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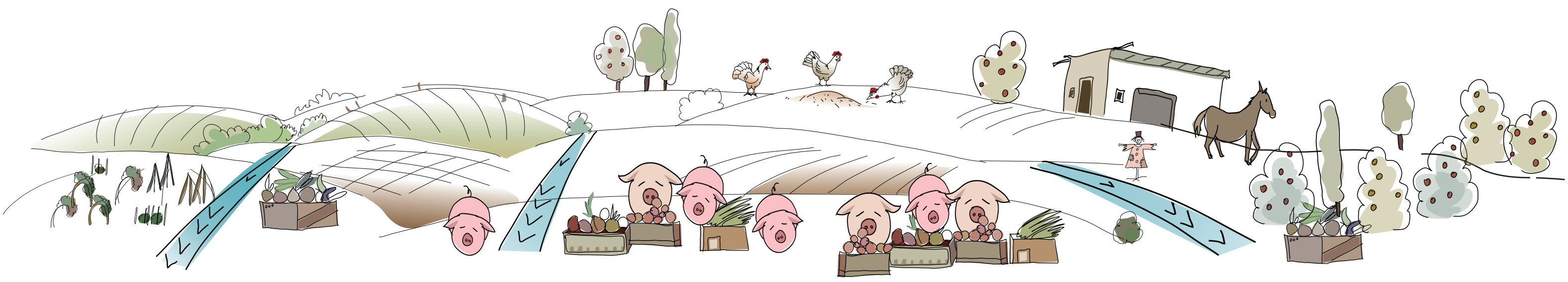
07.利用畜牧沼液配製高品質有機液肥及作物之肥培應用

Studies on the Utilization of Fermented Livestock Liquid and Appropriate Fertilization for Three Crops



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Studies on the Utilization of Fermented Livestock Liquid and Appropriate Fertilization for Three Crops

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Abstract

The livestock liquid commonly contains humic acid, amino acid and minerals, hence, it can be used for the fertilization of crops. This studies were conducted to use livestock fermented liquid to produce liquid fertilizers and irrigated on two kind of crops (tomato and waxapple). The experiment were designed as common liquid fertilizer and diluted by groundwater (CF), fermented livestock liquid fertilizer and diluted by groundwater (LF), fermented livestock liquid and diluted by groundwater (LL), fermented livestock liquid fertilizer and diluted by effluent (LFE), and the treatment of no liquid fertilizer (CK). The results showed that the most excellent of fruit weight, width and length were by the treatment of LF, and the sugar degree was by the treatment of LFE. Hence, the treatment of LF was more excellent than CF. The analysis of microbiology in LF, WF and LL showed that the microbiological varieties were most abundant in the LF than other two samples. The main microbiologies were fungus, *Bacillus mycoides* and *Bacillus subtilis*. Anthrachose of mango was inhibited by one of the *Bacillus subtilis* in LF. Among the treatments, LF was the best for the quality of jujube, especially on the fruit weight and sugar degree were 8.9% and 5.8% higher than CK, respectively. This results provided the primary information on reusing of livestock waste for crops.

Key words: Livestock liquid, Effluent, Tomato, Waxapple, Jujube

Introduction

In Taiwan, the main livestock farming was concentrated at Pingtung, Yunlin and Chianghua county. The treatment of livestock waste was commonly proceeded by the three-stage sysyem including soild-liquid separation, anaerobic and aerobic fermentation in the field area of livestock farming. By the complete treatment, the effluent was drained to rivers, however, part river was still polluted occasionally. The biogas was produced after anaerobic fermentation of livestock waste (Chen et al., 2008; Weiland, 2010; Bao et al., 2019), and then the residual solid and liquid were fertilized to farmland (Holm-Nielsen et al., 2009).

In addition to plant disease and insect, the inbalance of nutrients absorption will influence plant growth. Especially in the poor soil properties and the soil nutrients that uneasily preserved. The main 16 kinds of nutrient elements are necessary for plants (Kholmanskiy *et al.,* 2019). For sustainly obtaining the balance nutrients, the fertilization is necessary.

Except that, in case of adjusting the appropriate ingredients by perfusion of liquid fertilizer that will make the rapid adsorption for crops and increase the quality of fruits production. There are great amount of minerals, amino acids and humic acids in the livestock liquid that can promote the growth of plants (Richardson and Ternes, 2011), however, the negative influence of heavy metals and environmental hormons that should be evaluated (Kelessidis and Stasinakis, 2012). This study was conducted to evaluate irrigated water that was insteaded of livestock liquid to produce the liquid fertilizer. On the other hand, after application, the effect of different liquid fertilizers on tomato and waxapple were compared. In this experiments, the circular agriculture and appropriate fertilization will be achieved.

Materials and method

Experimental design and production of liquid fertilizer

This experiment was designed for the production of liquid organic fertilizers by livestock liquid. The materials were used as below, the drainage water (or livestock liquid) 300 liter (L), soybean powder 9 kg (kilogram), rice bran 9 kg, phosphate rock powder 9 kg, seaweed powder 9 kg, molasses 18 kg and fermentating microbiology 3 kg. The hydrolysis of soybean by will produce high polypeptide and amino acids and then serve abundant nitrogen fertilizer to plants (Kanu et al., 2009; Zhao et al., 2012). phosphate rock powder (tricalcium phosphate) is commonly a kind of phosphorus fertilizer in the phosphorus source in fertilizer (Xu et al., 2019). Vijayakumar et al. (2018) showed that application of a lower concentration (20%) of seaweed liquid fertilizer (SLF) will increase fresh weight, leaf area, protein, carbohydrate and lipids of *Capsicum annum* L. Hence, the seaweed was used to supply the potassium in liquid fertilizer. The productive methods were as follows. At first, the 300 L plastic barrels were prepared, and the groundwater (or fermented livestock liquid) and prepared materials were all put into the barrel. And the the liquid fertilizer were stirred by electric stirrer two times every day for 14 days. The stirring duration was 5 minute every time. After 30 days, the crop experiments were proceeded. The experimental designs were described as Table 1. The tomato (CK, CF, LL, LF, LFE) and waxapple (CF, LF) experiments were started from young fruit stage of the two kind of crops. The irrigative frequency was 7 days and the 1,500 L every time, hence, the total liquid fertilizer amount was 7,500 L totally. The soil and leaves were sampled and analyzed before and after experiments. And the quality of fruits were estimated in the harvested stage.

Pretreatment and analysis of soils and plants

1.Pretreatment and analysis of soil

After taking back soil samples, get them air dried and grinded. Shake them through a 2mm sieve. Here is how the soil will be analyzed. (1)pH: water : soil = 1:1, measured by a pH meter (McLean, 1982). (2)Organic matter: measured by wet oxidation method described by Nelson and Sommer (1982). (3)Ca, Mg, K: Extract the K, Ca, Mg from the soil by 0.1N HCl. The content of K, Ca and Mg is measured by inductively coupled plasma spectrometer (Jobin Yvon-2000) (Baker and Suhr, 1982). (4)P: it will be measured by molybdenum blue method (Bray No.1) (Murphy and Riley, 1962). (5)Fe, Mn: Microelements of Fe and Mn can be extracted from the soil by 0.1N HCl. Its content can be measured by an AA spectrometer (Cope and Evans, 1985).

2.Pretreatment and analysis of leaves (Chang, 1981)

Clean the dusts and chemical residuals on the leaves by tap water. Put the leaves into an oven (70-75 °C). Grind them after 2 to 3 days and put them into a bottle. The leaves will be resolved by concentrated sulphuric acid and analyzed by the following methods. (1)N: it will be measured by Kjeldahl method. (2)P: it will be measured by molybdenum yellow method (Bray No.1). (3)K, Ca, Mg are measured by inductively coupled plasma spectrometer (Jobin Yvon-2000). (4)Fe, Mn: The concentrations of Fe and Mn are measured by inductively coupled plasma spectrometer (Jobin Yvon-2000).

3. Analysis and application of microbiology in liquid fertilizer

(1)Microbiology analysis in the different liquid fertilzers

After sampling 1 ml of liquid fertilizers, and 9 ml distilled water was added. The mixture was shaked. And then the 1 ml mixture was sampled, and 9 ml distilled water was added. After multiple dilution, the liquid was smeared on the surface of solid medium. Three replicates were proceeded. After that, the solid medium was placed to the growth chamber that containing constant temperature (27 ºC). After the microbiology was observed apparently, the total microbiological amount was calculated averagely for three replications. The calculative formula was as below, Average amount of microbiology= Average microbiology= average microbiology of three replications 1/dilutive fold 10 (unit: CFU/ml).

(2)The test of microbiology isolated from liquid fertilizer for the antibiosis of mango anthraconosis

Anthrax is a kind of important disease on mango (Liu et al., 2014). Some method were found to to inhibit anthrax effectively (Jiao, *et al*., 2018). At first, the processing groups were set as follow. The isolated microbiology strain from liquid fertilizer was inoculated to the medium containing agar that located the 1/4 right district. The medium were cultured in the growth chamber containing temperature 30 ºC for 1 day. And then the anthraconosis srain was inoculated on the 1/4 left district. And then the medium was continuously placed in the growth chamber that the temperature was set at 30 ºC. On the other hand, the treatment of check (CK) was set that only inoculating anthraconosis srain on the 1/4 left district of medium and there were no isolated microbiology strain on the medium. When the hyphae of anthraconosis srain in the CK treatment was spreaded to the 1/4 right district of medium, the inhibition zones of processing groups were investigated.

Results and Discussion

The experiment of liquid fertilizer by fermented livestock liquid for crops

Table 2. showed that the soil pH of tomato was 6.77 before experiment, however, it was reduced after experiment at all treatments. It was possible that the application of chemical fertilizer and fermented livestock liquid made the reduction of pH. The reason why the application of LF was reduced to the lowest pH among all treatments may be stronger acidity in fermented livestock liquid (data not shown). The soil organic matter, phosphorus, potassium, calcium and magnesium were all higher in the all treatments after experiments. In addition to supplement of essential nutrients, either increasing the available elements. However, the increase of microelements were limited. Table 3 showed that the nitrogen, phosphorus, calcium, magnesium, manganese, copper and zinc in the leaves of tomato were slightly higher after all treatments. About the fruits quality of tomato, the treatments of fermented stock liquid (LF and LFE) were higher than that of non-fermented in Table 4. The fruit weight, fruit width and fruit weight were all excellent in the treatment of LF, however soluble solid was highest in the LFE. In general, after the production of liquid fertilizer by fermented livestock liquid, and then applied to tomato that will increase the quality of tomato. Vijayakumar et al. (2018) showed that the usage of seaweed liquid fertilizer can increase the quality of *Capsicum annum* L.

In the experiment of waxapple, the comparative experiment was only the production and application of liquid fermented livestock fertilizer and common fertilizer (LF and CF). Table 5 showed that soil pH were all reduced among different treatment. All nutrients were all increased after treatments. The elements in the leaves of waxapple (Table 6), fruit weight, fruit width and fruit length and soluble solid for LF were all higher than CF (Table 7). Lin and Chiu (2019) showed that the quality of waxapple was influenced by the absorption of abundant nutrients and water. In this experiment, we found that when the appropriate liquid fertilizer was irrigated, the quality of waxapple will be increased. Among the treatments, LF was the best for the quality of jujube, especially on the fruit weight and sugar degree were 8.9% and 5.8% higher than CK, respectively.

The water can be replaced by fermented livestock liquid for the production of liquid fertilizer. And then it can be apply to tomato after diluting 400 times by irrigation water of fermented livestock liquid during fruit-setting stage. The fermented livestock liquid was used to produce liquid fertilizer, and then diluted 400 times by irrigation water for waxapple and jujube at fruit-setting and fruit mature stages.

The analysis and application of microbiology in liquid fertilizer

In the Table 8, it showed that the microbiology phase in LF was most abundant among the treatments of LL, LF and CF. The main microbiology phase were fungus, Bacillus mycoides and Bacillus subtilis. The C groups were the most abundant in the treatment of WF. The C-3 was chosen for the inhibitive experiment of anthrachose of mango. The result showed that anthrachose was inhibited by C-3 (Fig. 2). Hence, the microbiology in fermented livestock liquid for the inhibition of pathogen can be advanced research. Duan et al. (2019) regarded that *Bacillus subtilis* is a kind of microbiology that can inhibit some plant pathogen.

Conclusion

The fermented livestock liquid contains some beneficial materials that can promote the growth of plants. In addition to irrigating directly to crops, it can either rerard as the medium of liquid fertilizer products. From this experiment, the quality of tomato, waxapple and jujube were all increasing when applying the fermented livestock liquid fertilizer (LF or LFE). On the other hand, the microbiological phase was abundant in the treatment of LF, it was important clue for advanced research in the screening beneficial microbiology in the fermented livestock liquid.

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Table 1. The experimental treatments of livestock liquid fertilizer

Treatments	Description
CK	The treatment of no liquid fertilizer
CF	The liquid fertilizer was produced by water and diluted by water for 400X
LL	Because the liquid fertilizer was high in electrical conduction, so it was diluted for 10X
LF	The liquid fertilizer was produced by livestock liquid and diluted by water for 400X
LFE	The liquid fertilizer was produced by livestock liquid and diluted by effluent for 400X

common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF), fermented livestock liquid and diluted by groundwater (LL),
fermented livestock liquid fertilizer and diluted by effluent (LFE),
the treatment of no liquid fertilizer (CK).

Table 2. The variation of soil properties in tomato garden before and **after** experiments

Treatments	pH	OM	P	K	Ca	Mg	Fe	Mn	Cu	Zn

	(%)		--------------------------(mgkg^{-1})------------------------------							
[1]B.E.	6.77	2.50	128	276	3045	401	198	121	10	20
CK	6.75	2.45	135	266	3334	382	244	114	14	15
CF	6.12	3.60	134	345	3202	620	162	221	7.9	71
LL	6.46	4.31	124	370	3492	661	284	246	17	22
LF	6.15	4.97	160	395	3064	559	293	245	20	50
LFE	6.11	3.99	143	383	3157	560	175	241	16	33

[1] B.E.: before experiment
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
fermented livestock liquid fertilizer and diluted by effluent (LFE),
the treatment of no liquid fertilizer (CK).

Table 3. The variation of nutrients in the leaves of tomato before and after experiments

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	
	--------(%)---------			---------------------(mg kg^{-1})--------------------						
[1]B.E.	2.35	0.356	2.08	63865	3645	230	145	1272	110	20
CK	2.25	0.399	2.03	62990	3800	151	148	1325	124	
CF	2.00	0.400	1.90	66879	4465	168	367	1308	120	
LL	2.21	0.360	2.19	69150	3943	153	371	1263	131	
LF	2.69	0.391	1.91	65851	4482	150	393	1307	131	
LFE	2.97	0.389	1.90	67999	4230	159	381	1265	120	

[1] B.E.: before experiment
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
fermented livestock liquid fertilizer and diluted by effluent (LFE),
the treatment of no liquid fertilizer (CK).

Table 4. The compared fruit quality of tomato at harvesting stage

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Solube solid (°Brix)
CK	12.8	3.9	2.3	7.3
CF	13.8	4.1	2.2	7.8
LL	14.7	4.2	2.4	7.3
LF	15.9	4.2	2.5	7.5
LFE	12.9	4.0	2.3	7.9

common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
fermented livestock liquid fertilizer and diluted by effluent (LFE),
the treatment of no liquid fertilizer (CK).

Table 5. The variation of soil properties in waxapple orchard before and after experiments

Treatments	pH	OM	P	K	Ca	Mg	Fe	Mn	Cu	Zn
		(%)	---------------------------------(mgkg^{-1})---------------------------------							
[1]B.E.	6.76	1.51	280	350	6109	372	128	198	6.9	23
CF	6.74	1.74	291	361	6115	371	120	177	6.8	19
LF	6.75	1.76	293	359	6130	376	130	185	7.1	22

[1] B.E.: before experiment
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
fermented livestock liquid fertilizer and diluted by effluent (LFE),
the treatment of no liquid fertilizer (CK).

Table 6. The variation of nutrients in the leaves of waxapple before and after experiments

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
	----------(%)--------			--------------------(mg kg^{-1})--------------------					
[1]B.E.	1.82	0.113	1.72	7332	2979	308	41	6	18
CF	1.85	0.121	1.72	7312	2888	311	45	10	20
LF	1.87	0.125	1.74	7318	2797	314	44	12	22

[1] B.E.: before experiment
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF)

Table 7. The compared fruit quality of waxapple at harvesting stage

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Soluble solid (°Brix)
CF	101.1	6.1	6.7	8.5
LF	107.4	6.2	6.8	11.9

common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF)

Table 8. The nutrient concentrations of mature leaves of jujube between different treatments

Treatments	Nutrient concentration									
	N	P	K	Ca	Mg	Mn	Fe	Cu	Zn	Na
	--------------------%------------------					--------------mg kg^{-1}-----------------				
(Before anthesis)										
CK	2.36	0.17	1.39	2.89	0.41	234.8	177.7	3.7	44.2	152.6
LL	2.29	0.16	1.58	3.22	0.42	196.0	130.5	3.4	32.7	143.7
LF	2.09	0.15	1.73	2.84	0.33	238.7	140.6	3.8	44.1	171.7
CF	2.16	0.19	1.31	2.70	0.45	257.5	127.8	4.1	49.4	164.4

(Fruit-setting stage)										
CK	2.41	0.16	1.42	4.13	0.45	483.7	268.9	8.1	69.7	301.2
LL	2.43	0.16	1.66	3.51	0.42	489.3	244.5	7.3	97.6	293.0
LF	2.33	0.15	1.87	3.31	0.33	435.3	184.0	8.6	72.4	316.4
CF	2.16	0.14	1.84	3.40	0.40	528.8	254.1	9.5	84.7	312.2
(After harvesting)										
CK	2.74	0.17	1.27	3.66	0.29	236.0	218.0	4.8	121.0	172.9
LL	2.75	0.17	1.59	2.98	0.20	153.0	162.5	4.5	176.1	169.3
LF	3.02	0.20	1.79	2.53	0.24	166.3	227.8	5.4	122.0	192.1
CF	3.09	0.19	1.60	3.39	0.33	314.8	450.5	6.3	145.4	259.6

common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
the treatment of no liquid fertilizer (CK).

Table 9. The nutrient concentration of jujube fruits between different treatments

Treatments	Nutrient concentration									
	N	P	K	Ca	Mg	Mn	Fe	Cu	Zn	Na
	--------------------%------------------					--------------mg kg^{-1}-----------------				
CK	0.72	0.11	1.20	0.078	0.038	8.35	24.41	1.63	8.20	77.40
LL	0.63	0.09	1.28	0.047	0.028	4.42	6.09	2.08	4.97	62.76
LF	0.87	0.12	1.34	0.050	0.047	8.47	21.34	1.45	7.23	78.28
CF	1.05	0.11	1.22	0.054	0.045	9.40	18.19	1.11	7.76	112.07

common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
the treatment of no liquid fertilizer (CK).

Table 10. The quality of jujube fruits between different treatments

Treatments	Fruits quality			
	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Soluble solids (°Brix)
CK	98.8±5.7a[z]	61.6±2.3a	55.1±0.8a	13.8±0.4b
LL	100.6±9.3a	61.7±2.7a	56.3±1.1a	13.8±0.3b
LF	107.6±7.4a	62.4±1.3a	56.7±1.4a	14.6±0.2a
CF	104.2±11.0a	62.7±0.6a	55.9±0.7a	14.0±0.8ab

[z] Mean ± standard error (n=10). Means within each column followed by the same letters(s) are not significantly different at 5% level by Fisher's protected LSD test.
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid fertilizer and diluted by groundwater (LF),
fermented livestock liquid and diluted by groundwater (LL),
the treatment of no liquid fertilizer (CK).

Table 11. The microbiology phases in different liquid fertilizer were analyzed

treatments	A-1	B-1	B-2	C-1	C-2	C-3	C-4
	-----------------------------(CFU/ml)--						
LL	212	-	-	-	-	-	-
CF	-	142	40	-	-	-	-
LF	-	-	-	230	310	190	47

*C-1:fungus C-2:Bacillus mycoides C-3及C-4: Bacillus subtilis
common liquid fertilizer and diluted by groundwater (CF),
fermented livestock liquid and diluted by groundwater (LL),
the treatment of no liquid fertilizer (CK).

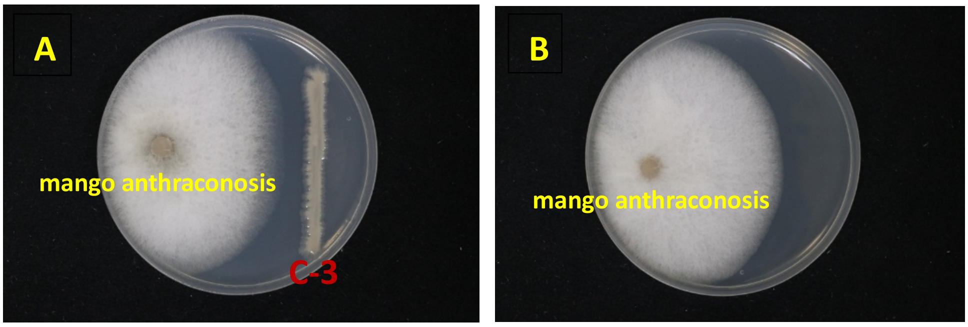

Fig. 1. The *Bacillus subtilis* (C3) strain screened from fermented livestock liquid fertilizer (LF) was chosen for the test of antibiosis of mango anthraconosis (A:treatment, B:check)

References

Baker, DE, Suhr, NH (1992) Atomic absorption and flame emission spectrometry. In A.L. Page, R. H. Miller and D. R. Keeneys. (eds.) Methods of Soil Analysis, Part 2. Agronomy Monograph No. 9. 2nd edition.ASA-SSSA, WI. p. 13-26.

Bao W, Yang Y, Fu T, Xie GH (2019). Estimation of livestock excrement and its biogas production potential in China. Journal of Cleaner Production. 229: 1158-1166.

Chang, S. H. 1981. Current plant analysis in our province. Fertilizer demand diagnoses technology. Special Issue No. 13, Taiwan Agricultural Research Institute. p.53-59

Chen, Y., J. J. Cheng and K. S. Creamer. 2008. Inhibition of anaerobic digestion process: a review. Bioresource Technology. 99: 4044-4064.

Cope. J.T. and C.E. Evans. 1985. Soil testing. Advances in Soil Sci. 1:201-228.

Duan , M., Zhang, Y., Zhou, B., Wang, Q., Gu, J., Liu, G., Qin, Z., Li, Z. 2019. Changes in antibiotic resistance genes and mobile genetic elements during cattle manure composting after inoculation with Bacillus subtilis. https://doi.org/10.1016/j. biortech.2019.122011

Holm-Nielsen, J. B., T. Al Seadi, and P. Oleskowicz-Popiel. 2009. The future of anaerobic digestion and biogas utilization. Bioresource Technology. 100: 5478-5484.

Jiao, G. S., Kim S., Moayeri, M., Thai A, Cregar-Hernandez, L., McKasson, L., O'Malley, S., Leppla, S. H., Johnson, A. T. 2018. Small molecule inhibitors of anthrax edema factor. Bioorganic & Medicinal Chemistry Letters. 28:134–139.

Kanu, P.J., Kanu, J.B., Sandy, H., E, B.A., Kande, J., Mornya, P.M.P., Huiming, Z., 2009. Optimization of enzymatic hydrolysis of defatted sesame flour by different proteases and their effect on the functional properties of the resulting protein hydrolysate. Am. J. Food Technol. 4 (6), 226–240.

Kelessidis A, Stasinakis AS. 2012. Comparative study of the methods used for treatment and final disposal of sewage sludge in European countries. Waste Manag. 32:1186-1195.

Kholmanskiy, A., Smirnov, A., Sokolov, A., Proshkin, Y. 2019. Modeling of extraction mechanism of mineral elements by plants. Current Plant Biology.

(https://doi.org/10.1016/j.cpb.2019.100104)

Lin Y. H. Chiu J. Y. 2019. Studies on the sod culture and the management of soil moisture for the improvement of waxapple quality. Afr. J Biotech. 18:719-725.

Liu, K., Wanga, X., Young, M. 2014. Effect of bentonite/potassium sorbate coatings on the quality of mangos in storage at ambient temperature. Journal of Food Engineering. 137: 16–22.

McLean, E.O.1982. Soil pH and lime requirement. In A.L.Page，R.H. Miller and D.R. Keeneys.(eds.) Methods of Soil Analysis, Part 2. Agronomy Monograph No.9. 2nd edition.ASA-SSSA, WI. p.199-224.

Murphy, J. and J. P. Riley. 1962. A modified single solution method for determination of posphate in natural waters. Anal. Chem. Acta. 27:31-36.

Nelson, D.W. and L.E. Sommer. 1982. Total carbon, organic carbon,and organic matter. In: A.L. Page. Miller and D.R. Keeneys. (eds.) Method of Soil Analysis, Part 2. Agronomy Monograph No. 9. 2nd edition. ASA-SSSA, WI. p.383-411.

Richardson SD, Ternes TA. 2011. Water analysis: emerging contaminants and current issues. Anal Chem. 83:4614-4648.

Vijayakumar S, Durgadevi S, Arulmozhi P, Rajalakshmi S, Gopalakrishnan T, Parameswari, N. 2018. Effect of seaweed liquid fertilizer on yield and quality of Capsicum annum L. Acta Ecologica Sinica. (https://doi.org/10.1016/j. chnaes.2018. 10.001)

Weiland, P. 2010. Biogas production: current state and perspectives. Applied Microbiology and Biotechnology. 85: 849-860.

Xu, J. C., Li-min Huang, Chengyu Chen, Jing Wang, Xin-xian Long. 2019. Effective lead immobilization by phosphate rock solubilization mediated by phosphate rock amendment and phosphate solubilizing bacteria. Chemosphere. 237:1-9.

Zhao, Z., Liao, D., Sun, J., Tong, Z., Huang, K., Sun, G., Wu, Z., 2012. Kinetic model of enzymatic hydrolysis of protein about the protein of silkworm pupae – Alcalase system. International Conference on Biomedical Engineering and Biotechnology 356–359.