	6.5	8.8	5200	63.29	35.16	1.28	27.47
P 5: OFSW + sewage sludge (75%+ 25% by weight)	6.2	6.3	2800	48.48	26.93	0.96	28.05
* Standard values suitable for composting	5.5-8.0	-	-	> 20	30 - 40	> 0.6	25-50: 1

**** Source: Standard, Zucconin, and de Bertolidi, [19].***

Evaluation of physical-chemical characteristics of the matured compost

The release of carbon in gaseous form, volatile organic acid or other chemicals are associated with odors of composting feedstock's materials. The organic substrate often of high odors, potential accumulates in excess under air–limited/ or low pH conditions (17). In all piles ammonia and other gasses were most profound up to 4 weeks, and potential of odor was decreased gradually with the composting process proceeds. No odors were generated after 6 weeks of decomposition, and that probably because of periodical mixing, which improved the oxygen supply in the piles and provided better activity of microbial consortia. Composting of OFMSW during summer season required 4 – 8 weeks were more than 70% weight loss was recorded, earthy smell of material after one week cleanly indicated the maturity of the compost (18). Gautam (1) noted that the weight loss gradually becomes more pronounced during the first week of the composting, as microbial activity increased to maximum.

During the composting process, a gradual change in the quality in the raw materials was monitored. It was observed that, after 6 to 10 weeks, it stabilized and appeared black humus – like substances in all piles. After completion of the composting process, black colored humus like substance was generated in each pile having an earthy smell. The compost materials were left for an extra 4 weeks after maturation for curing, then sieved through 2 mm sieving and packaged for further agriculture application Fig.(2).

pH

In all piles, initial pH values of raw and mixed materials were found to be less than 7. As the decomposition process, increased the pH values gradually increased up to 7.7 during week 2 Fig.(3). While, the final pH values ranged from (7.8 to 7.89) at the end of maturation and curing period, indicating the stability of organic matter.

Earlier researchers have indicated that the pH range of 5.5–9.0 was suitable for microbial decomposition of organic materials, while the composting process was most effective at pH values between 6.5 and 8.0 (20 and 21). Also Cofie (22) observed at the end of compost maturation, pH values of 7.8 and 8.1 respectively in two compost heaps which are also found in accordance within range obtained in earlier studies.

Fig.(2): Mature compost after 14 weeks of the composting process.

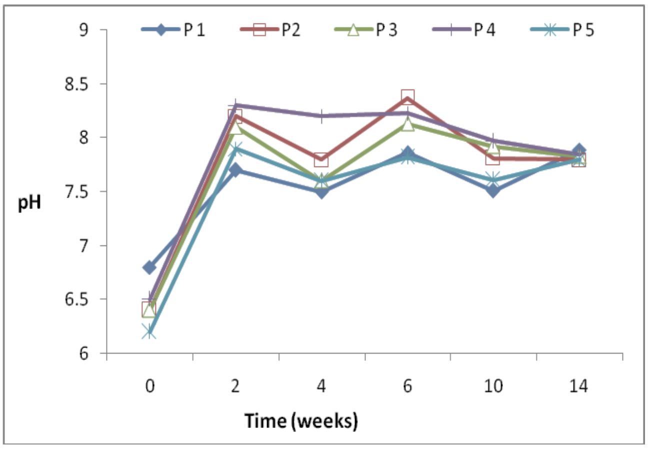


Fig.(3): pH changes during the decomposition of organic waste in different composting piles. [P1: Organic fraction of solid waste (OFSW) (100%), P2: OFSW+ Buffalo manure (66%+ 33% by weight), P3: OFSW + Buffalo manure (75%+ 25% by weight), P4: OFSW + chicken manure (75%+25% by weight) P5: OFSW + sewage sludge (75%+ 25% by weight).

EC

The EC an indication of the salinity of different substrates and it is also reflects the maturity of compost. The salinity content of compost is due to the presence of sodium, chloride, potassium, nitrate, sulfate and ammonia salt (23). The EC values of initial compost samples were high varying from 5.8 to 8.8 and decreased to the minimum value in all piles after 4 weeks of composting due to higher degradation rate Fig.(4). The EC values started to increase after 4 weeks of composting, and highest EC values of all piles were observed at the end of the composting process and during curing ranged from 3.11 to 5.41 dS/m. Liu (24) and Yadva and Gary, (25) obtained the same results, and they indicated that the increase in EC might have been due to release of different mineral ions, such as phosphate, ammonia and potassium. Also the high values of EC could be due to the effect of the concentration of salts as a consequence of degradation of organic matter (26).

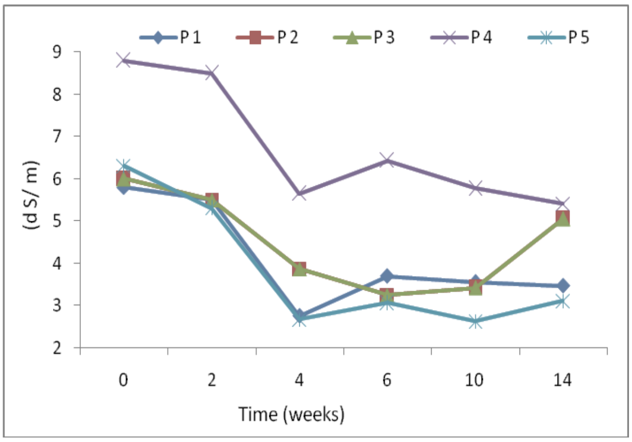


Fig. (4): EC changes during the decomposition of organic waste in different composting piles.

Organic carbon (C %) and C/N ratio

The changes in carbon percent (C%) content N% and C/ N ratio during the composting process of the different piles were shown in Table (3).

Table (3)
Changes of organic C % and C/N ratio characteristics of the Matured Compost.

Times	Organic C %					C/ N ratio					Recommended Standards
	P 1	P 2	P 3	P 4	P 5	P 1	P 2	P 3	P 4	P 5	
0	31.47	38.43	37.65	35.16	26.93	37.02	35.58	32.74	27.47	28.05	Organic
2	17.19	26.77	21.56	24.85	16.05	14.75	25.26	16.09	11.12	14.59	C % >30[1]
4	13.16	19.84	18.01	18.80	12.74	12.18	14.69	15.83	10.27	15.16	C:N
6	12.90	17.98	16.79	17.32	12.22	11.12	14.98	15.26	9.47	13.58	ratios
10	15.70	15.81	15.19	16.12	12.06	12.27	17.57	15.19	8.85	11.48	< 25[2]
14	14.28	16.13	16.01	16.85	12.26	10.98	18.75	15.40	9.16	11.35	

Note: [1 and 2]Limit of organic matter and C:N ratio specified by the Environmental Protection Agency in accordance with Waste Licensing under the Waste Management Act 1996.
[P1: Organic fraction of solid waste (OFSW) (100%), P2: OFSW+ Buffalo manure (66%+ 33% by weight), P3: OFSW + Buffalo manure (75%+ 25% by weight), P4: OFSW + chicken manure (75%+ 25% by weight), P5: OFSW + sewage sludge (75%+ 25% by weight).

The initial C % in the piles varied from 26.9 to 38.43% and they decreased as the decomposition process increased, reflecting a notable mineralization of organic matter. At the end of the process, the lowest C % was observed in pile 5, and the highest in pile 4. The high C %, mainly resulted from the higher concentrations of non - biodegradable compounds present in pile 4 compared to other piles. During the composting process, most of the carbon was lost in the form of CO_2 and other gasses. Pile 4 contained the highest proportion of chicken manure; hence, its decomposition occurred slowly (24).

The C/N ratio is one of the main characteristics that describe the compost process. The high C/N ratio indicates the presence of unutilized complex nitrogen; whereas completion of the process (compost maturity) is indicated by the reduction of ratio to 25: 1 – 30: 1. In the present study, the C/N ratio varied from (27.47 to 37.02) % at the initial stage of composting, which decreased gradually with the passage of substrate decomposition Table (3) and Fig.(5). In all piles, within 6 weeks of decomposition, the C/N ratio decreased, and remained rather stable up to 14 weeks, except in pile 2 the C/N ratio increased to 18.75.

In the current study during the active composting, the C/N ratio decreased from 27.47–37.02 at the initial stage of the composting to 9.47–15.26 in all piles after 6 weeks of composting process, and during curing continued to decrease to 9.16–15.18, except in pile 2 the C/N ratio increased to 18.75. The decrease of C/N ratio could be the result of bioconversion of organic carbon into carbon dioxide, followed by elimination in the organic acid content (27). It has been stated that when the C/N ratio is less than 20, the compost is mature and can be used without restriction (28 and 29).

The ratio of final C/N to initial C/N is a good indicator for determining the stage of maturity of the compost [30]. The results of

C/N $_{final}$ to C/N $_{initial}$ were decreased to 0.34–0.38 in all piles and remained stable until the end of the composting process.

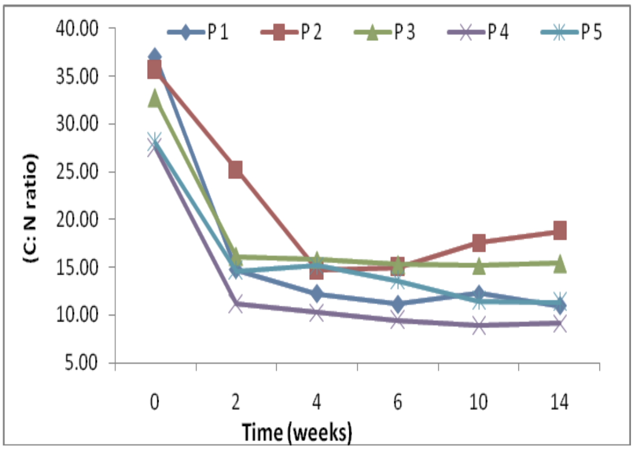


Fig.(5): C/N ratio changes during the decomposition of organic waste in different composting piles.

Total Nitrogen (N %), Phosphorous (P %) and Potassium (K %).

The composted product was analyzed for total N, P and K %; the results are shown in Table (4). At the early stage of the composting process, the total nitrogen percent (N %) varied from 0.85 to 1.28% of the material, with lowest N % in pile 1 (OFSW) and highest in pile 4 (OFMSW + chicken manure). The N % increased with time until the week 2 in all piles and then decreased at week 4, and then increased continuously in all piles reaching at the end of maturation to (1.04 to 1.84) except in pile 2, where there was an obvious decrease in N % over the time. The decrease in N % could be attributed to the loss of N through the generation of ammonia (31); the increase N % is due mainly to the loss of C % in the form of carbon dioxide resulted in an increase in N content per unit of material.

Phosphorous is also an important nutrient for plant growth. Total phosphorous is usually expressed in terms of percentage (%) per dry weight. During the composting process, the total phosphorous concentration varied from 1.11 to 1.6% in all piles Table(4). Also the results showed maximum phosphorous % in pile 3 (OFSW + Buffalo manure 3:1 by weight). In comparison with recommended standards by Bordna- Mona, (32) the total phosphorous were found high in all piles samples. Elango *et al.*, (33) found that the total phosphorous content gradually increased during thermophilic composting process of municipal solid waste and water solubility decreases with humification, and also suggested that, phosphorous solubility during the decomposition process was subjected to further immobilization factor.

In the current study, potassium percentage varied from 1.18 to 3 % in all piles Table (4). However, the results also revealed a higher potassium concentration reached 1.97 and 3 % in pile 2 and 3 respectively. The comparisons of results obtained with recommended standards, the total potassium concentration was founded within the normal range except in pile 2 and 3. The increase K % in piles 2 and 3 could be attributed to increase of microbial activity to decomposition of compost materials into smaller particle sizes which can absorb relatively large quantities of water and still maintain structural integrity and porosity could prevent the loss of potassium from the compost formed (34). Potassium is not known to have harmful or toxic effects on human beings and it helps in plant growth as an essential nutritional element.

Table (4)
Changes of Total N (%), P (%), and K (%) characteristics of the matured compost.

Times (Weeks)	Total N %					Total P %					Total K %				
	P 1	P 2	P 3	P 4	P 5	P 1	P 2	P 3	P 4	P 5	P 1	P 2	P 3	P 4	P 5
0	0.85	1.08	1.15	1.28	0.96	0.6	0.75	0.9	1.0	0.8	0.7	1.2	1.6	0.6	0.9
2	1.17	1.06	1.34	2.24	1.10	-	-	-	-	-	-	-	-	-	-
4	1.08	1.35	1.14	1.83	0.84	-	-	-	-	-	-	-	-	-	-
6	1.16	1.20	1.10	1.83	0.90	-	-	-	-	-	-	-	-	-	-
10	1.28	0.90	1.00	1.82	1.05	-	-	-	-	-	-	-	-	-	-
14	1.30	0.86	1.04	1.84	1.08	1.11	1.26	1.6	1.48	1.23	1.18	1.97	3.0	1.33	1.40

Note: Recommended range of N % not available, the total P% (0.4 – 1.1) and total K % (0.6 – 1.7) (32).

Water Holding Capacity (%)

Water holding capacity is the amount of water held in pores after the gravitation loss for a specified time (23). The water holding capacity of compost samples in all piles was increased during composting and varied from 69 to 90 % Table (5). The results also showed that maximum holding capacity (90 %) was obtained in pile 2 and 3 when OFMSW is combined with buffalo manure in the ratio of (2:1 and 3:1 by weight). The increase of water holding capacity in the piles in comparison to the initial values reveals that, the amount of water held in the pores of compost particles increases with days of decomposition of compost materials. These results could be an indication of active decomposition process and break down of compost materials into smaller particles, resulting in an increase of bulk density of compost (35).

Table (5)
Changes of water holding capacity characteristics of the matured compost, P1 – P5 piles.

Time (Weeks)	Water holding capacity (%)				
	P 1	P 2	P 3	P 4	P 5
0	14	40	45	30	42
2	-	-	-	-	-
4	-	-	-	-	-
6	-	-	-	-	-
10	-	-	-	-	-
14	71	90	90	85	69

Heavy metal and micronutrient characteristics

The data presented in Table (6) showed that the windrow system was more effective for heavy metal and nutrients marinating. The chemical analysis of heavy metal and nutrients agreed with WHO criteria (World Bank. Integrated resource recovery, 1987) (36). Also the results of the current study agreed with that obtained by Sadik (4) they observed an increase in the accumulation of micronutrients (Fe, Cu, Zn) and heavy metals (Cd and Pb) in the compost pile (brown: greens: animal manure at ratio 1:1:2 respectively) supplemented with BZT^{R} compost activator. The finding of the current study also showed that the treating of OFMSW with Buffalo, chicken and sewage sludge increased the accumulation of heavy metals and nutrients in all piles. It could be concluded that a window system may be recommended for better methods for recycling of OFMSW and animal wastes.

Table (6)
The heavy metal and micronutrient (ppm) properties of compost piles.

Compost	*Week*	*Cd*	*Pb*	*Cu*	*Zn*	*Fe*	*Mn*
P 1	0	0.856	35.02	36.31	265	9870	82.25
	14	1.7	39.0	69.0	413	11760	180.0
P 2	0	0.458	16.63	15.69	150	7830	72.74
	14	1.9	41.0	150	310	19130	268
P 3	0	0.505	14.66	19.46	143	9190	72.48
	14	1.4	16.0	110	315	10220	496
P 4	0	0.509	36.02	26.0	210	7180	74.24
	14	2.5	45.0	71	357	9710	312
P5	0	0.743	42.14	38.5	340	12630	114.8
	14	2.5	46.0	82.0	416	14930	235.0

Effect of Temperature and Microbial Characteristics

The results of temperatures fell gradually in all piles (P1 to P5) but at different rates and to different extent Fig.(6). Temperature values recorded were higher in the piles 2, 3 and 4 than the pile 1 and 5 as a result better aeration and decomposition rate. The temperature values in piles (P2, P3 and P5) rose from 25 to the more than 50°C in week 2 to the peak recorded value of more than 61°C. However temperature in the piles (P1 and P5) rose from 24 to around 40 in week 2 to the peak recorded value of 51 and 46°C respectively. The temperature of all piles treatments regularly decreased off gradually towards during the maturation as obtained by Rashad (37). Thus, the variation in temperature in all piles affects the survival of different microbial communities in all piles system and hence the different rate of decomposition.

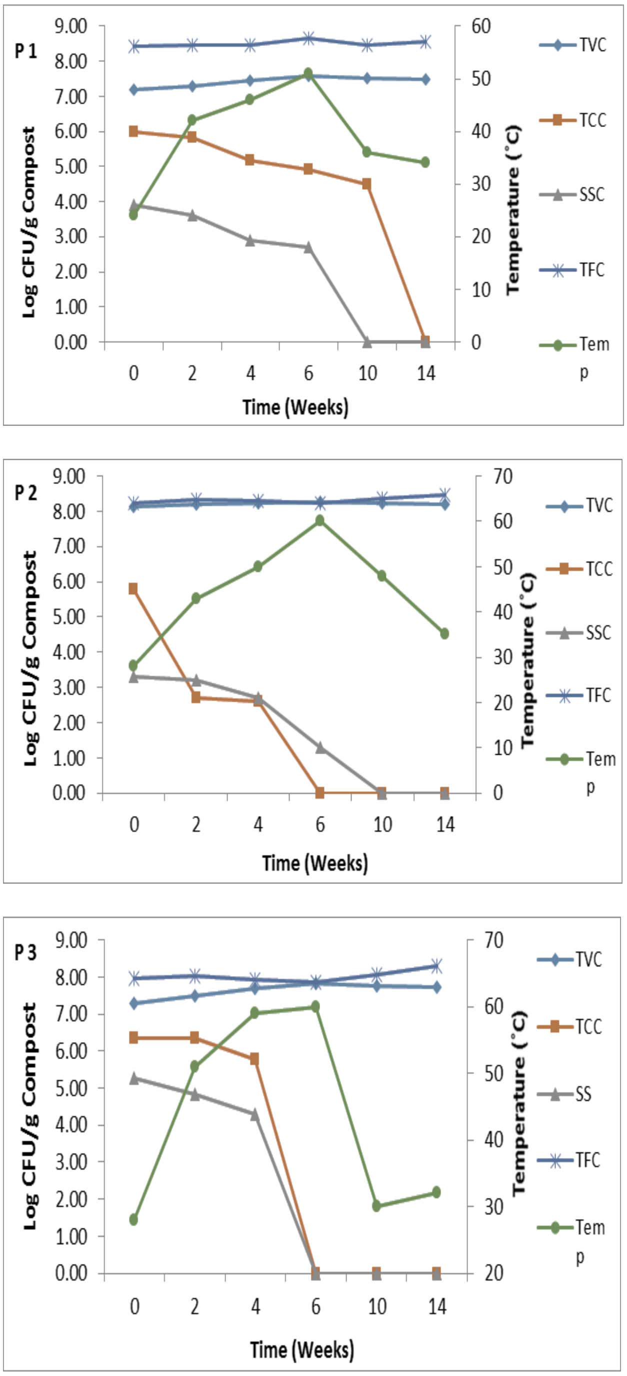
Microbial survival plays an important role during decomposition, acting an indicator of the effectiveness of the composting process, and the appearance of specific microorganisms reflects the maturity and potential of compost [38]. In the current study, changes in microbial culture communities were followed by plating serial dilutions on selective agar. Total viable count in all piles showed a marked increase in initial composting process and a marked decrease at the end product of compost. As temperature increased from 24°C to more than 40 °C during week 0 to week 2, there was a slight increase in the total viable counts in all piles ranged from (7.18–8.18 log cfu/g of compost in 7.88–8.20 log cfu/g of compost) (cfu×10^{-6}). Total viable count further increased to (7.28–8.20 log cfu/g of compost in 7.57–8.26 log cfu/g of compost) when the temperature increased during week 2 to week 6.

This occurred because thermophilic microorganisms could be dominated in the process during this period. The initial rise in temperature in all piles was due to heat generated by the existence of a large quantity of bacteria which are fast growing and responsible for the initial breakdown of organic matter and the generation of heat as reported by many researchers (39 and 3). A further fall in temperature to around 30°C in all piles reduced slightly the total viable count at the end of maturation stage.

Also data from this study showed that in the early stage of composting, characterized by a high content of easily degradable substrate, it could be expected that the microbial counts represent a higher percentage compared to the stabilized compost, where the substrate availability is greatly decreased.

Differences among treatment were particularly evident over time. In the samples collected in the last stage of the study, in June 2014, generally the total number of bacteria in P2, P3 and P4 was higher than the total number in P1 (OFSW 100%) and P5 (OFSW +sewage sludge 75%+25% by weight)Fig.(6).

The increase in total bacterial density in the amended piles was a result of enhanced microbial development due to the compost, which furnishes accessible nutrients to the microorganisms (40). These results were agreed with Badr El-Din (41), observed an increase in the number of total bacteria in an agrarian soil mannered with composted organic residues relative to soil treated with mineral fertilizers.



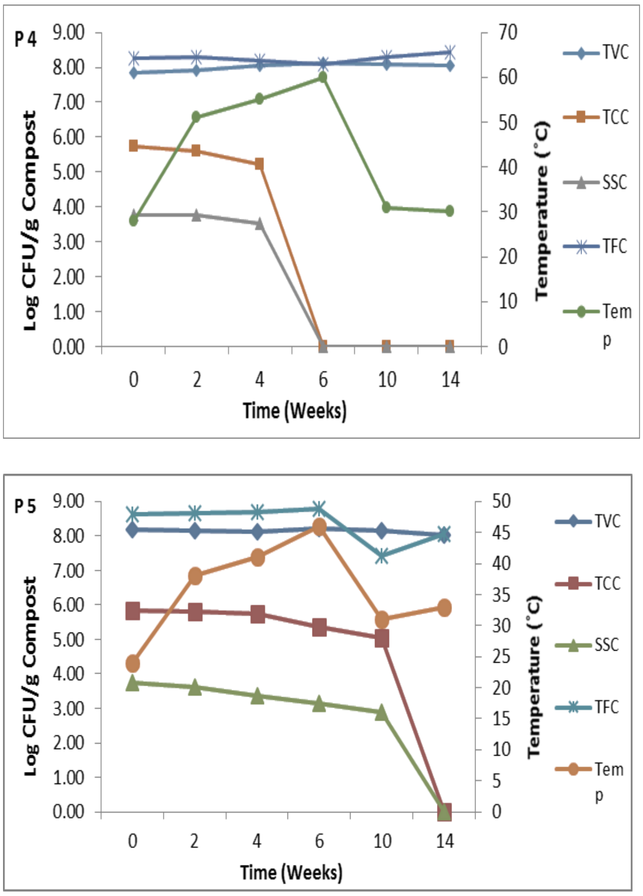


Fig.(6): The effect of temperature and microbial survival in piles (1-5). The results are the mean value

One of the important benefits of composting process is to control pathogenic microorganisms to avoid a contamination of waste (38). The presence of pathogen in the compost was investigated by targeting the load of total Coliforms and *Shigella* and *Salmonella* count during the composting process. Coliform bacteria were recorded in Pile 1 and 5 up to 10 weeks. In case of piles 2, 3 and 4, Coliforms were found till 6 weeks of decomposition, but the number of colonies decreased and finally none of the Coliforms were detected in maturing compost. Absence of *Shigella* and *Salmonella* in the decomposition process of all piles was detected till 6 weeks, with the exception in the pile 1 and 5 these organisms were recorded till (10 to 14) weeks of decomposition. Furthermore, results showed that total coliform, and *Shigella* and *Salmonella* detection decreased with the compost pile temperature raises.

Sadik (4) reported that achievement to maximum temperature (over 55°C) in a windrow system in related times 10 days ensured hygienic characteristics of compost and destruction of the pathogen and parasite according to WHO criteria 15 and USEPA regulation for PSRP and conditions in the windrow composting system, according to PFRP regulations of USEPA.

The results of the study indicate that the thermophilic active composting process in the windrow system was capable of destroying pathogen bacteria. Earlier studies founded that horizontal windrow composting guarantee and good control over fecal pathogens. In the current study, no detectable numbers of fecal Coliforms were found in compost samples two to three months old, thus no secondary contamination occurred during curing. from two independent experiments. [TVC: total viable count; TCC: total coliform count; *Salmonella* and *Shigell*a count; TFC: total fungi count].

For detection of fungal diversity, Rose Bengal agar plates were used. The results showed that the cfu count of fungi declined gradually as the decomposition proceeded Fig.(6). There was a slight rise in the total fungi count of compost in all piles during week 0 to week 2 when there was a rise in temperature from 24°C to over than 40°C.

The temperature rise in week 4 to week 6 from 52°C to above 60°C caused a decrease in the total fungi count in piles 2, 3 and 4, with exception in piles 1 and 5 the fungi numbers increased slightly with a slight increase in temperature from 41 to 51°C during week 4 to week 6. The total fungi count in piles 2, 3 and 4 increased from week 6 to week 10 and continued to end of compost maturation as temperature fell during week 6 to week 14 from 61 to 30°C.

The total fungi count observed during week 10 and 14 of compost was higher than the initial total fungi count. These results confirm with the findings by Saludes (39) and Kutsandzie (3) they mentioned that the cooling phase of the composting process is dominated by fungi and other main decomposers in breaking down the lignocelluloses components. Also Tiquia (17) reported that most fungi were eliminated when the temperature of compost piles exceeded 50°C but the microbial populations recovered when the temperature decreased to below 45°C.

Conclusion

Based on the results of the current study it can be concluded that organic fraction of MSW is suitable for composting because of the existence of a high percentage of biodegradable organic substrate, acceptable moisture content and the C/N ratio in the waste. However, the composting process and compost quality included (easy handling of the materials, reduced odor emissions and correction of C/N ratio) could further be improved by adding inoculating agents like animal manure, poultry manure, sewage sludge etc. in the OFMSW. The results of the study obviously indicate that the biodegradation and recycling of OFMSW using bulking agent transformed to enriched composts within 6 weeks. Physiochemical parameter analysis of compost from the point of view pH, EC, organic matter, total nitrogen, and C/N ratio agreed with the recommended standards. The N % increased with time in all piles reaching at the end of maturation to (1.04 to 1.84), the total phosphorous were found high in all piles and varied from 1.11 to 1.6 % in all piles. However, the results also revealed a higher potassium concentration varied from 1.18 to 3 % in all piles. The water holding capacity of compost samples in all piles was increased during composting and varied from 69 to 90 %. The windrow system was more effective for heavy metal marinating; heavy metals are like (Cd, Pb) and micronutrients like (Cu, Zn, Fe, and Mn) were found to be within the permissible limits of WHO criteria. The variation in the temperature recorded in all piles systems caused differences in the total viable counts, coliform and pathogen and fungi counts in all piles. Biological study, concern the most of them pathogenic bacteria population were reduced in most of piles after 6 weeks of composting. Various parameters show that the piles 2, 3 and 4 when OFMSW were mixed with Buffalo and poultry manure in the ratios 66: 33 and 75: 25 has the most appropriate composting condition, and this ratio can be adopted when the composting process developed. The final compost product could be recommended that the OFMSW is suitable for composting using the turning windrow system, which can be used as fertilizer or soil amendment.

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الخلاصة

تم انشاء نظام الـ (Windrows) لتحويل المخلفات العضوية الى سماد في معمل تدوير النفايات العضوية الصلبة في اليوسفية في مدينة بغداد, للتحري عن امكانية تحويل المخلفات الصلبة العضوية للمدن الى سماد عضوي. اظهرت نتائج تحليل النفايات الصلبة على احتوائها ٦٤% من المخلفات العضوية القابلة للتفكك و ٣٦% غير قابلة للتفكك. احتوت المكونات العضوية على نسبة عالية من الـ C/N بلغت ٣٧,٢, ونسبة قليلة من النيتروجين. تم اضافة بعض المخلفات العضوية مثل مخلفات الجاموس, الدواجن ومخلفات الحماة النشطة الى المخلفات المنزلية االعضوية لمعالجة نقصان النيتروجين والحصول على نسبة ملائمة لـ C/N في كومات السماد. تم قياس عدة عوامل خلال فترة التسميد (التحويل) للمخلفات العضوية الصلبة وللخلطات, لتقييم مدى ملائمتها للسماد العضوي. بينت النتائج بات المخلفات العضوية الصلبة تحولت الى مادة سوداء وذات رائحة شبيه برائحة التربة بعد ٦–١٠ اسابيع من عملية التسميد. تراوحت قيم الرقم الهيدروجيني للسماد العضوي بعد التنضيج من (٧,٨–٧,٨٩), التوصلية الكهربائية تراوحت من (٣,١١–٥,٤١) دسي سيمنز/متر. لوحظ من خلال النتائج ازدياد في النسبة المئوية للـ N % مع الزمن في جميع الكومات وتراوحت في نهاية التسميد من(١,٠4 الى ١,٨٤)%, في حين تراوحت قيم الفسفور الكلي في الكومات من (١,١١ الى ١,٦)%. كما اظهرت النتائج ايضا الحصول على تركيز عالي من البوتاسيوم في جميع الكومات وبلغ من (١,١٨ الى ٣) %. كما ازدادت قدرة السماد العضوي الناتج بالاحتفاظ للماء وبلغت نسبة الاحتفاظ من (٦٩ الى ٩٠) %. كما بينت النتائج بان نظام الـ (Windrow) اكثر فعالية في استرداد العناصر الثقيلة. لوحظ ارتفاع في درجات الحرارة بشكل سريع في الكومات ٢, ٣ و ٤ فوق ٥٠م° لمدة ٤ اسابيع وبلغت ٦٠م مما ادى الى سرعة تفكيك المخلفات العضوية, بينما لوحظ ارتفاع بطي للحرارة في الكومات ١ و ٥. بينت النتائج زيادة سرعة التفكك للمخلفات العضوية من خلال متابعة نسبة الـ C/N, اذ انخفضت نسبة C/N من ٢٧,٤ – ٣٧,٠٢ الى ٩,٤٧ – ١٥,٢٦ بعد ٦ اسابيع من عملية التسميد. اظهرت نتائج العد الكلي للبكتريا الحية في

جميع الكومات زيادة ملحوظة في بداية عملية التسميد وعند زيادة درجات الحرارة, وانخفاظ ملحوظ في نهاية العملية. كما لوحظ من خلال النتائج اختفاء البكتريا المرضية (بكتريا القولون) وبكتريا *Salmonella* و *Shigella* بعد الاسبوع السادس من عملية التسميد في الكومات ٢, ٣ و ٤ في حين لوحظ ظهور هذه الممرضات حتى الاسبوع العاشر في الكومات ١ و ٥. كما لوحظ من خلال النتائج انخفاض في العدد الكلي للفطريات في الكومات عندما ارتفعت درجات الحرارة من ٥٢ الى ٦٠م° في الكومات, بينما بدات الاعداد بالزيادة في نهاية عملية التسميد بعد انخفاض الحرارة الى ٣٠م°. من خلال نتائج الخصائص الفيزيائية والكيميائية والمايكروبية التي تم الحصول عليها في الدراسة, يمكن التوصية بان المخلفات الصلبة العضوية ملائمة لتحويلها الى سماد عضوي باستخدام نظام التسميد (Windrows).