International Journal of Plant & Soil Science

21(3): 1-12, 2018; Article no.IJPSS.39082
ISSN: 2320-7035

Effects of Cheese Whey on Some Chemical and Physical Properties of Calcareous and Clay Soils

Emad F. Aboukila[1*], Elsayed A. A. Abdelraouf[1] and Ibrahem Gomma[1]

[1]Department of Natural Resources and Agricultural Engineering, College of Agriculture, Damanhour University, Damanhour, Egypt.

Authors' contributions

This work was carried out in collaboration between all authors. Author EFA designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors EAAA and IG managed the literature searches, the analyses of the study and performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2018/39082
Editor(s):
(1) Kofi Agyarko, Associate Professor, College of Agricultural Education, University of Education, Winneba, Ghana.
Reviewers:
(1) Mexoese Nyatuame, Ho Technical University, Ghana.
(2) Saeed Akhtar Abro, University of Sindh, Pakistan.
Complete Peer review History: http://www.sciencedomain.org/review-history/23009

Original Research Article

Received 19th November 2017
Accepted 30th January 2018
Published 3rd February 2018

ABSTRACT

Cheese whey is the main by-products generated by the cheese industry. It is acidic and rich in organic matter and nutrients which makes it ideal candidate to use as soil amendment. Incubation experiment was conducted to assess the potential of using cheese whey to increase soil fertility in calcareous and clay soils. Amendments were six levels of mozzarella cheese whey; 0, 1, 2, 3, 4, and 5% (oven dry weight basis). Cheese whey were applied to the tested soils, placed in pots and incubated aerobically under field capacity and field conditions for three months. After incubation, selected soil chemical parameters were measured, the cumulative water evaporation was measured as well. The electrical conductivity (EC) of the whey treated soil increased slightly in comparison to the initial EC in both soils. While, soil OM, available N, available P, and available K were significantly increased by all application rates compared to the control in both tested soils. The increase range was from 84 to 300% for OM; 10 to 136% for N; 40 to 155% for P; and 71 to 157% for K in clay soil. However, in calcareous soil, the range was from 17 to 177% for OM; 9 to 93% for N; 120 to 584% for P; and 175 to 550% for K. The soil pH decreased with increasing levels of cheese whey from 8.10 to 7.54 in clay soil and from 8.21 to 7.87 in calcareous soil. Suggesting that

**Corresponding author: E-mail: emad@damanhour.edu.eg;*

cheese whey was effective at adding OM, N, P, and K to soils while decreasing the soil's pH. The cumulative evaporation increased with time in both soils. The application of whey to the clay soils reduced the cumulative evaporation but it did not exhibit a trend in the calcareous soils. The use of cheese whey therefore in agricultural production provides an economic and environmentally friendly method of disposal, while improving soil fertility.

Keywords: Organic wastes; cheese whey; organic matter; electrical conductivity; macronutrients; cumulative evaporation; soil reclamation.

1. INTRODUCTION

Whey is a liquid by-product of cheese and cottage cheese produced from processed milk. Nine kilograms of whey result for each kilogram of cheese [1]. The whey varies in character depending upon cheese production process. Generally, it is a moderate acidic with high plant nutrient content, soluble salt, and chemical oxygen demand, compared to most other water wastes [1]. Most cheeses are made by biological culture processes that coagulate the milk proteins, and the resulting whey is often called "sweet" whey. This type of whey, a co-product from the production of hard cheeses, often has a pH of 5.6 or higher. By comparison, the term "acid whey" reflects the low pH of the whey, typically ranging from 3.6 - 4.5 with an average value of 4.1. Some creamed cheeses and cottage ones are made by coagulating the milk proteins, and the produced whey is usually called "acid". Sodium chloride is added in some cheese-making processes which might produce a sodium-whey. If the latter whey is added to a soil, it degrades some soil physical properties, such as soil structure, hydraulic conductivity, water flux density and bulk density, which may be adversely affected by the exchangeable sodium. These physical properties frequently reduce seed germination or plant growth [2]. Whey is very salty, even without salt or acid additions, due to the salts that come from the milk [1]. Whey commonly contains about 8% solids and 40-50 g kg^{-1} of readily decomposable organic compounds, lactose and primarily proteins [3]. Acid whey contains beneficial nutrients to plants, such as nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur. These nutrients are found in sufficient amount to allow for the use of acid whey to either complement or substitute the application of manure or inorganic fertilizer. It also contains elements that could be detrimental to plant growth such as sodium and chloride. Some whey contains more than 1000 mg Na^+ kg^{-1}, limiting their usefulness in agriculture [4]. Incorporated low-Na^+ whey improves physical and chemical properties of sodic soils [4,5,6]. Soluble salts in the whey decrease the thicknesses of clays diffuse double-layer, promoting flocculation. Adding whey proteins and lactose in soil stimulate aerobic microbes that create polysaccharides and other organic compounds, and promote fungal growth [7], both of which aid the formation and subsequent stabilization of soil aggregates [8,9,10]. Since whey improves the soil structure, its use as a soil amendment would transform the often-discarded by-product into a valuable resource. The recycle of cheese whey in agricultural systems will provide cheese producers another income stream and reduce disposal costs. Therefore, using the whey as a soil amendment can help cheese producers to protect the environment and increase their profit. As whey is mostly water, its use as a soil amendment is economically feasible only near the whey source if transportation costs are borne solely by the land owner [11,1].

The plant nutrient benefits of land applied whey have more recently been demonstrated on calcareous soils in the 7.6 to 8.8 pH range under irrigation in an arid climate [4,5,12]. Coarse-textured materials commonly have limited water-holding capacities, low cation exchange capacity, low organic matter content, and are subjected to surface crust formation. By adding organic wastes such as whey to such coarse soil, the water-holding capacity might increase. Fine-textured materials, while they can hold more water, can have lower hydraulic conductivities, infiltration rates, or anaerobic root zones [13].

The annual demand for organic fertilizers in Egypt is evaluated to be more than 150 million tons $year^{-1}$ while the various types of farm waste are estimated at 26 million tons $year^{-1}$, of which about 60 % are burned [14]. Due to the deficiency of organic farm waste in Egypt, industrial organic byproducts may be used as alternatives to traditional organic fertilizers.

In Egypt, cheese whey is a waste product and available in large quantities at no cost throughout the year. Given the recent escalation in fertilizer costs, alternative uses for such products need to be explored. Therefore, the objective of this study was to assess the potential for using cheese whey as an organic source to increase soil fertility in clay and calcareous soils. Adapting this system may alleviate the environmental and economic problems of excess waste and degraded soil.

2. MATERIALS AND METHODS

2.1 Study Locations

An experiment was carried out during the summer of 2016 at the experimental farm of the College of Agricultural, Damanhour University, Egypt.

Two soil types were selected for this study; the first one was Calcareous soil (*Typic Calciorthids*) collected from the region of Gianaclis, El Beheira Governorate, Egypt (Approximately latitude is 30°53' 37.23"N and 30° 07' 04.56"E). The second one was Clay soil *(Typic Torrifluvents)* collected from the region of Damanhour, El Beheira Governorate, Egypt (Approximately latitude is 31° 02'23.8"N and 30° 26' 23.6"E). The climate of El-Beheira governorate is typically Mediterranean with dry and hot summers and cool and wet winters. The mean annual temperature is 20.4° C, average high temperature is 26.2° C and mean low temperature is 14.6° C. Annual precipitation is 102 mm, mainly falling in the months of November through February [15].

2.2 Soil Sampling

Soil samples were collected at a depth of 0–30 cm, air-dried and sieved through a 2-mm sieve prior to analysis. Sub-samples of the air-dried soil were used for the chemical and physical parameters. The main properties of the soil are shown in Table 1.

2.3 Amendment Material - Cheese Whey

Mozzarella cheese whey, a by-product from the mozzarella cheese industry, was obtained from Elgendy cheese company, Abou-Elmatamir, El-Beheira Governorate, Egypt. The main properties of the cheese whey are shown in Table 1.

2.4 Experimental Setup

Cheese whey was applied to two types of soils: clay and calcareous soils at 6 different rates; 0, 1, 2, 3, 4, and 5% (L0, L1, L2, L3, L4, and L5, respectively) dry matter content. All treatments were applied to 1kg soil and placed in polyethylene pots. Pots were placed in the open field in a randomized complete block design with three replications for each treatment. In order to

Table 1. Initial characterizations of the studied soils and whey

Analyte	Calcareous soil	Clay soil	Cheese whey
pH (1:2.5 w:w)	8.20	8.17	3.80*
EC (dS m^{-1}, 1:2.5 w:w)	3.32	1.53	5.26*
Available N (mg 100 g^{-1})	22.3	28.5	2625**
Available P (%)	0.55	1.50	0.125**
Available K (%)	0.05	0.09	0.305**
Total $CaCO_3$ (%)	9.65	5.25	-----
Organic matter (%)	0.45	1.09	3.10
Dray matter	-----	-----	4.0
Organic C (%)	0.26	0.63	-----
Sand (%)	87.75	45	-----
Silt (%)	5.25	23	-----
Clay (%)	7.00	32	-----
Texture	Loamy sand	Clay loam	-----
Ca^{+2} (meq l^{-1})	17.5	8.2	15*
Mg^{+2} (meq l^{-1})	6.2	4.1	16*
K^{+} (Meq l^{-1})	2.5	0.2	2.43*
Na^{+} (Meq l^{-1})	5.9	4.3	1.3*
CO_3^{-2} (Meq l^{-1})	18.0	0.0	0*
HCO_3^{-} (Meq l^{-1})	6.5	10.0	0.4*
Cl^{-} (Meq l^{-1})	9.5	6.3	29*

** Measured directly in the whey, ** Total form of nutrient in whey (dry weight basis)* allow applied amendments to have an effect on soil properties, all pots, along with controls, were incubated aerobically under field conditions for three months starting on 1st of June 2016. The moisture content of the treated soil was kept constant during incubation by calculating the field capacity and periodically weighing the pots and adding water to compensate for evaporative loss. After incubation, the soils were analyzed for some physical and chemical properties.

2.5 Cumulative Evaporation

Three months after incubation, all pots were saturated with water. The saturation process aims to collect data for cumulative evaporation of the whey treatments. The pots were weighed every three days to obtain the water losses. Weighing the pots continued for 15 days. The data of water losses were used to calculate the cumulative water evaporation.

2.6 Soil Analysis

Soil samples were air dried, ground to < 2 mm, and analyzed for pH in 1:2.5 soil water suspension [16]. Electrical conductivity (EC) was determined in 1:2.5 soil water extract [16]. Calcium carbonate equivalent (CCE) was estimated by the pressure-calcimeter method [17]. Available nitrogen was extracted by 2M KCl and determined by Microkjeldehl method [18]. Soil organic matter was determined by the modified Walkley-Black method as described by [19]. Available K was estimated by 1 N ammonium acetate solution and measured by the flame photometer [16]. Available phosphorus was extracted with 0.5 N $NaHCO_3$ solution and measured by spectrophotometer [20]. Soluble Ca^{+2} Mg^{+2}, $CO3^{-2}$, $HCO3^{-}$, Cl^{-} were determined in 1:2.5 soil water extract by titration methods [16]. Soluble Na^{+} and K^{+} were measured in 1:2.5 soil water extract by the flame photometer [16]. Particle-size distribution was determined by hydrometer as described by [21].

2.7 Statistical Analysis

To test for statistical differences, an analysis of variance was calculated using PROC GLM followed by Fisher's protected least significant difference for mean comparisons using SAS 13.1 statistical software [22]. A significance level of $\alpha = 0.05$ was chosen to reduce the likelihood of a Type II error during the analysis of incubated soils.

3. RESULTS AND DISCUSSION

Decreasing soil pH of alkaline soils leads to increases in nutrient availability. Soil pH values significantly decreased with increasing addition of cheese whey waste of both soil types (Fig. 1). The pH values ranged from 8.10 to 7.54 in the clay soil with a difference of 0.54 pH unit among the whey treatments. The highest pH was for control treatments and the lowest was for treated soil with highest whey level (L5). Similarly, soil pH range was from 8.21-7.87 in the calcareous soil (Fig. 1). The pH decreased in a similar trend to the clay soil but with lower rate. The difference between the control and level 5 is 0.34 pH unit. So, the whey effects on reduction of soil pH was greater in clay soil than in the calcareous soil.

The effect of whey on soil pH depends on both the initial pH of soil and whey applied [23]. The reduction of pH was affected by the whey application rate. As the application rate increased the pH decreased compared to the initial or control treatments. This reduction in the pH values might be due to increase of the groups of carboxyl and phenol as a result of the decomposition of organic residue and the reduction of bicarbonate in the soil. [24] reported decreases of pH that might be due to the presence of phenolic and fatty acids which resulted from organic source composition. [25] reported that nitrification was responsible for the falling pH values and increasing electrical conductivity during organic waste decomposing. Similarly, [26] stated that increasing application rate of acid whey decreased the pH in silt loam soil. [4] found that the pH was decreased due to the addition of cottage cheese whey.

The electrical conductivity (EC) of the whey treated soil increased slightly in comparison to the initial EC in the control in both soils (Fig. 2). The mean relative increase in EC of clay soil were 1.9, 3.2, 9.1, 9.7 and 18.8 % at L1, L2, L3, L4, and L5 of whey levels, respectively. While, the mean relative increase in EC of calcareous soil were 11.9, 10.7, 16.5, 16.8 and 18.6 % at L1, L2, L3, L4, and L5 of whey levels, respectively. The EC ranged from 1.54 (control treatment) to 1.83 (L5 treatment) dS m^{-1} in the clay soil. The corresponding range was from 3.28 to 3.89 dS m^{-1} in the calcareous soil. The differences in the EC between the two soils are attributed to the different initial EC of both soils, while the differences among the EC of the treatments are attributed to the incubated whey and the control (L0) in both soils. The increases in the EC of the soils are due to the high salt content of whey (5.26 dS m^{-1}). Partially, the increases in EC may be due to the release of inherent soluble salts and mineralizing during the decomposition process of the whey. The soil EC is mainly due to ionic species (K^+, Cl^-, SO_4^{2-}, and NO_3^-) that exist either in whey or generate through organic source mineralization and transformation [26]. As described earlier for pH, the whey reduced the acidity of the soil in comparison to the initial pH. This reduction in the soil pH might have increased the solubility of some salt existed in the soil too. Similar results are reported by [4] who found that the EC of soil increased significantly due to the application of cottage cheese whey. [5] stated that the soluble solute in silt loam soil increased as the application rate of acid whey increased. Due to the high content of

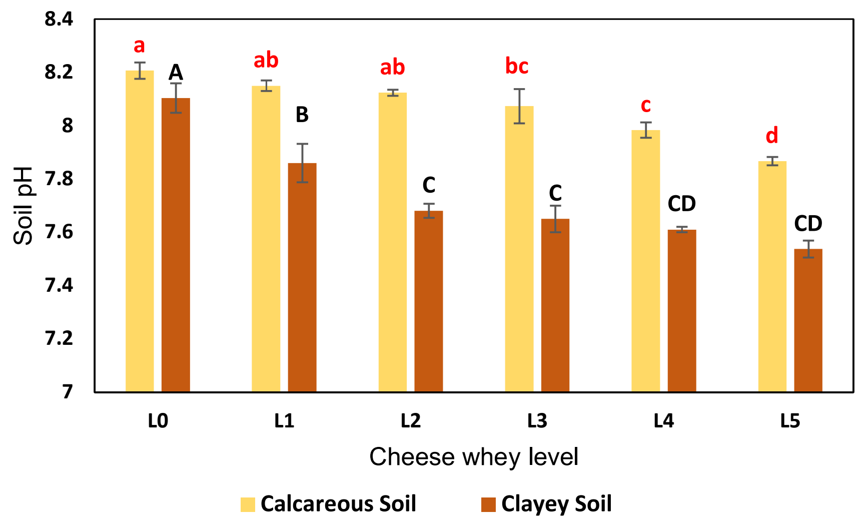

Fig. 1. Effect of different whey levels on the soil pH of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

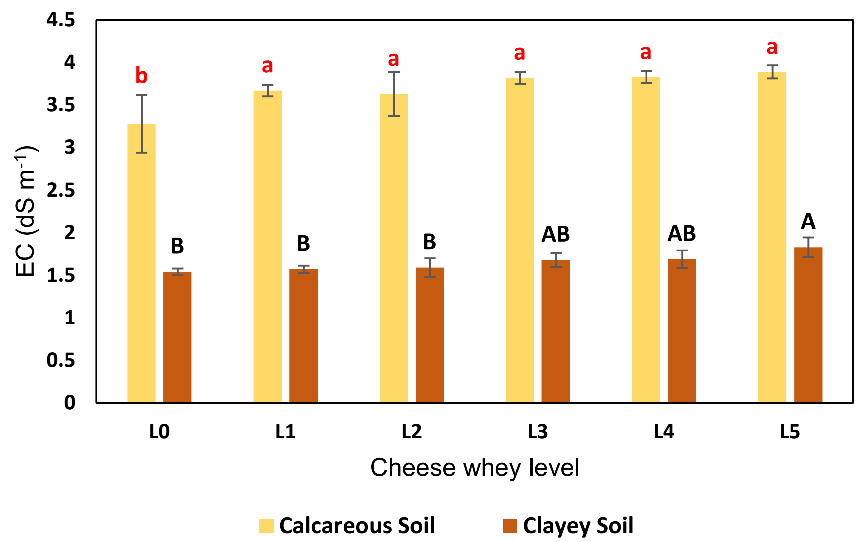

Fig. 2. Effect of different whey levels on the soil electrical conductivity of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

soluble salts in whey [3], addition of more than four inches of whey to soil may lead to increasing electrical conductivity of soil to more than 4 dS m^{-1}. Above this level, crop yields are often adversely affected. Yield reduction may be observed for salt-sensitive crops such as soybeans, green beans, and red clover [3].

Fig. 3 shows the percentage soil organic matter (OM) in both used soils. All whey levels led to significant increases in soil OM. The magnitude of the increase in OM tended to correspond with the quantities of OM added by each treatment; thus, the largest increases were observed with the L5 treatments. The OM ranged between 1.01% (control) to 4.04 % in the clay soil. The mean relative increase in OM% of clay soil were 84, 186, 218, 266 and 300 % at L1, L2, L3, L4, and L5 of whey levels, respectively. In the calcareous soil, the OM range was 0.47 to 1.3 %. The mean relative increase in OM% of calcareous soil were 17, 72, 96, 138 and 177 % at L1, L2, L3, L4, and L5 of whey levels, respectively. The results showed that the increase in OM% was higher in clay soil than calcareous soil. This increasing of OM% in clay soil than calcareous with increasing whey rates could be attributed to the formation of organic complexes on clay mineral surfaces [27], which protect the organic matter from microbial attack. It is also attributed to increasing microbial biomass with increased organic matter inputs. The organic matter percentages increased in parallel with both the pH and the EC. Similarly, [28] reported that addition of organic manure increases organic matter content which in turn increases the levels of Ca^{2+}, K^{+} and Mg^{2+}.

Organic wastes such as whey can be used not only as a source for soil organic matter and / or pool for plant nutrients, but it can be used as bioremediation materials. [29] studied the impacts of applying lactate and whey to aquifer materials to achieve dechlorination of Trichloroethylene (TCE). He found that the addition of whey supported the biogeochemical conditions and energy production required to achieve full dechlorination of TCE with high rates of vinyl chloride (VC) reduction.

Soil N, P, and K were significantly increased by all whey application rates compared to the control suggesting that all whey levels were effective at adding N, P and K to both soils (Figs. 4, 5, and 6). The high rate of cheese whey (L5) significantly produced larger increases in soil N, P and K than the other whey levels. Soil N, P and K increased as the application rate of whey increased. Mineralization of organic materials as well as the nutrients present in the cheese whey were responsible for increasing the availability of plant nutrients in soil. Furthermore, cheese whey should be applied before planting to give sufficient time for natural oxidation of organic materials, which in turn enhances the soil available nutrients.

The mean relative increase in available N content of clay soil were 10, 15, 32, 87 and 136 % at L1, L2, L3, L4, and L5 of whey levels, respectively. While, the mean relative increase in available N content of calcareous soil were 9, 37, 68, 77 and 94 % at L1, L2, L3, L4, and L5 of whey levels, respectively. The clay soil treatments showed greater nitrogen contents than the calcareous soil treatments. These higher nitrogen contents of clay soil treatments might due to the initial higher N and OM content in the clay soil (Table 1) and probably the lower pH levels of the clay soil treatments. However, since all the treatments had pH greater than 7.0 (Fig. 1), ammonia losses increased generally [30]. In contrast, [31] found that volatilization of NH_3 was independent of soil type (three soil types with pH < 7) and whey application rate.

The concentration of available Phosphorus (P), which is considered as the most available P pool for plant uptake are shown in Fig. 5. The mean relative increase in available P content of clay soil were 40, 94, 115, 118 and 155 % at L1, L2, L3, L4, and L5 of whey levels, respectively. While, the mean relative increase in available P content of calcareous soil were 120, 187, 292, 422 and 584 % at L1, L2, L3, L4, and L5 of whey levels, respectively. This increase in available P could be due to the reduction in pH as a result of acidity of whey and organic matter decomposition. The higher relative increase of available P in calcareous soil than clay soil could be attributed to more organic matter decomposition in calcareous soil than clay soil. So, organic phosphorous mineralized to available inorganic phosphorous in calcareous soil more than clay soil. [32] reported that acid whey supplies P, expressed as P_2O_5, approximately 1.7 kg P_2O_5 m^{-3}. At this value, 168 m^3 h^{-1} application rate supplies about 285 kg of P_2O_5. [33] conducted a field study to determine the interactions among P application rate, source, extractability, and soil organic carbon (OC) concentration. A Portneuf silt loam was fertilized with monocalcium phosphate (MCP), cheese whey, and dairy manure. All forms of P increased more per unit of added P in the order manure > whey > MCP and were correlated with the soil OC concentrations.

The mean relative increase in available K content of clay soil were 71, 100, 129, 157 and 157 % at L1, L2, L3, L4, and L5 of whey levels, respectively. While, the mean relative increase in available K content of calcareous soil were 175, 350, 375, 500 and 550 % at L1, L2, L3, L4, and L5 of whey levels, respectively. The higher relative increase of available K in calcareous soil than clay soil could be attributed to more organic matter decomposition in calcareous soil than clay soil. [32] showed that potassium as K_2O content of acid whey was with a mean value of 1.93 kg m^3. Thus, acid whey if applied at this rate will supply more than what is annually removed with harvest of crops like corn or alfalfa.

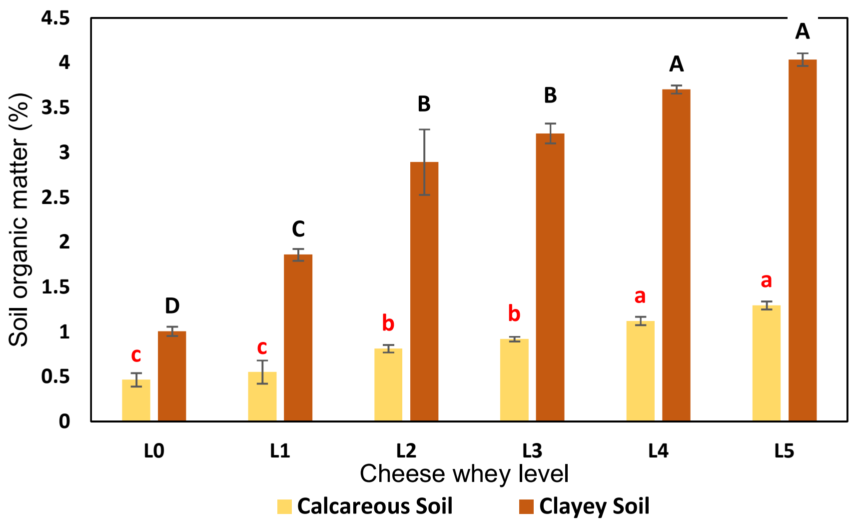

Fig. 3. Effect of different whey levels on the soil organic matter of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

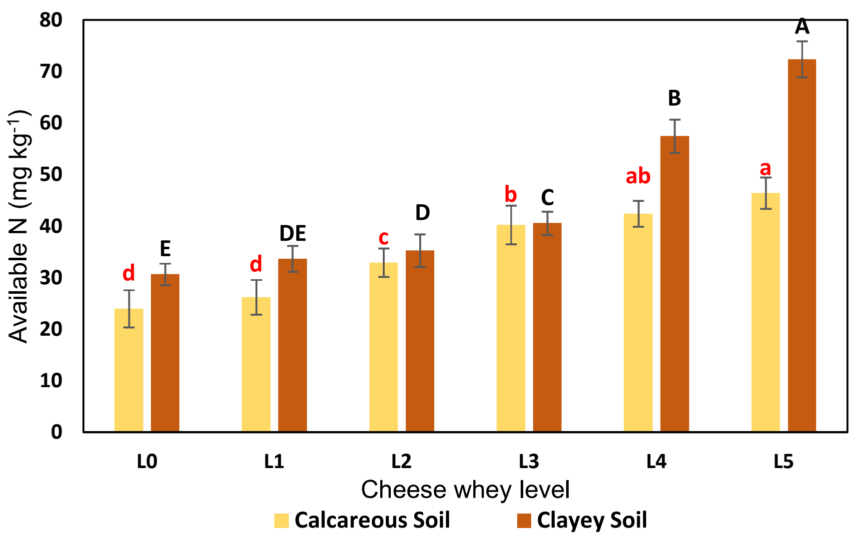

Fig. 4. Effect of different whey levels on the available soil nitrogen of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

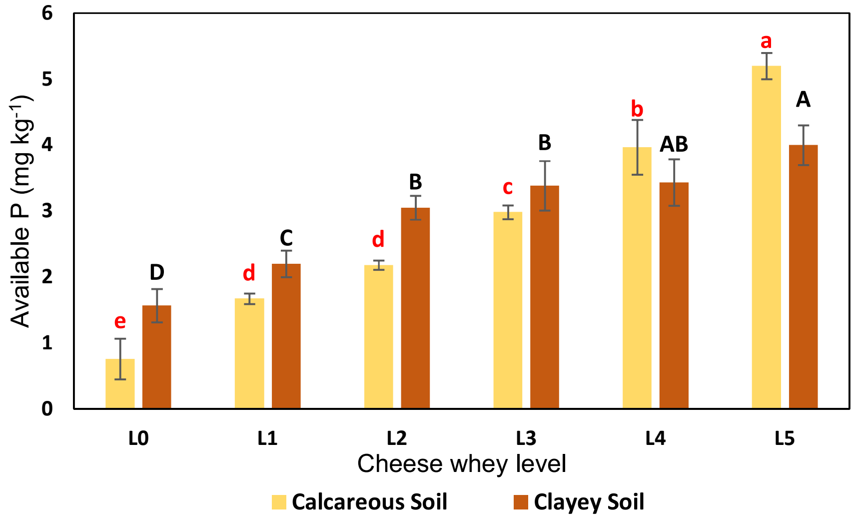

Fig. 5. Effect of different whey levels on the available soil phosphorus of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

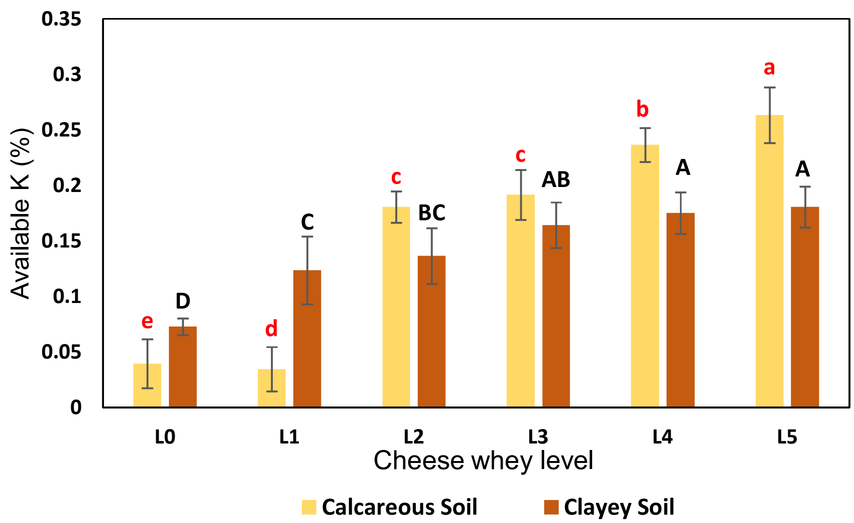

Fig. 6. Effect of different whey levels on the available soil potassium of clay and calcareous soils. All values represent the mean of three replicates ± S.D. Columns labeled with the same letter are not significantly different at α =0.05

[28] found that addition of organic manure increased the organic matter content which in turn increased the levels of Ca, K and Mg. The addition of organic source might provide supplemental exchangeable ions such as K^+ in the incubated soil. Similar results are reported by [14] who reported that the application of spent grain to calcareous soil led to reducing pH and increasing soil water holding capacity, organic matter, dissolved organic carbon, macronutrients, micronutrients, germination parameters and squash yield.

The cumulative evaporation is considered as an indicator to the physical properties of a soil that are function to aggregation/agricultural practice. Figs. 7 and 8 show the cumulative water evaporation from the clay and calcareous soils, respectively. In general, the cumulative evaporation increased with time. The application of whey to the clay soils reduced the cumulative evaporation. It can be concluded that the addition of whey to the clay soil increased the water holding capacity. Increasing the soil water

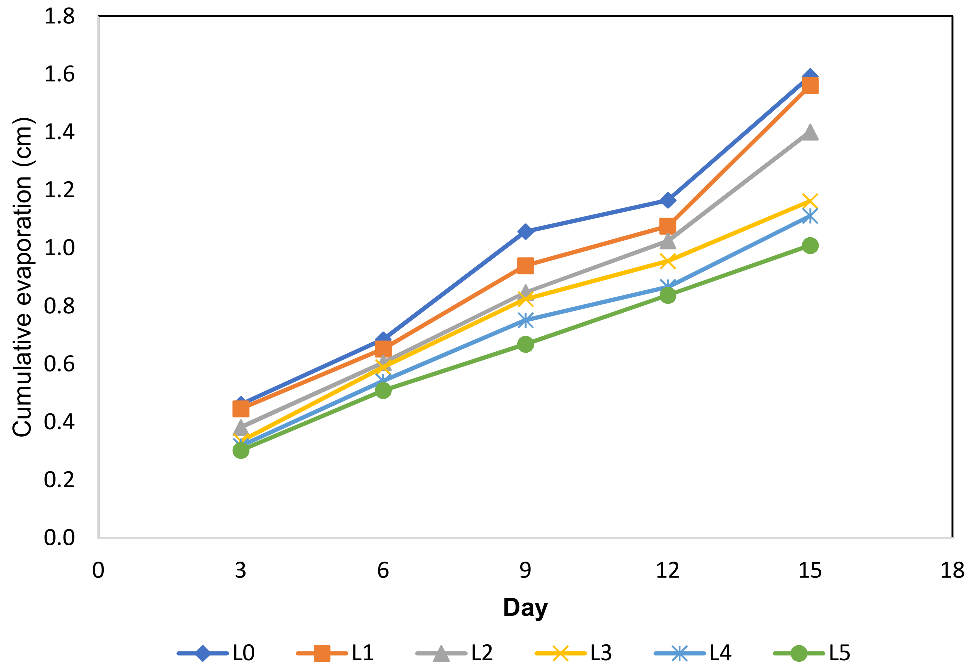

Fig. 7. Effect of whey incubation on the cumulative evaporation of clay soil at different levels of whey

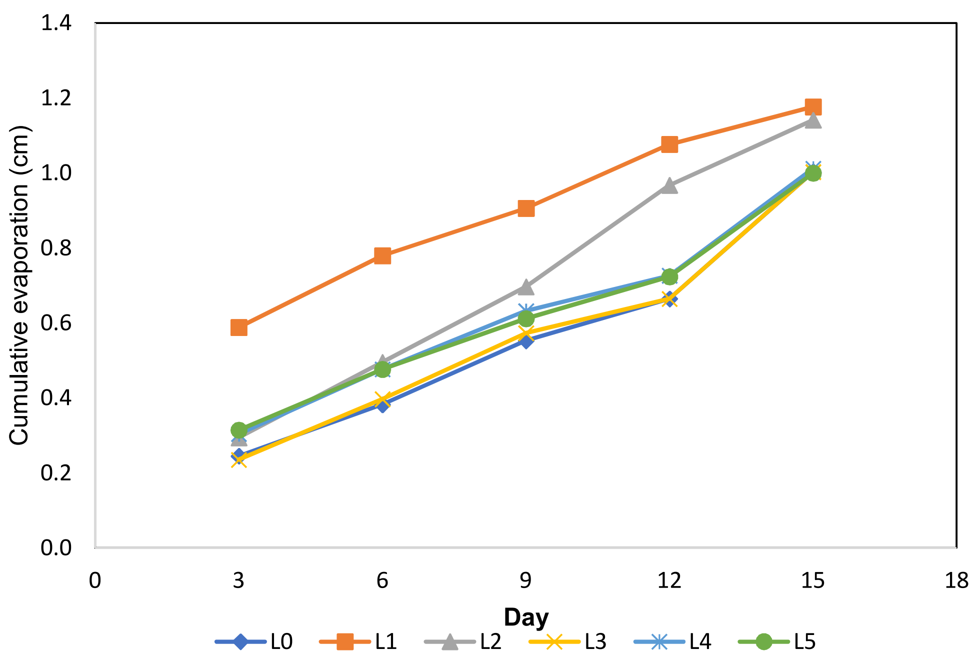

Fig. 8. Effect of whey incubation on the cumulative evaporation of calcareous soil at different levels of whey

holding capacity can be attributed to the high level of organic matter (Fig. 3) and the clay content (32%). So, the whey application has a positive effect on the water storage in the clay soil. [34] reported that hydrophilic organic matter, which is reported to decrease the wettability of soils, was found to increase the absorption of water into soils in the vapor form.

The application of whey to the calcareous soils does not exhibit a consistent trend (Fig. 8). The cumulative water evaporation followed the following orders L1>L2>L4> L0= L3>L5 during the whole period of evaporation. The discrepancy between the clay soil and calcareous soils might be attributed to the differences in clay contents between the two soils. [35], in a study of the aggregate stability of non-sodic soils, noted that the addition of soluble salts (such as are present in cheese whey) to the soil solution reduced the diffuse double-layer thicknesses of clay domains, resulting in clay flocculation. This improved aggregation changes in the pore size distribution, which increased the flux density of both air and water through the soil profile [36]. Whey increased the aggregate stability of structurally degraded calcareous soil in irrigation furrows [37] which can affect water flow in soils in both vapor and liquid forms [36].

4. CONCLUSION

The application of cheese whey to clay and to calcareous soil proved to be an extremely effective method of reducing soil pH and increasing organic matter, nitrogen, phosphorous, potassium, and soil water holding capacity. Demonstrating this amendment has the capacity to improve physical and chemical limitations, initiate nutrient cycling, and provide a hospitable environment for vegetation. Therefore, use of cheese whey waste in agricultural production provides an environmentally friendly and economic method of disposal, while improving soil fertility. The examined treatment must be further conducted as long-term field experiments to determine whether the results obtained in this short-term and controlled experiment also occur under variable field conditions.

ACKNOWLEDGEMENTS

The authors acknowledge Prof. Ibrahim Nassar, College of Agricultural, Damanhour University, for assistance in experimental set-up, editing and reviewing the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Robbins CW, Lehrsch GA. Cheese whey as a soil conditioner. In: Wallace A, Terry RE. (Eds.), Handbook of Soil Conditioners: Substances that Enhance the Physical Properties of Soil. Marcel Dekker Inc., New York. 1998;167-186.
2. Gami SK, Godwin GS, Czymmek KJ, Ganoe KH, Ketterings QM. Acid whey pH and nutrient content. Cornell Agronomy Factsheet #96. Cornell Univ., Ithaca, NY. Accessed 10 September 2017. Available:http://nmsp.cals.cornell.edu/publications/factsheets/factsheet96.pdf
3. Kelling KA, Peterson AE. Using whey on agricultural land- A disposal alternative. University of Wisconsin -Extension, A3098. 1981;1-6.
4. Robbins CW, Lehrsch GA. Effects of acidic cottage cheese whey on chemical and physical properties of a sodic soil. Arid Soil Res. Rehab. 1992;6:127-134.
5. Jones SB, Robbins CW, Hansen CL. Sodic soil reclamation using cottage cheese (acid) whey. Arid Soil Res. Rehab. 1993;7:51-61.
6. Lehrsch GA, Robbins CW, Hansen CL. Cottage cheese (acid) whey effects on sodic soil aggregate stability. Arid Soil Res. Rehab. 1994;8(1):19-31.
7. Sonnleitner R, Schinner F, Lorbeer E. Effects of straw, vegetable oil and whey on physical and microbiological properties of a chernozem. Appl. Soil Ecol. 2003;22:195-204.
8. Lynch JM, Bragg E. Microorganisms and soil aggregate stability. Adv. Soil Sci. 1985;2:133-171.
9. Roldán A, Albaladejo J, Thornes JB. Aggregate stability changes in a semiarid soil after treatment with different organic amendments. Arid Soil Res. Rehab. 1996;10:139-148.
10. Amézketa E. Soil aggregate stability: a review. J. Sustain. Agric. 1999;14:83-151.
11. Zall RR. Cost effective disposal of whey. Dairy Indus. Int. 1980;45(4):30-39.
12. Robbins CW, Hansen CL, MF Roginske, DL Sorensen. Extractable potassium and soluble calcium, magnesium, sodium, and potassium in two whey- treated calcareous

soils. Journal of Environmental Quality. 1996;25(4):791-795.
13. Lehrsch GA, Robbins CW. Cheese whey as an amendment to disturbed lands: Effects on soil hydraulic properties. Paper presented at the International Land Reclamation and Mine Drainage Conference and the Third International Conference on the Abatement of Acidic Drainage, Pittsburgh, PA, April 24-29, 1994.
14. Aboukila EF, Nassar IN, Rashad M, Hafez M, Norton JB. Reclamation of calcareous soil and improvement of squash growth using brewers' spent grain and compost. Journal of the Saudi Society of Agricultural Sciences; 2016 (*In press*). DOI:http://dx.doi.org/10.1016/j.jssas.2016.09.005
15. Climate-Data.org. Climate: Beheira Governorate. Accessed 15 September 2017. Available: https://en.climate-data.org/region/1599/
16. Jackson ML. Soil chemical analysis. Prentice-Hail, Inc., Englewood Cliffs, NJ, USA; 1958.
17. Nelson RE. Carbonate and gypsum. In: Page et al. (Eds.), Methods of soil analysis. Part 2. second ed. American Society of Agronomy, Madison, WI. 1982;181-197.
18. Bremner JM, Mulvaney CS. Nitrogen-total. In: Page et al. (Eds.), Methods of Soil Analysis, Part 2. 2nd ed. American Society of Agronomy, Madison, WI. 1982;595-624.
19. Nelson DW, Sommers LE. Total organic carbon and organic matter. In: Page et al. (Eds.), Methods of soil analysis. Part 2. Second ed. American Society of Agronomy, Madison, WI. 1982;539-577.
20. Olsen SR, Sommers LE. Phosphorus. In: Page et al. (Eds.), Methods of soil analysis. Part 2. second ed. American Society of Agronomy, Madison WI. 1982;403-430.
21. Gee GW, Bauder JW. Particle-size analysis. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1: Physical and Mineralogical Methods. Second ed. American Society of Agronomy and Soil Science Society of America, Madison, WI. 1986;383-411.
22. SAS Institute. The SAS system for windows. Release 13.1. SAS Inst., Cary, NC; 2013.
23. Hayes MHB, Wilson WS. Humic Substances, Peats and Sludges: Health and Environmental Aspects. Elsevier - Science; 1997.
24. Achak M, Hafidi A, Ouazzani N, Sayadi S, Mandi L. Low cost biosorbent banana peel for the removal of phenolic compounds from olive mill wastewater: kinetic and equilibrium studies. J. of Hazardous Materials. 2012;166:117-125.
25. Sánchez-Monedero MA, Roig A , Paredes C, Bernal MP. Nitrogen transformation during organic waste composting by the Rutgers system and its effects on pH, EC and maturity of the composting mixtures. Bioresource Technology. 2001;78:301-308.
26. Mekki A, Dhouib A, Sayadi S. Changes in microbial and soil properties following amendment with treated and untreated olive mill wastewater. Microbiol. Res. 2006;161:93-101.
27. Sollins P, Homann P, Caldwell BA. Stabilization and destabilization of soil organic matter: Mechanisms and controls. Geoderma. 1996;74:65-105.
28. Frempong, ME, Ofosu-Anim J, Blay ET. Nutrient supply strategies on growth and yield in okra (*Abelmoschus esculentus* L.) Moench. Ghana J. Hort. 2006;5:73-81.
29. Kissell SM. Comparing the effect of carbon sources, lactate and whey, on biological reductive dechlorination of TCE in Laboratory flow through columns. M.S. Utah State Univ. All Graduate Theses and Dissertations. 5394; 2016.
30. Boswell FC, Meisinger JJ, Case NL. Production, marketing and use of nitrogen fertilizers. In: Engelstad, OP, editor. Fertilizer Technology and Use. 3rd ed. SSSA Madison, WI. 1985;229-292.
31. Ghaly AE, Rushton DG, Mahmoud NS. Potential air and groundwater pollution from continuous land application of cheese whey. Amer. J. Appl. Sci. 2007;4:619-627.
32. Ketterings Q, Czymmek K, Gami S, Godwin G, Ganoe K. Guidelines for Land Application of Acid Whey. Department of Animal Science Publication Series No. 247. Cornell Univ., USA; 2017.
33. Robbins CW, Freeborn LL, Westermann DT. Organic phosphorus source effects on calcareous soil phosphorus and organic carbon. J. Environ. Qual. 2000;29:973-978.
34. Leelamanie DAL. Changes in soil water content with ambient relative humidity in relation to the organic matter and clay. Tropical Agric. Res. & Ext. 2010;13:6-10.

35. Lehrsch GA, Sojka RE, Jolley PM. Freezing effects on aggregate stability of soils amended with lime and gypsum. In: Poesen JWA, Nearing MA, (eds.) Soil Surface Sealing and Crusting. Catena Supplement, No. 24. pp. 115-127. Catena Verlag, Germany. ISBN 3-923381-33-6; 1993.
36. Hillel D. Introduction to soil physics. Academic Press, New York; 1982.
37. Lehrsch GA, Robbins CW, Brown MJ. Whey utilization in furrow irrigation: Effects on aggregate stability and erosion. Bioresource Technology. 2008;99:8458-8463.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/23009