Investigation of the Effect of Zarkooh Mine Sulfur on Composting Process of Animal Manure (Cow and Poultry)

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Abstract

Introduction: Every year, a great amount of manure is used in Pistachio orchards, which will be used as a valuable resource for promoting soil fertility if it is processed appropriately. This study aims to examine the use of sulfur from the Zarkooh mine to optimize the process of compost production of cow and poultry manure.

Materials and Methods: Zarkooh Mine Sulfur in the amounts of 0, 200 and 300 kg per ton of cattle manure (T0, T1, and T2) and the amounts of 0 and 250 kg per ton of poultry manure (H0 and H1) were used in 3 replications as factorial in a completely randomized design. A sampling of the treatments was done for 7 weeks and factors including the temperature, EC, PH, humidity, organic matter percentage, the concentration of micro-macro nutrients, as well as the microbial population were evaluated after applying treatments.

Results: In the cow and poultry manure treatments, the changing trend of the temperature, EC, C/N ratio, and all measured elements significantly differed from the control ($P< 0.01$). The results of processing cow and poultry manure showed that the most significant changes in the temperature were observed in treatments T2 (42 c°), T1 (36 c°), and H1 (33.3 c°) compared to the control (27 c°). During the processing of the manure, the C/N ratio and humidity significantly decreased in all treatments compared to the control ($P< 0.01$). Besides, salinity in the cow manure treatments using Zarkooh mine sulfur decreased from the first to the seventh weeks ($P< 0.01$) than that in the control; however, it increased in the poultry manure. The results showed that the microbial population in the cow and poultry manure treatments decreased significantly using Zarkooh mine sulfur compared to control ($P< 0.01$).

Conclusions: Based on the results of the C/N ratio and the microbial population at different sampling times, it can be concluded that the best time for cow manure processing with 200 kg Zarkooh mine sulfur was in the sixth week. Besides, the best time for cow manure processing with 300 kg of Zarkooh mine sulfur was the fourth week, and the best time for processing poultry manure from the Zarkooh mine was the sixth week. Therefore, the processing time decreased for cow manure with a higher application of Zarkooh mine sulfur.

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1. Introduction

In arid and semi-arid regions faced with qualitative and quantitative limitations of irrigation water sources, an increase in organic matters of soil using animal manure could have important effects on solving the problem, given their high capacity in absorbing and retaining moisture [1]. Therefore, it is necessary to annually and optimally use animal manure and organic matters depending on the type, amount, and method of using them in pistachio orchards of Kerman province. According to instructions provided by Mahmoudi Meymand (2008), the processing of animal manures before their use in gardens will be suitable if there are sufficient moisture and aeration [2]. According to the literature, the use of elemental sulfur in the processing and decomposition phase depends on the biologic oxidation, particles size, as well as method and time of consumption of sulfur, and soil traits, including the microbial population (*Thiobacillus bacteria*), moisture, and aeration conditions [3].

Sulfur is a chemical element found in nature. This element was initially used in manure to improve the physicochemical properties of the soil. Afterward, it was widely used in pesticides [4]. However, sulfur could be used in arid and semi-arid soils as a modified matter to decrease soil pH, increase solvability of some nutrient elements, and adjust the negative effects of soil lime [5]. Mir Seyed Hosseini (2018) studied the effects of elemental and bentonite sulfur on sulfur and phosphorus in lime soil and on the growth properties of corn. According to the results, the application of sulfur with animal manure in lime soil increased phosphorus and sulfur, thereby providing and improving the growth properties of corn [6]. In another study, the results showed that the application of organic matters at different levels led to a decrease in soil pH [7]. However, the results of another research using elemental sulfur and organic matters showed that the addition of elemental sulfur without organic matters, in 80 days, decreased the pH of some experimental soils up to 0.2 units. In contrast, the addition of elemental sulfur with organic matters significantly increased the pH of some experimental soils [8].

The nature of the used raw matters, temperature conditions, and heating time are among the most effective factors in producing processed manures [9]. Animal manures contain a higher amount of nutritional elements needed for plants because of their high nutritional values. Accordingly, if they are processed, they will have a higher capacity for cation exchange than processed manures of plant sources [10]. Unprocessed manures could have negative effects on plant growth through ammonia sublimation [11], apart from being a major potential source of dangerous pathogens that can be transferred by surface runoff. Instructions for animal manure processing suggest obtaining moisture and mixing it with CTC (Carboxymethyl cellulose) along with manure aeration. The processing of manure using these instructions takes 6 to 8 weeks. [12]. No research has been conducted on applying sulfur from the Zarkooh mine to animal manure for processing them. A large amount of manure is produced in Iran, which is not used optimally. The use of processed manures is very important, in particular, in arid and semi-arid regions with organic matter shortages [13]. Therefore, the use of new methods of processing animal fertilizers is important as well. This study aims to consider the effects of Zarkooh mine sulfur on the processing of animal manures and pistachio wastes and to accelerate the trend.

2. Materials and Methods

This study was conducted in a completely randomized design with three replications in the Nogh region of Rafsanjan City in 2019. The research method included providing initial moisture, applying treatments, and mixing them with Zarkooh mine sulfur in the first step. The cow and poultry manures were watered using a water tank. They were mixed with sufficient moisture so that water could not come out from beneath them. The entire animal manure spread on the ground, mixed with Zarkooh mine sulfur in studied amounts (0, 200, and 300 kg per ton of the cow manure (T0, T1, and T2), and 0 and 250 kg per ton of the poultry manure (H0, H1)); next, they were piled in heaps or the shape of cones (Fig. 1). The initial measured moisture was from 35 to 45%. Each treatment, 0.5m thick, was separately spread on the ground. After that, the sampling was performed every week to evaluate studied indices and their microbial activity. Fig. 1 shows how the treatments were applied. Also, Table 1 demonstrated the chemical properties of Zarkooh mine sulfur (Shimi Gostar Rezvan Co.). Fig. 1. Different steps of the current research: A) First step: Providing initial moisture and applying sulfur treatments, B) Mixing cow and poultry manures with sulfur to create a homogenous mixture, and C) Measuring the mass temperature using a thermometer.

Table 1- Chemical Properties of Sulfur from the Zarkooh Mine (Uban Laboratory)

Properties	EC (ds/m)	PH	OM (%)	CaSo4 (%)	TNV (%)	N (%)	K (mg/kg)	P (mg/kg)	So_4 (meq/L)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)
Zarkooh Mine Sulfur	6.61	6.7	3.3	42.4	47.0	0.4	134	2.1	21	30.5	21.5	15

Evaluation indices

Manure temperature measurement:

Changes to the manure mass's temperature of applied treatments were determined using a thermometer (scan temp 330-Germany) during the sampling periods [14].

EC and pH measurement:

Electrical conductivity (EC) and pH, at the concentration of 1.10 of the treatments and the control were measured using the EC meter and pH meter in the laboratory after sampling.

Moisture measurement:

In the samples of experimental treatments, the moisture was determined by weighing samples and putting them in an oven at 105 ℃ in 24h. Next, the dried samples in the oven were weighed using a weighing scale, and differences in the weight of moist and dried samples were measured. In the final step, the moisture percentage was calculated [15].

Chemical analysis:

The concentrations of phosphorus, potassium, calcium, magnesium, iron, zinc, manganese and copper were determined using the dry ash method and digestion by normal hydrochloric acid, phosphorus by the vanadate method and the spectrophotometer, potassium and sodium by the atomic emission and the flame photometer, calcium and magnesium by the titration method and iron, zinc and manganese by the ICP device. Besides, nitrogen was read using the Kjeldahl method and the organic carbon percentage by the Walkley-Black method [15]. Therefore, the C/N ratio was calculated based on the ratio of organic carbon to nitrogen. The moisture content in all treatments and the control were measured after every sampling. The experiments were conducted in the Uban laboratory at the Pistachio Research Center.

Microbial population measurement:

Microbial population was examined at the time of processing in the cow and poultry manures. To cultivate and investigate the microbial population in the treatments, 50g of every sample in three replications and 450ml of sterile distilled water containing 1g l^{-1} of peptone were added. The flasks were shaken on a shaker at 150 rpm. Next, dilutions 1-10 to 3-10 from the obtained suspensions were provided, and 100ul of MA (Malt Agar) for mold and yeast growth, PDA (potato dextrose agar) for fungus growth, and NA (nutrition agar) for bacterial growth were scattered on the culture settings. Besides, Petri dishes were kept at 30 for 3 to 7 days in the dark, and grown colonies of different microorganisms, including bacteria, fungi, molds, and yeasts were counted in different culture settings.

Statistical Analysis

Data were analyzed as factorial in a completely randomized design by SPSS software. The mean compressions were compared using Duncan's test at a 5% probability level.

3. Results

The results of processing cow manure with sulfur from the Zarkooh mine showed a significant difference between different treatments and the control at a 1% confidence level. The treatments showed a significant positive effect on the temperature, moisture, EC, C/N ratio, phosphorus, potassium, calcium, magnesium, iron, zinc, manganese, and copper at different times. It could be concluded that the effect of sulfur on the treatments was significant at different times at 5% ($P< 0.05$) (Table 2).

Results from the studied indices in the cow manure showed that the temperature in T2 was significantly higher than that in T1. Besides, it was significantly higher in T1 than that in the control. In addition, salinity was significantly lower in T1 and T2 than in the control. However, there was no significant difference among the treatments (Table 3).

Regarding the percentage of the measured organic matters, there were no significant differences between the control and the treatments; accordingly, and it was lower in T2 than in that T1, with that in T1 was less than the control. Additionally, there was no significant difference between the control and the treatments in the nitrogen percentage. Accordingly, the nitrogen percentage was higher in T1 than the control, with that in the control was higher than T2. Besides, there was a significant difference between the control and the treatments in the C/N ratio, which was higher in the control than in the treatments, but there were no significant differences among the treatments (Table 3).

Table 3 showed the variance analysis results of the concentrations of nutritional elements. Accordingly, the concentration of potassium, phosphorus, manganese, and copper, except for iron, was significantly higher in the control than in the cow manure treatments. Besides, there was a significant difference between the control and the treatments in the calcium concentration, which was higher in the treatments than in the control. However, the difference was not significant among the treatments. Additionally, there was a significant difference between the control and the treatments in the manganese concentration, which was higher in T2 than in the control; in addition, T1 had the least value of the manganese concentration. Also, the iron concentration was significantly higher in the control than in other treatments. The mean compression results of the treatments showed that T2 was significantly lower in the iron concentration than T1 (Table 3).

Considering the volume ratio of Zarkooh mine sulfur in the manure and the lower concentration of the mentioned elements compared to the cow manure (Table 2), the lower concentration in other nutritional elements in the applied treatments than that in the control was rational.

The relationship between the temperature and time treatments (Fig. 2) showed that the temperature difference between T1 and T0, and also between T2 and T0 was significant from the first week to the fifth week, but it was not significant in the sixth week, which indicated the decreased effect of sulfur and microorganisms in the studied treatment (Fig. 2). According to Fig. 2, the highest temperature in both treatments was observed in the second, third, and fourth weeks, yet it started a decreasing trend afterward. In the first week, there was a significant difference in the temperature among all treatments and in the control; however, it was not significant in the second, third, fourth, and fifth weeks between the treatments, but it was significant compared to control. In addition, in the sixth week, there was no significant difference in the temperature between T2, T1, and in the control.

To achieve the final results and to group different treatments, we used multivariate statistical methods (clustering) by employing all investigated traits based on the squares of Euclidean distances using the Ward method (Fig. 3). Results from data analysis using the clustering method for the cow manure treatment showed that the three treatments were classified into two main groups, including the first group (control) and the second group (200 kg and 300 kg of Zarkooh mine sulfur). Accordingly, the two concentrations of sulfur 200 kg and 300 kg were classified into one subgroup, which had the same traits and effects. Therefore, we could use 200 kg of Zarkooh mine sulfur f to process the manure.

Table 2- The analysis of variance for the effect of different treatments on chemical traits in cow manure

Sources of Variation	df	Temp. (°C)	Moisture (%)	EC (dsm^{-1})	pH	OM (%)	C/N	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
Treatment	2	1628.7**	923.9 **	12.29 **	0.041 ^{ns}	1899.77 **	233.73 **	0.123**	0.121 **	15.7**	5.88 **	1.411**	2.11E^{14}**	1924161.2**	10886.1 **	227658.2 **
Time	5	340.27 **	117.1 **	0.944**	0.288 *	43.68 **	43.16**	0.674**	0.037 **	0.377**	67.75**	0.659**	5.7E^{8}**	181419.4 **	1057.8**	11771.7**
Treatment *time	10	96.06*	68.08 **	1.132**	0.161 *	47.98**	13.98 **	0.196**	0.011 **	0.183**	31.48 **	1.755**	1.74E^{7}**	52060.9**	1017.4**	6968.2 **
Error	36	2.24	1.87	0.09	0.029	1.25	0.232	0.001	0.0018	0.001	0.008	0.001	14556.5	249.96	6.036	33.84
CV %	-	11.9	5.8	4.6	3.81	12.0	12.2	8.25	19.8	17.7	12.7	16.5	23.2	19.1	16.0	14.4

NS: * and ** are insignificant and significant differences at 5% and 1%, respectively (Sampling was done every week)

Table 3-The comparison of means for the effect of different treatments on the chemical traits in cow manure

Treatment	Temp.	Moisture	PH (1.10)	ECe	OM (%)	C/N	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (%)	Mn (%)	Cu (%)	Zn (%)
Total mean of T0	24.9 c	35.7a	6.8 a	7.04b	38.1a	13.1a	1.7b	0.24a	2.62 a	9.8b	1.4b	2594a	813a	82a	372a
Total mean of T1	30.9 b	34.3b	5.8b	7.2ab	32.2b	10.4b	1.8a	0.13b	1.08b	11.11a	0.98c	2171b	412b	43b	199b
Total mean of T2	34.5 a	32.9c	6.0b	7.14b	26.8c	9.8c	1.6c	0.15b	1.06b	12a	0.60a	1661c	405b	48b	194b
First week (T0)	27d	41.5a	7.1a	7.1b	48.2a	6.15a	1.8b	0.25a	2.6a	9.8cd	1.4b	2698a	930a	82a	371a
First week (T1)	34 bc	38b	6.3b	7.0b	37.5b	1.12b	1.8b	0.08f	0.85b	8.3d	1.1bc	2684a	214h	23f	142cd
First week (T2)	38ab	37b	6.4b	7.0b	29.4d	4.11bc	1.5d	0.06g	0.37c	8.5d	0.75cd	2511a	174c	17g	156c
Second week (T0)	27.2d	39a	7.3a	7.1b	47.2a	2.15a	1.8b	0.22b	2.6a	9.8d	1.4b	2684a	929a	82a	373a
Second week (T1)	38.3ab	37b	6.0b	7.7a	35.2b	8.10c	1.9ab	0.08f	1.3b	8.6d	0.8cd	2484b	210b	28e	129d
Second week (T2)	41.3a	34b	6.1b	7.0b	29.0d	7.10c	1.6c	0.06g	1.4b	8.9d	1.4b	2094cd	202hi	22f	58e
Third week (T0)	29.0c	39a	6.9a	7.07b	38.6b	2.13b	1.7b	0.24a	2.6a	9.7d	1.4b	2617a	926a	83a	371a
Third week (T1)	38.3ab	36b	6.1b	7.7a	33.4c	2.10c	1.9ab	0.09f	0.76d	9.1d	0.8cd	2249c	234g	37d	141cd
Third week (T2)	40.0a	34b	6.1b	7.1b	29.9d	2.10c	1.7bc	0.08f	0.73d	9.6d	1.7b	1886d	216h	42c	155c

Forth week (T0)	26.0d	37.3b	6.8a	7.2b	35.5b	4.11bc	1.8b	0.23ab	2.6a	9.8d	1.4b	2593a	929a	82a	377a
Forth week (T1)	36.3ab	35b	6.0b	7.4a	32.8c	6.9cd	1.0a	0.12e	1.06c	10.8c	1.2bc	2161cd	355f	49c	222b
Forth week (T2)	42.0a	33d	5.7c	7.2b	26.6de	1.9cd	1.7bc	0.11e	0.54d	11.5c	1.2bc	1543e	224h	59b	160c
Fifth week (T0)	25.1de	33.8d	6.8a	7.1b	33.0c	6.10c	1.8b	0.23ab	2.6a	9.7d	1.4b	2551a	928a	83a	372a
Fifth week (T1)	30.6c	33d	5.5c	7.2b	29.5d	6.8d	1.0a	0.16d	1.04c	13.6b	1.1c	1940d	472e	44c	218b
Fifth week (T2)	37.6b	32d	6.0bc	7.2b	25.9de	4.8d	1.8b	0.24a	1.15c	15.1a	1c	1211f	548d	55b	241b
Sixth week (T0)	23e	30e	6.7a	6.7c	32.3c	8.11bc	1.7bc	0.26a	2.6a	9.8d	1.4b	2514a	930a	82a	369a
Sixth week (T1)	25d	31e	5.4c	6.6c	28.5d	7.9cd	1.7bc	0.20c	1.2c	13.5b	0.9c	1846d	677c	43c	245b
Sixth week (T2)	26d	31e	6.1b	6.7c	24.9e	5.9cd	1.5d	0.24a	1.5b	15.3a	3.6a	1195f	740b	54b	249b
Seventh week (T0)	24de	29f	6.7a	6.6c	31.9fc	5.11bc	1.6c	0.24a	2.4a	10.3c	1.1c	2507a	891ab	82a	371a
Seventh week (T1)	27.3d	30e	5.3c	6.6c	28.5d	4.10c	1.6c	0.20c	1.4c	13.1b	0.9c	1837d	724b	55b	232b
Seventh week (T2)	27.5d	30e	6.1b	6.6c	24.2e	4.9cd	1.5d	0.25a	1.7b	15.1a	1.8b	1187f	730b	59b	237b

* In each column, the means with the same letter were not significant at a confidence level of 5% using Duncan's multiple range test (T0, T1, and T2 were in the control, the 200 kg, and 300 kg Zarkooh mine sulfur in a ton of cow manure, respectively).

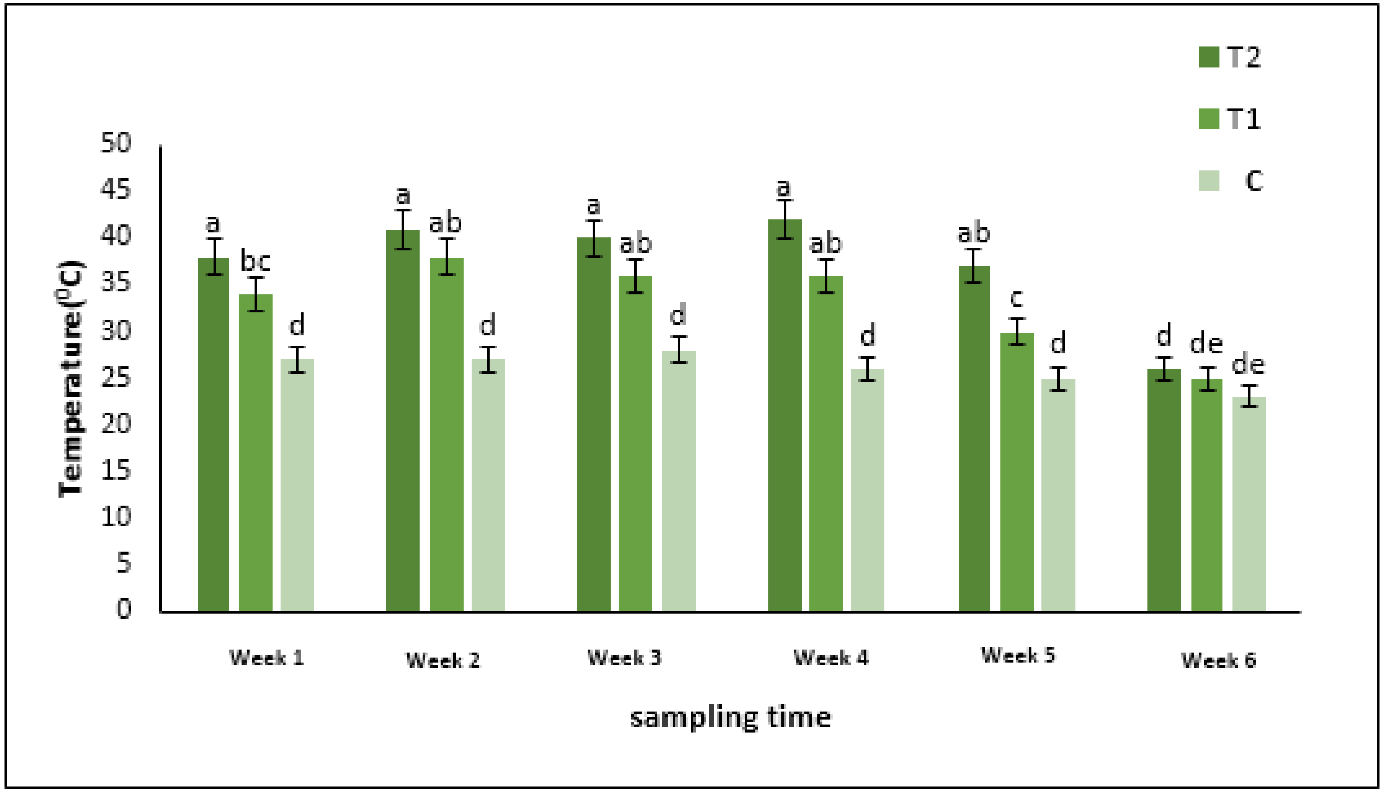

Fig. 2- The relationship between the time and temperature treatments in the cow manure 200 kg and 300 kg of Zarkooh mine sulfur (the means with the same letter were not a significant different at the probability level of 0.05 using Duncan's multiple range test).

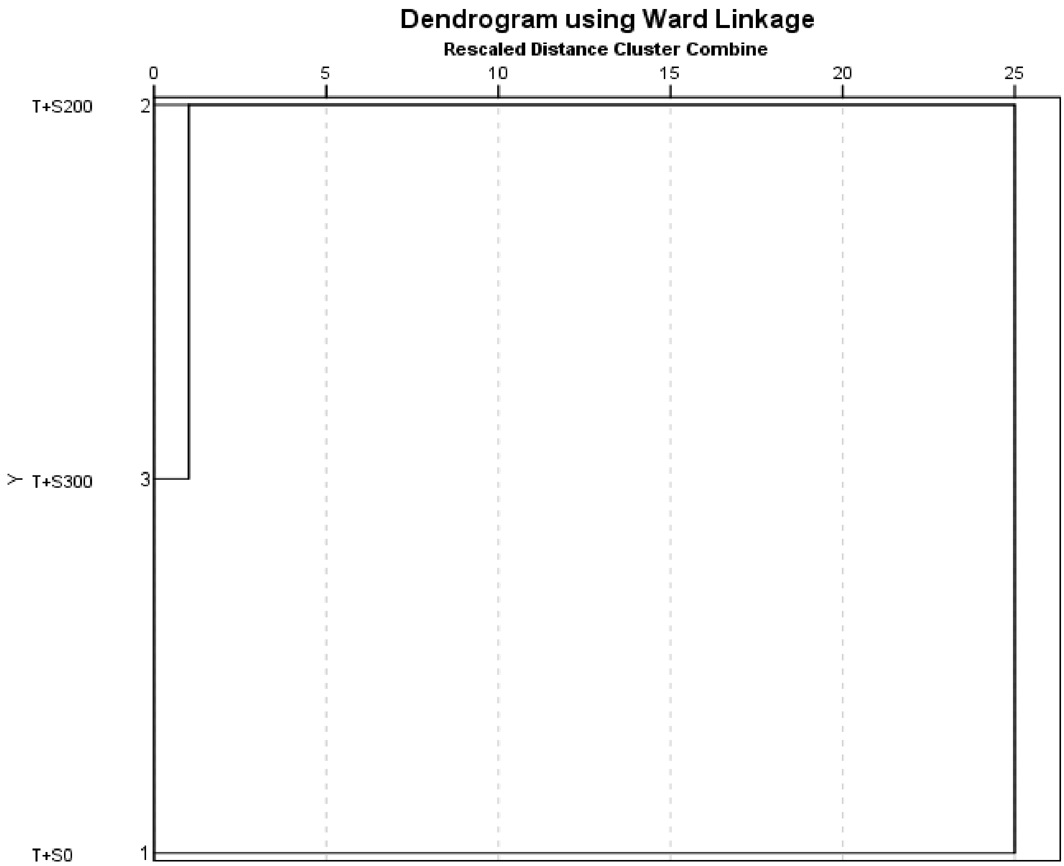

Fig. 3- The tree diagram (dendrogram) obtained from grouping the control and the sulfur treatments using 16 indices in cow manure processing based on the squared Euclidean distance using the Ward method (T: animal manure; S0, S_{200}, and S_{300} are the control, the treatment with 200 kg, and the tratment with 300 kg of sulfur in one ton of cow manure, respectively).

Results from grouping the time treatments showed that the times were classified into two main groups. Accordingly, Zarkooh mine sulfur treatments significantly accelerated the processing of cow manure. Besides, the sixth and fourth weeks performed similarly in most traits in Zarkooh mine sulfur 200 kg and 300 kg, so they were classified under one cluster (Fig. 4). Therefore, we need six weeks to be able to process animal manure with 200 kg of sulfur and four weeks with 300 kg Zarkooh mine sulfur.

Investigation of factors measured in poultry manure

Data analysis of poultry manure showed that changes in the temperature, EC, C/N ratio, and all measured elements had a significant difference compared to the control (Table 4). The mean comparison of the poultry manure (Table 5) showed that the temperature in the H1 treatment was significantly higher than the control. Based on Table 6, the moisture percentage was higher in H0 than H1. Besides, the organic matter percentage, C/N ratio, nitrogen, phosphorus, and copper were higher in the control than the H1 treatment. However, EC, calcium, magnesium, iron, manganese, and zinc were higher in the treatment with Zarkooh mine sulfur than in the control, with a significant difference existing between them.

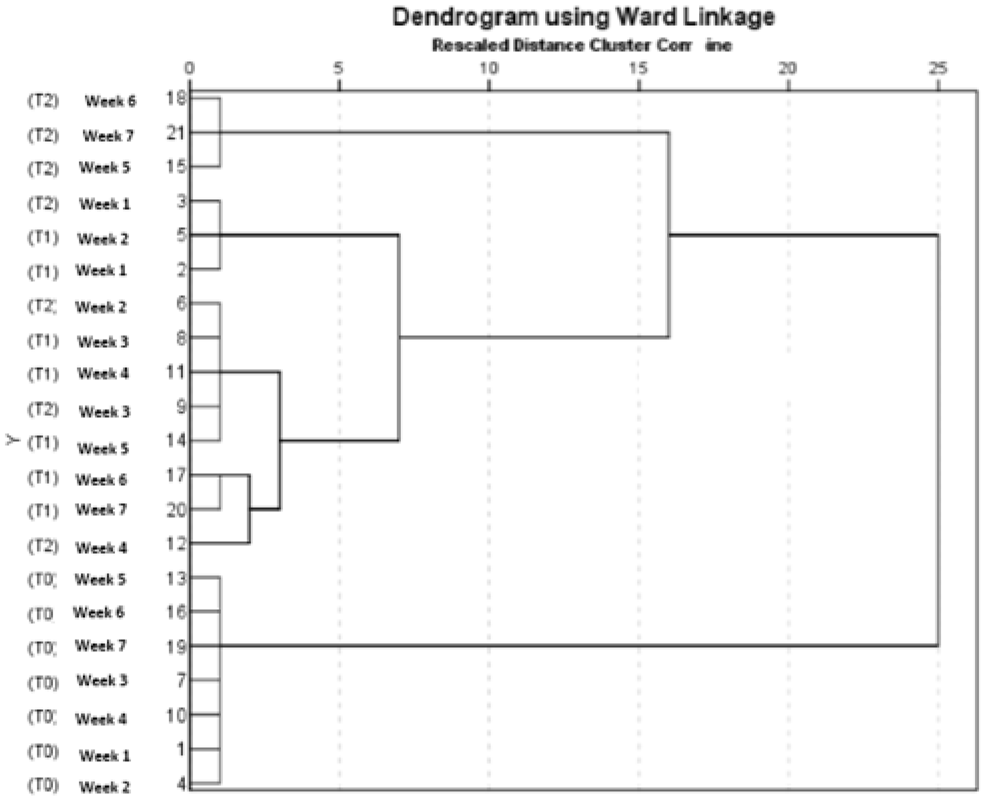

Fig. 4- The tree diagram (dendrogram) obtained from grouping different experimental treatments using 16 indices in processing cow manure based on the squared Euclidean distance by utilizing the Ward method (Sampling was done every week).

Table 4. The analysis of variance for the effect of different treatments on chemical traits in poultry manure

Mean Squares																
Sources of Variation	**df**	**Temp.**	**Moisture**	**EC (dsm^{-1})**	**PH**	**OM (%)**	**C/N**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**Fe ($mg\ kg^{-1}$)**	**Mn ($mg\ kg^{-1}$)**	**Cu ($mg\ kg^{-1}$)**	**Zn ($mg\ kg^{-1}$)**
Treatment	1	4.27 **	545.35**	32.6**	0.028ns	14679**	30.7**	23.59**	13.24 **	0.035**	59.4**	1.91**	15527104**	286027 **	16728 **	145801**
Time	6	37.27 **	7.35 **	2.4**	0.346 **	513.1**	39.2**	2.21**	0.585 **	0.057**	18.38 **	0.745**	34110743**	240043 **	2125 **	339684**
Time*treatment	6	37.27 **	7.35 **	2.7**	0.033 ns	483.1 **	11.6 **	1.1**	0.661 **	0.036**	44.17 **	0.603 **	9214395 **	371506 **	2557 **	337649 **
Error	28	0.405	1.38	0.123	0.037	6.5	0.08	0.007	0.47	0.54	0.115	0.023	1454	333.88	44.2	114.6
CV %	-	13.63	9.76	16.77	3.02	16.7	15.36	17.29	17.14	13.41	14.4	19.32	10.38	16.37	14.02	16.38

NS: * and ** are insignificant and significant differences at 5% and 1%, respectively (Sampling was done every week)

Table 5- The comparison of means for the effect of different treatments on the chemical traits in poultry manure

Treatment	Temp.	Moisture	EC (dsm^{-1})	pH	OM (%)	C/N	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
Total mean H0	21b	42a	6.7b	7.33a	67a	10.3a	3.8a	1.3a	1.93a	6.79b	1.3b	2228b	446b	122a	542b
Total mean H1	24a	41b	6.9a	7.34a	59b	9.5b	3.6b	1.1b	1.70b	7.64a	1.5a	2857a	462a	96b	566a
First week H0	20cd	48a	6.5b	7.37b	71a	11b	3.69a	1.94a	1.79b	6.98bc	1.24b	2358c	415d	104c	505cd
First week H1	22 d	45b	5.8c	7.36b	73a	13a	3.23b	1.83b	1.66bc	7b	0.96c	1686d	512c	89e	460d
Second week H0	25b	46b	6.5b	7.39b	71a	11b	3.73a	1.59d	1.94b	7.25b	1.63a	2496c	416d	95d	516cd
Second week H1	30a	44b	6.3b	7.45b	67b	11b	3.36b	1.05g	1.44c	6.68c	1.26b	1878d	390f	86e	445e
Third week H0	25b	45b	6.6b	7.33b	68b	10b	3.75a	1.47e	1.82b	6.15c	1.24b	2136c	410d	107c	517cd
Third week H1	31a	44b	6.8b	7.31b	62bc	9.7c	3.72a	1.01g	1.39c	6.59c	1.28b	2123c	430d	81e	489d
Fourth week H0	22d	41d	6.8b	7.29c	67b	10.4bc	3.75a	1.38f	1.46c	6.85c	1.09c	1895d	512c	121b	521c
Fourth week H1	26b	42cd	7.2a	7.28c	56c	8.6d	3.83a	1.03g	1.55c	7.7b	1.16bc	2153c	445d	93d	553c
Fifth week H0	21d	40d	6.8b	7.36b	64bc	10c	3.77a	0.96h	1.95b	6.58c	1.06c	2056e	517c	142a	528c
Fifth week H1	24b	41d	7.4 a	7.35b	54c	8d	3.85a	0.93h	1.68bc	8.21a	1.76a	2175c	478d	96d	648b
Sixth week H0	19cd	37e	7a	7.39b	63bc	9.7c	3.78a	0.96h	2.34a	6.95c	1.08c	2365c	521c	143a	596b
Sixth week H1	20bc	37e	7.5a	7.38b	50 d	7.8de	3.78a	1.04g	1.94b	8.14a	1.8a	4994b	572b	125b	743a
Seventh week H0	18cd	36ef	7.1a	7.35b	62bc	9.5c	3.80a	0.96h	2.21a	6.74c	1.25b	2296c	419b	146a	612b
Seventh week H1	18cd	35f	7.5a	7.30b	49d	7.3de	3.77a	1.01g	2.27a	8.54a	1.58a	5002a	612a	107c	628b

* In each column, the means with the same letter were not significant at a 5% confidence level using Duncan's multiple range test (H: poultry manure; H_0 and H_{250} were the control and the 250 kg Zarkooh mine sulfur in a ton of poultry manure, respectively).

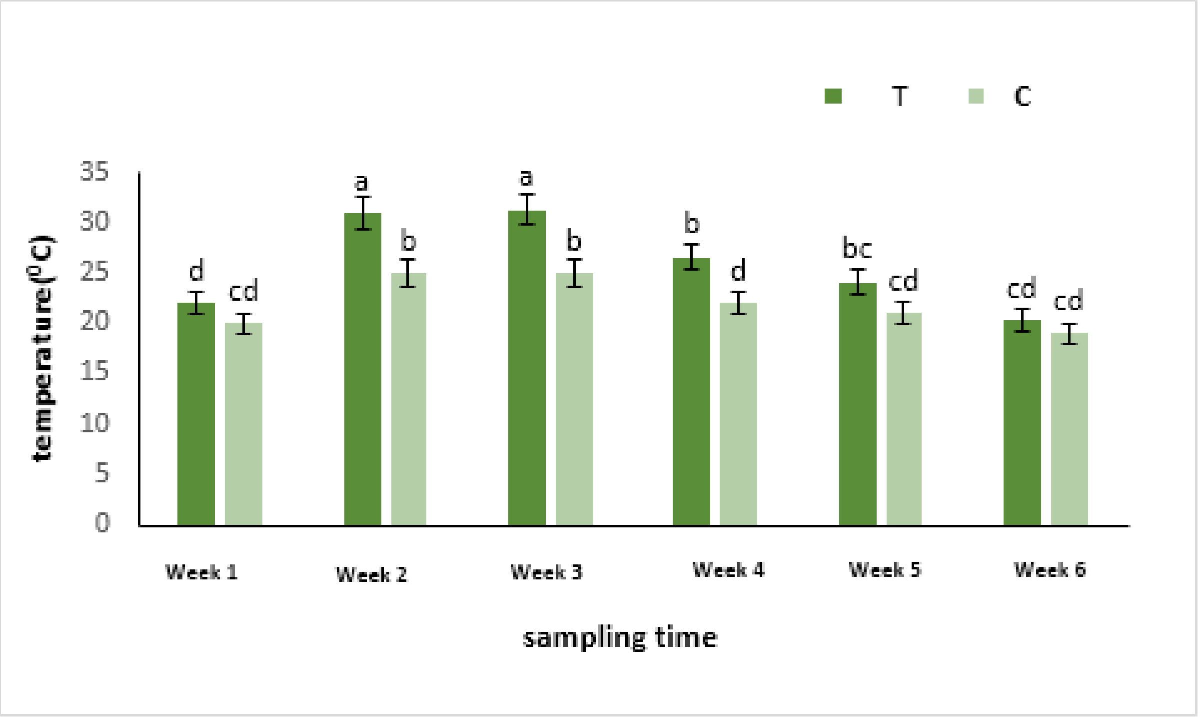

Fig. 5- The relationship between the time and temperature treatments in the poultry manure treated with 250 kg of Zarkooh mine sulfur and the control (the means with the same letter were not significant at 0.05 using Duncan's multiple range test.)

The figure of the relationship between the sampling temperature and time in the control and the H1 treatment (Fig. 5) showed that the temperature difference was not significant in the first week, but it was significant in the second to fourth weeks. Besides, there were no significant differences between the control and the treatment groups in the fifth and sixth weeks.

Results from using the multivariate clustering statistical method and the Ward method showed that different times were classified into two groups. Since treatments with Zarkooh mine sulfur (250 kg) had more similarities in the sixth and seventh weeks, the effects of sulfur treatment on the processing of poultry manure were related to the sixth week (Fig. 6). The results were presented in Table 5. According to this table, the effects of sulfur treatment compared to the control were related to the increased concentration of nutritional elements (phosphorus, calcium, magnesium, iron, manganese, and zinc).

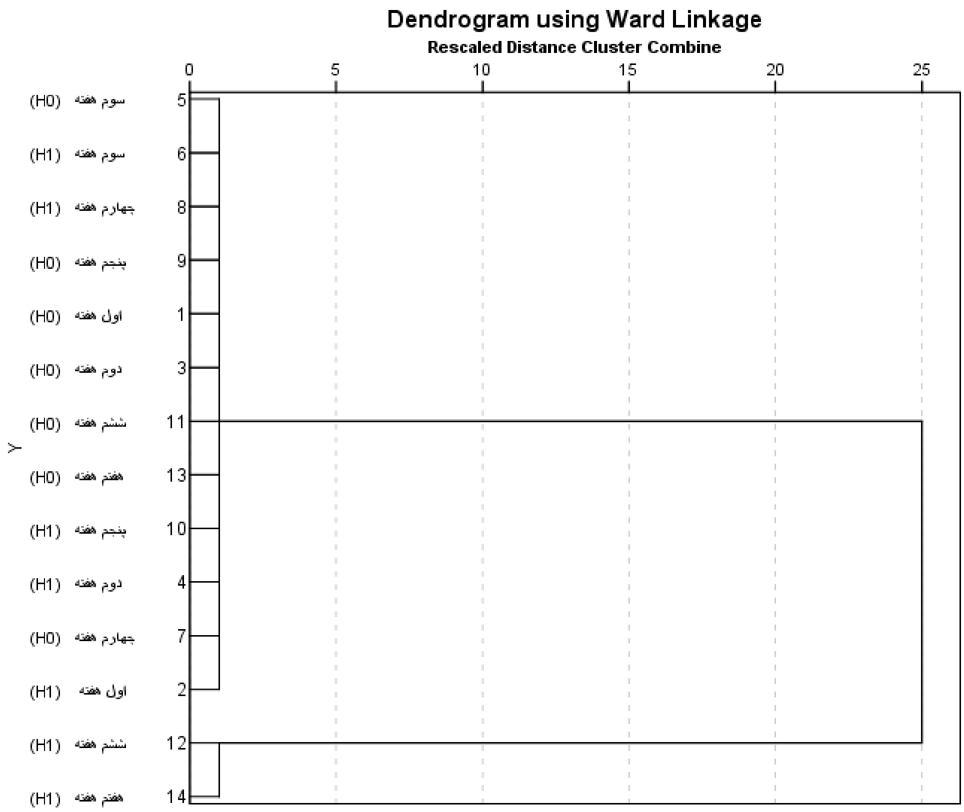

Fig. 6- The tree diagram (dendrogram) obtained from grouping different times of the use of experimental treatments using 16 indices assessed in processing poultry manure based on the squared Euclidean distance using the Ward method (Sampling times are every week)

Microbial Population

Results from the microbial population test among different treatments showed significant differences. In general, the largest microbial population observed in molds, yeasts, and bacteria was related to the third and fourth weeks that were different depending on the types of micro-organisms. According to the results, changes in the microbial population were varied in 200kg and 300 kg of cow manure, as well as in poultry manure, which was 2×10^5 to 3.3×10^9, 1.1×10^5 to 3.8×10^9, and 2×10^5 to 8.5×10^8, per gram of the dry matter, respectively. Besides, the microbial population decreased in 200 kg and 300 kg of sulfur with cow manure, as well as in poultry manure. Furthermore, the population of molds and yeasts in the cow treatment with 200 kg of sulfur was varied from 2×10^5 to 2×10^9. Similarly, it was varied in cow manure with 300 kg of sulfur from 1.8×10^6 to 3.4×10^9. Besides, the population of molds and yeasts in the cow manure treatment was varied from 1.7×10^4 to 3.2×10^9 per gram of the dry matter. The population of molds and yeasts in the poultry manure treatment with 250 kg of sulfur was varied from 2×10^5 to 2.2×10^8, and from 3.1×10^5 to 4.2×10^9 in poultry manure in the control. Besides, the bacterial population in cow manure with 200kg of sulfur was varied from 9×10^5 to 3.3×10^9, and it was varied from 1.1×10^5 to 3.8×10^9 in cow manure with 300kg of sulfur. Furthermore, the bacterial population in the control treatment of cow manure was varied from 1.01×10^4 to 9.32×10^8 per gram of the dry matter. Similarly, the bacterial population in poultry manure with 250kg of sulfur was varied from 1×10^6 to 8.5×10^8 per gram of the dry matter. The bacterial population in the control of the poultry treatment was varied from 4.3×10^8 to 9.12×10^9 per gram of the dry matter. According to the results, the population trend of the molds and yeasts in 200kg and 300kg of cow manures and poultry manure was ascending until the fourth week of sampling. However, the trend was descending from the fourth week to the sixth week (Fig. 7). Besides, the bacterial population in the cow manure with 200 kg of sulfur and the poultry manure experienced an ascending trend until the fourth week, yet it showed a descending trend after that. However, the bacterial population increased until the third week, yet it decreased in the cow manure with 300kg of sulfur, while it increased in the control (Fig. 8).

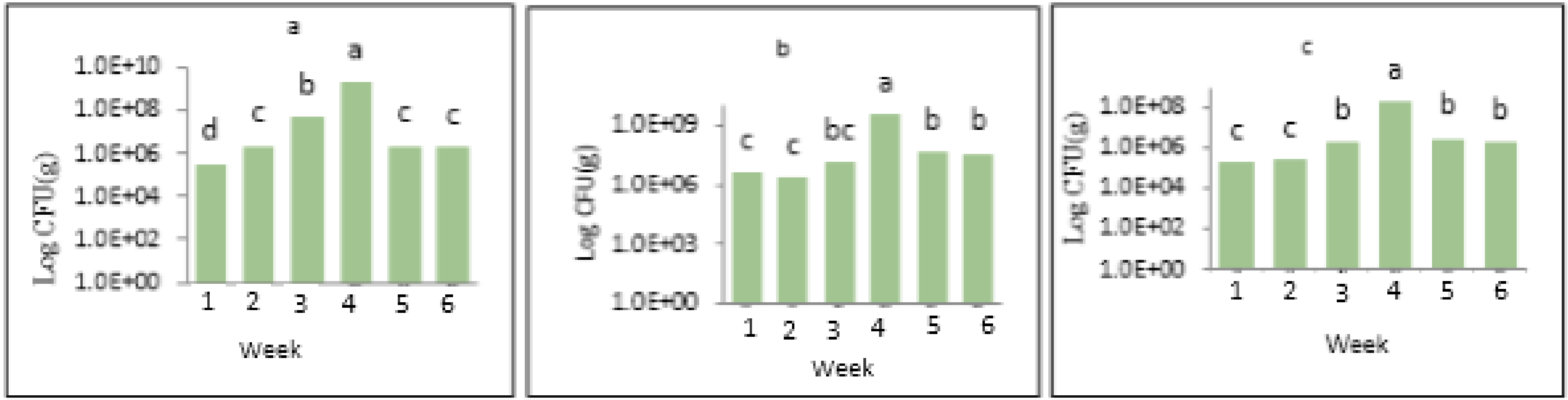

Fig. 7- The microbial population of molds and yeasts in cow manure treated with (a) 200 kg Zarkooh mine sulfur, (b) 300 kg Zarkooh mine sulfur, and (c) poultry manure treated with 250 kg Zarkooh mine sulfur

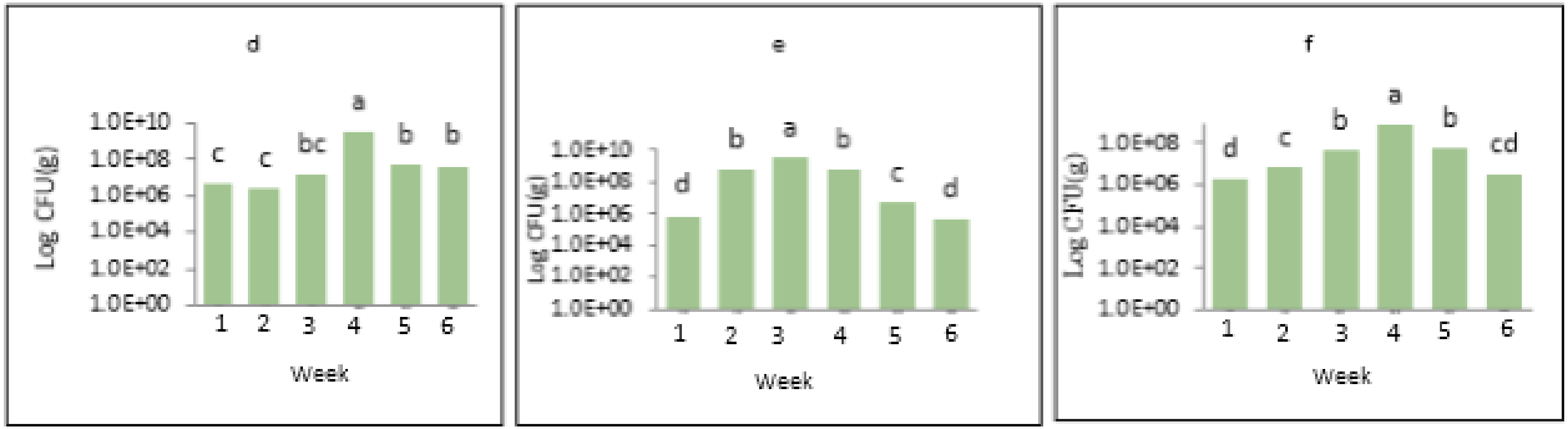

Fig. 8- The microbial population of bacteria in the cow manure treated with (d) 200 kg Zarkooh mine sulfur, (e) 300 kg Zarkooh mine sulfur, and (f) poultry manure treated with 250 kg of Zarkooh mine sulfur

4. Discussion

Based on the concentrations of the elements, the C/N ratio, and the microbial population at different times, the best time for processing cow manure with Zarkooh mine sulfur was in the sixth week in treatment 200 kg Zarkooh mine sulfur, the fourth week in treatment 300 kg Zarkooh mine sulfur, and the sixth week for poultry manure treated with Zarkooh mine sulfur. Besides, the best time was consistent with the tree diagram obtained from the time and Zarkooh mine sulfur treatment grouping.

According to the results, in the treatments of cow and poultry manures, the use of sulfur increased concentrations of some nutritional elements in the processed compost. According to the literature review, no research has been conducted on using sulfur in animal manures. However, some authors have considered it as a modified matter that decreases soil pH, increases solvability of some nutritional elements, and adjusts the negative effects of lime in arid and semi-arid regions [5]. Research reports that the use of sulfur and organic matter on different surfaces leads to a partial decrease in soil pH [7]. Malekuti *et al* (2001) studied the use of sulfur in the absorption of nutritional elements. They reported that not only is sulfur a nutritional element needed by plants, but it also affects soil acidification, thereby increasing the availability of nutritional elements, including phosphorus, iron, and zinc. According to their research, the use of sulfur was required for modifying the pH of lime soil. In addition, if 1kg of sulfur accompanied with animal manure and their moisture sufficiently added to citrus fruits in Jahrom, the pH would decrease and solvability of phosphorus and micronutrients would increase significantly [16]. Accordingly, their findings were consistent with the results of this study. Generally, sulfur modifies soil by changing its acidity conditions, thereby leading to an increase in element absorption such as phosphorus, calcium, manganese, and sulfate. In addition, it would improve soil, plant growth, and crop yield [17].

Research indicates that sulfur can increase the solvability of phosphorus and micro-nutrients, in particular, in lime soil [7]. According to the results of processed manures, it can be concluded that Zarkooh mine sulfur released the micro and macro-nutrients in the processing of manures.

The results showed that the moisture content decreased during the processing of manure, being consistent with the study of Malekutyan *et al* (2001) [16]. Decreased moisture during the composting process was considered as an index of the decomposition value. That is because the production of heat is accompanied by decomposition and leads to the evaporation of water [18]. According to our results, EC significantly decreased in cow manure treated with sulfur from the first week to the seventh week, and its value was less than the control. Results from examining EC from sulfur decomposition (Table 2) and its comparison with EC of cow manure (the control in the first treatment) showed that the salinity could be decreased due to the mass ratio of sulfur to manure and the lower salinity of the Zarkooh mine sulfur. By adding organic matter and produced salts, the needed substrate is provided for the growth and activity of micro-organisms. So, microbial respiration and biomass increase in them. Adding such substrates could decrease the negative effects of the pH tension and osmotic pressure, thereby improving physiochemical traits in soil [19].

Results from the study of Malekutyan *et al* (2014) showed that the changing trend of EC during the compositing of sewage sludge with pistachio skin wastes decreased from 14.32 dS/m to 11.91 dS/m after 30 days [20]. This decrease could be attributed to the decrease in the solved matter in water, ammonia evaporation, and sedimentation of mineral salts during the composition process [21]. These results were consistent with the result of Grigatti *et al* (2010) [22].

Salinity in H1 and N1 was less than H0 and N0, respectively; however, it increased at the end of the experiment so that the difference was insignificant in the sixth and seventh weeks, which could be due to the release of nutrient elements in H1 and N1 treatments and the salinity. Besides, pH is an important parameter during the compositing process. Accordingly, the decreased pH during the beginning of manure processing was due to the production of organic acids, incomplete oxidation of organic matter, the nitrification phenomenon, ammonia formation and its release into the atmosphere, and eventually release of hydrogen [23]. However, pH increased due to biological decomposition and mass conglomeration [24]. The final pH increase was reported by Malekutyan *et al* [25], Rama *et al* [26], and Brito *et al* [27]. Tables 4, 6, and 8 show that pH increased in all treatments and the control in the sixth and seventh weeks, being consistent with the related literature.

The C/N index is one of the important indices during manure processing [28, 29]. The descending trend of the C/N ratio, during the compositing process, was due to the faster consumption of carbon and the slower consumption of nitrogen. Concerning the cow and poultry treatments, the results of this study showed that the C/N ratio decreased in sulfur treatments compared to the control. The descending trend of the C/N ratio during the processing of manure showed better processing conditions of manure treatments with Zarkooh mine sulfur than the control. Considering the C/N ratio, the results showed that sulfur had a significant effect on the composition of elements in cow and poultry, being consistent with the studies of Malekuti *et al* [20], Gao *et al* [30], and Wang *et al* [23].

Gao *et al* (2015) reported that organic matter decreased by 17% during the composition process. Besides, the final amount of nitrogen was higher in the treatment than in the pure manure [30]. In a study on the composition of cow manure, Wang *et al* (2015) showed that the number of volatile solids and carbon had a descending trend during the process. In contrast, nitrogen showed an ascending trend. So that, the number of volatile solids, organic matter, and pH in the produced compost from poultry manure was higher than in cow and pig manure. In addition, the amount of nitrogen in poultry, pig, and cow manure was 28.2-2.06, 3.77-17.2, and 3.86-2.31, respectively [23].

Temperature is an effective factor in the compositing process (organic matter decomposition) and decreasing the number of pathogens [26]. According to the results, the temperature increased in cow and poultry manures, which reached its maximum value in the third and fourth weeks after application of the treatments. Over time and during the final phases of composition, the temperature decreased due to the decrease in the microorganisms' activity, which has been consistent with the effects of the temperature in the literature [31, 32]. The optimal temperature during the compositing process was 37-60 ℃ [33]. According to the results, Zarkooh mine sulfur increased the temperature in cow and poultry treatments, which could be due to the acceleration in the composting trend. Due to the relatively small size of the mass, the temperature increase in the thermophilic phase in cow and poultry treatments with sulfur was in a short time 42 ℃ and 31.3 ℃, respectively. In the study of Alidadi *et al* (2011), the temperature reached 55 ℃ after five stages of overturning [34].

In pistachio orchards, poultry manure is used in manure pits in winter; however, it is applied to the surface of the soil without composting in the growing season. According to the results of this study, the poultry treated with sulfur increased concentrations of calcium, magnesium, iron, manganese, and zinc. So, it has been one of the benefits of using Zarkooh mine sulfur in poultry manure processing. In addition, the microbial population is one of the damaging factors in orchards which leading to environmental pollution. Based on the results, using Zarkooh mine sulfur decreased the microbial population in poultry manure. Temperature is a key factor in the activity of micro-organisms, which destroy insect larvae and weed seeds. According to the literature review, keeping the compost temperature at 55 ℃ for 3 days leads to the removal of pathogens, including the bacteria salmonella that exists in unsterilized compost for 8 and 12 week [33, 35], which was consistent with our results regarding a decrease in the microbial population.

According to the results, the population of molds and yeasts in the cow manures treated with 200 kg and 300 kg Zarkooh mine sulfur and poultry manure treated with 250 kg Zarkooh mine sulfur had an ascending trend until the fourth week and then showed a descending trend from the fourth week to the seventh week. While, the population of bacteria in both cow manure (200 and 300 kg Zarkooh mine sulfur) increased up to the third week and then decreased, but in poultry manure up to the fourth week showed an ascending trend and then a descending trend. The largest population in the microorganisms during different weeks was related to the bacteria, which could be due to the high diversity and reproduction speed in bacteria compared to the other micro-organisms [36]. It should be noted that the number of fungi, molds, yeasts, and bacteria showed an ascending trend in the control.

Results of chemical decomposition in cow manure processed in the fourth and sixth weeks (the best time for cow manures processed with 200kg and 300kg of Zarkooh mine sulfur) were compared with Iran National Standards [37]. In this regard, measured indices including EC, PH, nitrogen, and potassium were in the 'first' category, and the organic matter percent, C/N, and phosphorus percentage were in the 'second' category of Iran National Standards. Besides, evaluated indices in the poultry manure in the seventh week (the best time for the processing of poultry manure) were compared with Iran National Standards. Accordingly, all evaluated indices were under the 'first' category.

5. Conclusion

Results of this study showed that the use of Zarkooh mine sulfur in all cow and poultry manure treatments led to a faster decrease in the C/N ratio, and the microbial population. Thus, the decomposition process occurred faster in Zarkooh mine sulfur compared to the control. According to the results, the processing time of cow manure treated with 200 kg and 300 kg Zarkooh mine sulfur was taken in six weeks and four weeks. Poultry manure treated with 250 kg Zarkooh mine sulfur was taken six weeks. Therefore, using smaller amounts of sulfur, the processing time of manure increased. Fungal and bacterial pollutions caused by animal manures decreased at the end of the processing time, and the concentration of some nutritional elements increased in the processed manures with Zarkooh mine sulfur.

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