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Establishing a Method to Evaluate the Maturity of Liquid Fertilizer by Liquid Fertilizer Germination Index (LFGI)

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With the ongoing growth of liquid manure production, it was necessary to build a proper certification system to check the fertilizer and pollutant qualities of manure fertilizer. The certification criteria of fertilizer and pollutant properties have been developed, but no certification method has been developed for testing the maturity of liquid manure fertilizer until now. Meanwhile, the germination index is a well–known parameter when measuring the maturity of fertilizer. Several methods are advised for measuring the germination of compost–based fertilizer. Until now, there was no specific method for certifying or performing a germination index test for liquid fertilizers. In this study, the ordinary germination index (GI) or Solid fertilizer germination Index (SFGI) is performed for 23 solid–composted fertilizers to evaluate the method's applicability when the average SFGI count is 137. However, when this method is applied to 26 liquid anaerobic manures, the average SFGI count was 22, with germination only happening for eight samples. When the LFGI method was applied for the same samples, the average LFGI count was 30 with 10 germinated samples. LFGI was applied to 66 liquid aerobic manure fertilizers that had mechanical maturity tests and were classified as 22 matured, 25 semi–matured, and 19 immature samples. The average LFGI results were 90 for matured samples, 25 for semi–matured, and 5 for immature. This study focused on finding a proper and acceptable germination index testing method to examine the maturity of liquid manure fertilizer.

Key words: Fertilizer dilution method, Germination index, Liquid fertilizer, Liquid Fertilizer Germination Index, Liquid manure

INTRODUCTION

The vast scale of livestock production produces a huge amount of manure around the world, which must be managed in a proper manner to avoid and reduce its negative effects on the environment (Burton & Turner, 2003). Due to the easy recycling and treatment methods of liquid manure compost or other treatment and easy application on crop fields, liquid manure fertilizer is becoming popular in Korea. Out of all the manure produced, 87% is recycled to land as compost and liquid organic fertilizer (Ahn, 2011). Among all types of livestock manure production, pig manure production is the highest according to Kim (2014) in the year 2013, the total annual livestock manure production was 47,235 × 1,000 tons. Among this, liquid composting as recyclable material was 3,997 × 1,000 ton/year, and pig manure production was 38.9% (Kim, 2014). The pig manure contains a vast amount organic matter, nitrogen, phosphorus, and potassium (Tam and Vrijmoed, 1990, 1993), along with variable quantities of calcium, magnesium, sulfur, and trace elements (Castillón, 1993), which may be found in an inorganic and soluble form. The demand for liquid pig manure as fertilizer is high due to its easy application, but compared to solid compost fertilizers, liquid manure fertilizers contain less nutrients, so liquid manure fertilizers have to be applied in large quantities (Kim *et al*., 2013). Therefore, with the high demand for liquid manure fertilizer, it was necessary to make and maintain some quality and standard measurement scales.

Along with fertilizer components, measuring the phytotoxicity and maturity are crucial elements to measuring prior to application. However, the maturity of compost reflects the level of phototoxic organic material decomposition (Gao *et al*., 2010). This may easily be examined by performing a Germination Index (GI) test (Kapanen and Itavara, 2001). This test is commonly performed by placing a number of seeds on a moist subtract (extracts), inside a container (on filter paper in a petri dish). This is then incubated in an incubator for a period of time under either dark or light condition.

The GI index is a simple and sensitive seed bioassay test method of performing a phytotoxicity test to measure the maturity of a compost based on the germination and root length of plant seeds placed in the compost (Selim *et al*., 2012; Sánchez and González, 2002; Helfrich *et al*., 1998; Zucconi *et al*., 1985).

A general method for performing the GI test for solid composted fertilizers (Solid Fertilizer Germination Index or SFGI) has been established by Zucconi (1981a); this has been testified by many scholars and accepted by the Korean Fertilizers Control Act; 2015(RDA Notification No. 2015–10). However, there was no established specific GI method that could certify the maturity degree for liquid fertilizers until now. Though the idea of Liquid Fertilizer Quality Certification (LFQC) system has been developed to certify the proper use of liquid livestock

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manure in an environment friendly way (Jeon *et al.*, 2013). Along with the specification of the fertilizer and pollutant materials, finding the maturity degree of liquid fertilizer is an essential criterion of the LFQC system, but it still has not mentioned any specific GI testing method. Therefore, determining a GI experiment method for liquid fertilizers was essential.

The preparation of a sample extract for the germination index is the most important stage. The proper level of sample and water (dilution of samples) ensures the controlled germination of the seeds. Solid composted fertilizers were actually diluted a second time when performing the GI test, because the manure or slurry is mixed with bulking agents (moisture control agent) while it gets composted. However, the liquid manure was treated in its raw liquid or semi–liquid form, so the dilution rate was not proper when performing the GI test for liquid fertilizers according to the SFGI method. This is why we have focused on finding a supportable and well accepted modified germination index formula in this study, which is applicable for liquid fertilizers (or liquid manure fertilizers). We named this modified formula the Liquid Fertilizer Germination Index (LFGI). The modification was on the dilutional (sample, water mixing rate) stage of the total GI testing processes.

MATERIALS AND METHODS

Materials

Solid composted fertilizer (23 specimens) was collected from a local agricultural market. Anaerobic fermented liquid manure (26 specimens) was collected from the Ichon biogas center. In total, 66 aerobically treated liquid fertilizers were collected from national livestock manure co–recycling facilities and manure distribution centers all across South Korea.

Experimental objectives

The total experiment was divided into five parts. 1) determine a proper dilutional (fertilizer sample and water mixture) method for the pretreatment of liquid fertilizer raw samples, 2) evaluate the SFGI method for its effect on solid composted fertilizer, 3) applying SFGI and LFGI on anaerobic digested liquid manure to compare the effects of both methods on the same liquid manure and 4) comparing the LFGI method with mechanical maturity testing to evaluate the effectiveness of the LFGI method as a reliable maturity testing process, 5) we also studied the changes of the physiochemical (fertilizer component) parameters of this samples to evaluate their appliances with LFGI.

Concept of LFGI

The LFGI dilution index was based on three concepts. First, the moisture values of the manure types. Second, the moisture volumes at a 65% moisture level (in 1 kg of standard manure) and their moisture–solid dilution ratios. Third, the average of all three dilution ratios as shown in Table 1. We consider this average value (1.533) a constant number.

The equation used to determine the moisture volume is

$$\textit{required amount(kg)} = \textit{raw manure volume(kg)} \times \frac{\textit{moisture of raw manure}(\%) - \textit{targgeted moisture volume}(\%)}{\textit{trageted moisture}(\%) - \textit{moisture volume of controll medium}(\%)}$$

level of liquid manure fertilizers, total solids, and the first dilution rate found through SFGI dilution multiplied by 1.533 to index the final dilution for liquid manure fertilizers. The index ranged from 95% moisture (or 5% solid) because it has been said the liquid fertilizers should contain 95% or higher moisture content (Jeon *et al.*, 2013). We named this index as LFGI dilution index (Table 2).

The general dilution and germination index formula for solid composted fertilizer

After measuring the moisture percentage of solid composted fertilizer, a sample was taken using the "$\frac{5 \times 100}{100 - \textit{moisture}} = \textit{sample volume}$" formula. The dilutional medium water was determined as, example, with 50% moisture content, total estimated volume (110 ml) = sample volume 10 g + water amount 100ml. Samples and water were taken in Erlenmeyer flasks for pre–treatment.

Treatment, extract application, and incubation

The samples and water were mixed using a water bath at 70°C for two hours. Sample extracts were filtered on no.2 Whitman filter paper. Two filter papers were placed in an 85 mm Petri dish and 5 ml of treated sample was applied in the Petri dish (Gao *et al.*, 2009; Monireh

Table 1. Moisture determination and constant dilution rate index of raw manure

Raw material	Composting process	Amount of raw material	Approximate highest level of moisture	Target moisture level	Resultant moisture volume	Dilution ratio	Average value
Pig manure	Scraped solid manure	1 kg	73.9%	65%	0.225	1.225	1.533
	Slurry type		90%		0.625	1.625	
	Manure, urine, liquid mixed composition		95%		0.75	1.75	

Table 2. LFGI dilution index (the final dilution index) for liquid composted fertilizer

Moisture (%)	TS (%)	First dilution rate	Constant index	Final dilution	Moisture (%)	TS (%)	First dilution rate	Constant index	Final dilution
95	5	2.0		3.1	97.3	2.7	1.54		2.4
95.1	4.9	1.98		3.0	97.4	2.6	1.52		2.3
95.2	4.8	1.96		3.0	97.5	2.5	1.5		2.3
95.3	4.7	1.94		3.0	97.6	2.4	1.48		2.3
95.4	4.6	1.92		2.9	97.7	2.3	1.46		2.2
95.5	4.5	1.9		2.9	97.8	2.2	1.44		2.2
95.6	4.4	1.88		2.9	97.9	2.1	1.42		2.2
95.7	4.3	1.86		2.9	98	2	1.4		2.1
95.8	4.2	1.84		2.8	98.1	1.9	1.38		2.1
95.9	4.1	1.82		2.8	98.2	1.8	1.36		2.1
96	4	1.8		2.8	98.3	1.7	1.34		2.1
96.1	3.9	1.78	1.533	2.7	98.4	1.6	1.32	1.533	2.0
96.2	3.8	1.76		2.7	98.5	1.5	1.3		2.0
96.3	3.7	1.74		2.7	98.6	1.4	1.28		2.0
96.4	3.6	1.72		2.6	98.7	1.3	1.26		1.9
96.5	3.5	1.7		2.6	98.8	1.2	1.24		1.9
96.6	3.4	1.68		2.6	98.9	1.1	1.22		1.9
96.7	3.3	1.66		2.5	99	1	1.2		1.8
96.8	3.2	1.64		2.5	99.1	0.9	1.18		1.8
96.9	3.1	1.62		2.5	99.2	0.8	1.16		1.8
97	3	1.6		2.5	99.3	0.7	1.14		1.7
97.1	2.9	1.58		2.4	99.4	0.6	1.12		1.7
97.2	2.8	1.56		2.4	99.5	0.5	1.1		1.7

et al., 2012; Amalia, 2011). Thirty radish seeds were placed in each Petri dish (Han, 2008), and this was repeated for five Petri dishes, using a total of 150 radish seeds (Zaha and Manciulea, 2013; Lau and Wong, 2001) (Xihu radishes; 85% germination). For the control, 5 ml of distilled water was used. Petri dishes were wrapped and sealed with Para films to protect against moisture loss and air penetration (Selim *et al*., 2012). Finally, they were kept in an incubator at 25 ± 1°C (Amalia, 2011), with 85 ± 1% humidity, and in dark condition (Tiquia *et al*., 1996; Gao *et al*., 2009). After 72 hours, 3 ml distilled water was added and wrapped with Para films again. The seeds were germinated for 120–125 hours, and the root length was measured.

Calculation of germination: Germination index was calculated in accordance with Zucconi *et al*., (1981b, 1985):

GR = (germination / control germination rate) × 100
RE = (root length / control root length) × 100
GI = GR × RE / 100.

Analytical methods and experiments followed to test the physiochemical properties:

The physiochemical properties of the 66 aerobic samples were analyzed for pH, Electrical Conductivity (EC), Total Phosphorus (TP), Total Nitrogen (TN) and Ammonium Nitrogen (NH_4–N), Nitric Nitrogen (NO_3–N), and Total Solid (TS). The pH and EC were measured with a handheld meter (YSI–556MPS, USA). NaCl was measured using the silver nitrate titration method, for after GI treatment by the ionic electronic method. TP was determined by the Ascorbic acid method (APHA, 2005). TN, NH_4–N, and NO_3–N were analyzed by the Kjeldahl method followed by the sewage analysis standard methods of JSWA, 1984. The maturity of samples was determined with a KSP gas analyzer.

RESULTS AND DISCUSSION

The germination index results for 23 composted solid fertilizer samples and 26 anaerobic liquid fertilizer samples according to their test method types

The germination index results of three types of GI test showed the accuracy and efficiency of the formula used to determine the germination according to their type. The suggested germination level for maturity testing was 70 (Jeon *et al*., 2013). We can see the distinction of the germination index of the samples in Table 3 based on the scale of 70 germination count.

When the SFGI method was used for the 23 composted solid fertilizers, the average germination was 137 and the minimum germination was 99, which means that

Table 3. Germination index test results of the 24 composted solid fertilizer samples (SFGI method) and the 26 anaerobic liquid digested samples (SFGI & LFGI methods)

Sample no.	Sample type	GI method	SFGI	Sample no.	Sample type	GI method	SFGI	GI method	LFGI
1			144	1			0		0
2			134	2			0		0
3			165	3			73		99
4			99	4			0		0
5			169	5			0		0
6			129	6			81		95
7			129	7			0		0
8			128	8			0		0
9			159	9			70		85
10			125	10			79		84
11			128	11			80		95
12	Solid composted	SFGI	143	12			66		74
13			134	13			7		79
14			134	14	Anaerobic liquid manure	SFGI	0	LFGI	0
15			103	15			0		0
16			186	16			0		0
17			119	17			0		0
18			136	18			0		0
19			190	19			0		0
20			156	20			0		27
21			148	21			0		0
22			102	22			0		0
23			104	23			54		81
Average			**137**	24			71		75
				25			0		0
				26			0		0
				Average			**22**		**30**

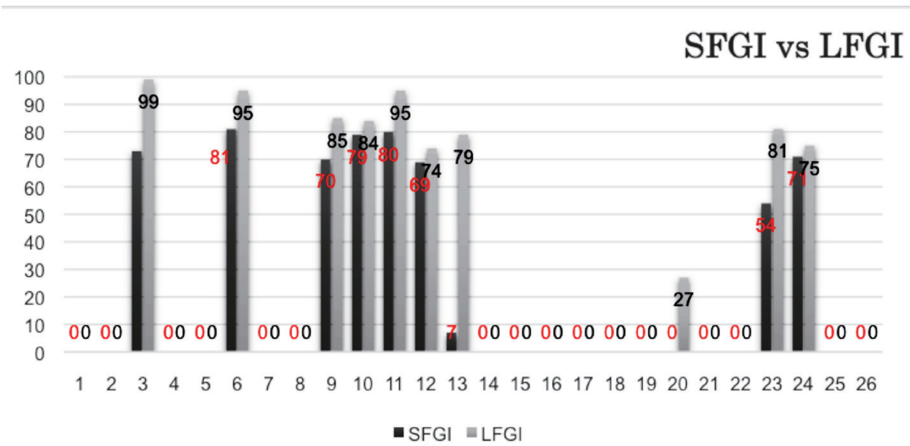

Fig. 1. Comparisons between the germination results of LFGI and SFGI (26 anaerobic liquid digested samples).

the SFGI method and dilution rate for composted solid fertilizer were accurately showing the samples' maturity. When it follows for SFGI and LFGI were applied for testing the germination index of 26 liquid anaerobic fertilizers. Here we see that when SFGI method was applied with SFGI dilution for liquid manures, the average germination was 22, the minimum germination was 0 (zero), and the highest germination was 81. Meanwhile, when we applied the LFGI method to the same samples, the average germination became 30, the lowest was 27 (lowest germination was 0 for the SFGI method), and the maximum germination was 99, whereas highest was 73 when SFGI was applied. Fig. 1 shows the differences between the germination methods applied to liquid anaerobic digested material more clearly.

GI results of aerobic composted samples (66): Application of LFGI methods and comparison of the germination results with the maturity degree (mechanical method)

According to mechanical maturity testing, 22 out of 66 samples were evaluated as matured, 25 samples were semi–matured, and 19 samples were evaluated as immature. We applied the LFGI to check the germination index and evaluate these 66 fertilizer samples maturity levels to the mentioned classification. Table 4 shows the germination index results, where according to the scale of 70 germination index maturity, 22 (samples 1–22) samples showed 90average germination count, where the maximum germination was 121 and the lowest was 77 (not counting 0 as lowest). The next 25 (samples 23–47) semi–matured fertilizers had average 25 germination, but among the germinated samples the lowest count was 9 and highest was 118. The 19 (samples 48–66) immature fertilizer samples had an average germination count of 5, where most of these samples had a 0 (zero) germination count.

Changes of pH, EC, and NaCl of 66 aerobic liquid fertilizer specimens

The pH values of the samples or growth media break the seed coats to insert more liquid from the medium. A study from Zaha *et al.* (2013) mentioned that pH is a valuable factor for microorganisms, nutrients, and soluble heavy metal, thus low pH of composting processes creates odor and slows undeveloped decomposition. Which may reflect on low germination. The pH range be should maintained at 6–9 during the composting proc-

Table 4. Germination index count of 66 aerobic composted liquid fertilizer samples, LFGI methods

Sample No.	LFGI	Sample No.	LFGI	Sample No.	LFGI	Sample No.	LFGI
1	96.03	23	0.00	45	0.00	48	0.00
2	89.65	24	0.1209	46	54.85	49	0.00
3	0.00	25	0.00	47	0.00	50	0.00
4	**121.19**	26	0.1017	**Average**	**25**	51	0.00
5	109.31	27	102.67			52	0.65
6	85.50	28	118.05			53	0.09
7	90.41	29	0.00			54	0.00
8	90.12	30	0.00			55	**102.52**
9	**77.87**	31	0.03			56	0.10
10	91.52	32	24.61			57	0.01
11	79.86	33	0.00			58	0.00
12	102.32	34	**9.38**			59	0.00
13	80.67	35	28.75			60	0.00
14	87.92	36	9.51			61	0.15
15	98.29	37	64.25			62	0.09
16	100.29	38	14.90			63	0.00
17	85.25	39	0.50			64	0.03
18	108.12	40	0.14			65	0.02
19	117.44	41	0.00			66	0.06
20	79.30	42	0.01			**Average**	**5**
21	91.42	43	93.42				
22	96.31	44	92.33				
Average	**90**						

N0. 1–22 (22) = mature
No. 23–47 (25) = semi–mature
No. 48–66 (19) = immature

Table 5. Physiochemical properties of the 66 samples with respect to the maturity degree

Items			Matured (22)	Semi–mature (25)	Immature (19)
pH	1)	Mean± SD*	7.9 ± 1.1	8.3± 0.5	8.3± 0.5
		Max	8.7	9.0	8.9
		Min	4.6	6.3	7.6
	2)	Mean± SD*	8.3 ± 1.3	8.7 ± 0.4	8.7 ± 0.1
		Max	9.1	9.1	8.9
		Min.	4.5	6.7	8.4
EC (mS/cm)	1)	Mean± SD*	9.9 ± 5.4	18.4 ± 6.6	20.6 ± 7.3
		Max	23.5	29.1	35.9
		Min.	4.1	5.4	10.3
	2)	Mean± SD*	5.1 ± 2.3	8.6 ± 2.7	9.3 ± 2.4
		Max.	10.6	13.4	14.4
		Min.	2.5	3.0	5.0
NaCl (mg/L)		Mean± SD*	1,007 ± 532.1	1,411 ± 592.7	1,587 ± 429.3
		Max.	2,523	2,513	2,533
		Min.	387	168	931
TN (mg/L)		Mean± SD*	534 ± 613.8	1,924 ± 949.6	2,242 ± 944.3
		Max.	2,942	3,397	4,277
		Min.	39	280	562
NH_4–N (mg/L)		Mean± SD*	238 ± 481.9	1,313 ± 766.5	1,752 ± 784.3
		Max.	2,228	2,858	3,488
		Min.	0	165	392
NO_3–N (mg/L)		Mean± SD*	74 ± 93.2	11 ± 7.9	14 ± 8.5
		Max.	426	27	36
		Min.	0	0	0
TP (mg/L)		Mean± SD*	182 ± 163.6	154 ± 126.4	129 ± 107.7
		Max.	608	634	463
		Min.	19	18	34
K (mg/L)		Mean± SD*	1,691 ± 857.2	2,425 ± 746.6	2,034 ± 779.9
		Max.	3,472	3,898	3,574
		Min.	88	796	34

1) Undiluted liquid manure Specimens
2) After the LFGI pre–treatment method applied to the extract (filtrate)
* SD* = Standard Deviation

ess, as mentioned by Silverstein, Eklind *et al*. and Michel *et al*. (2005; 2000; 1998).Based on maturity values of the 66 aerobic liquid fertilizer samples classified as mature, semi–mature, and immature and according to this classification, the pH (Mean) values in undiluted stage were changes in the order of 7.9, 8.3 and 8.3 shown in Table 5 and Fig. 2. Shaik and Mehar (2015) mentioned that a slightly reduced pH (i.e. increased acidity) and a slightly increased pH value (i.e. increased alkalinity) may have a positive impact on germination. However, their Mean pH values changes after the dilution as in order to 8.3, 8.7 and 8.7 (Table 5).

EC is related to the release of decomposing compounds and shows the soluble ions count, which is related to the quality of the compost or fertilizers. Lin (2008) mentions that the EC values show the salinity of composting, which may indicate the phytotoxicity through a low germination rate. Several studies show that the range of EC should be 2.0–3.5 mS/cm (Fernández *et al*., 2007; Tiquia, 2005; Saviozzi *et al*., 1987) for a preferable maturity. The evaluations of EC for the three stages of 66 aerobic liquid manures are shown in Fig. 2. The EC value was frequently increased from the matured to immature stage. The germinated samples' respective EC ranges (Mean) according to their evolution stages in undiluted form were 23.5–4.1(9.9) mS/cm, 29.1–5.4(18.4) mS/cm and 35.9–10.3(20.6) mS/cm. However, from Table 5 after performing the dilution according to LFGI dilution index, the EC values ranges (Mean) reduced in order to 10.6–2.5(1.6) mS/cm, 13.4–3.0(8.6) mS/cm and 14.4–5.0(9.3) mS/cm.

According to the liquid fertilizer quality certification

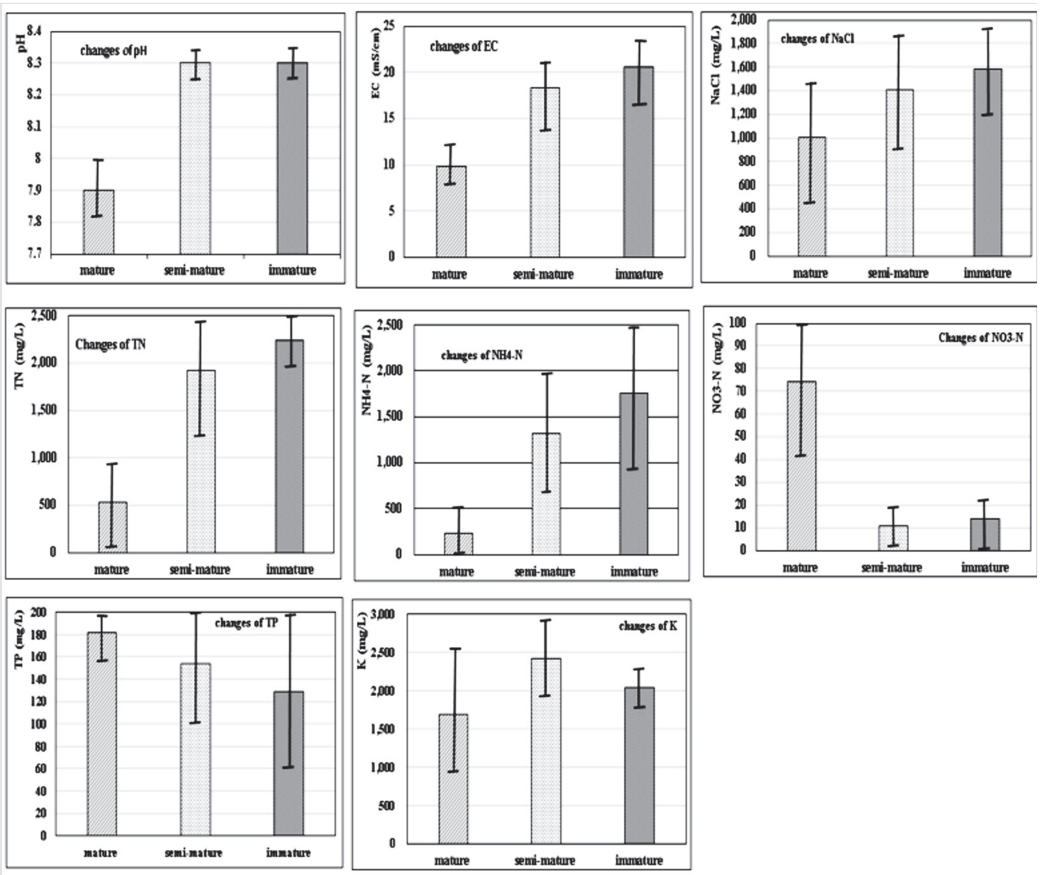

Fig. 2. Changes in pH, EC, NaCl, TP, K, TN, NH_4–N, and NO_3–N with respect to the degree of compost maturity (66 samples: matured 22, semi–matured 25 and immature 19).

(LFQC) system, the EC range should be 15 mS/cm or less (Jeon *et al.*, 2013). Fig. 3a shows the relative changes between LFGI and EC. Where the highest LFGI count was 121, had EC concentration of 6.9 mS/cm and the lowest LFGI count (on a GI count scale of 70) 77, had 6.3 mS/cm. Meanwhile, the highest EC concentration was 35.9 mS/cm with no germination count and the lowest EC concentration of 4.1 mS/cm had a moderate LFGI count of 89.

The proposed salt or NaCl level for liquid fertilizers in LFQC was 0.3% or less (Jeon *et al.*, 2013b). Mahmoodzadeh *et al.* (2013) mentioned in a study that germination happens in conditions with less salt stress, because seed germination may be stressed or slowed by the salt concentration of the medium (Khan *et al.*, 2000). The respective concentration ranges (mean) of NaCl changes for 66 aerobic specimens based on mature, semi–mature, and immature were 2,523–387(1,007) mg/L, 2,513–168(1,411) mg/L and 2,533–913(1,587) mg/L in the raw stage (Table 5). The sequential change of NaCl is shown in Fig. 2.

Changes of TN during the physicochemical evaluation of 66 aerobic samples

N is one of the most important fertilizer values of the NPK system, and TN is the sum of all types of available N found in sources. TN is one of the fertilizer values that is often used to index its maturity (Hosseine and Aziz, 2013). TN shows high enhancement (Fig. 2) between matured, semi–matured, and immature stages. The respective Mean values of which were 534 mg/L, 1,924 mg/L, and 2,242 mg/L (Table 5). From Fig. 3b, we see the TN concentration and GI count has a negative relation. LFGI count decreases while the concentration of TN increase (in other hand LFGI count increase with Decreased TN concentration). It is because the changes of TN concentration may dependents with the state of the of treatment stage (Kim *et al.*, 2015). The range of TN was uniformly changed with the GI results and maturity stages. From immature to matured stage the ranges of TN were 4,277–562 mg/L, 3,397–280 mg/L and 996–39 mg/L. The highest TN concentration of 4,427 mg/L (4.427%) had a 0 (zero) GI count, while it shows 102 LFGI count when TN concentration was 562 mg/L. With 280 mg/L TN concentration points LFGI counts of 102 in the same time the lowest TN concentration which was 39 mg/L had a 100 LFGI count.

Changes of NH_4–N, NO_3–N during the physicochemical evaluation of 66 aerobic samples

NH_4–N and NO_3–N are plant–available forms of N, while organic N is not immediately plant–available (Pettygrove *et al.*, 2009). NH_4–N and NO_3–N are the inorganic or mineral forms of N in manure fertilizers. In this part of the study, NH_4–N increased and NO_3–N decreased in accordance with the stages of specimens' maturity classification from matured to immature (Fig. 2). The respective Mean NH_4–N values increased as 238 mg/L,

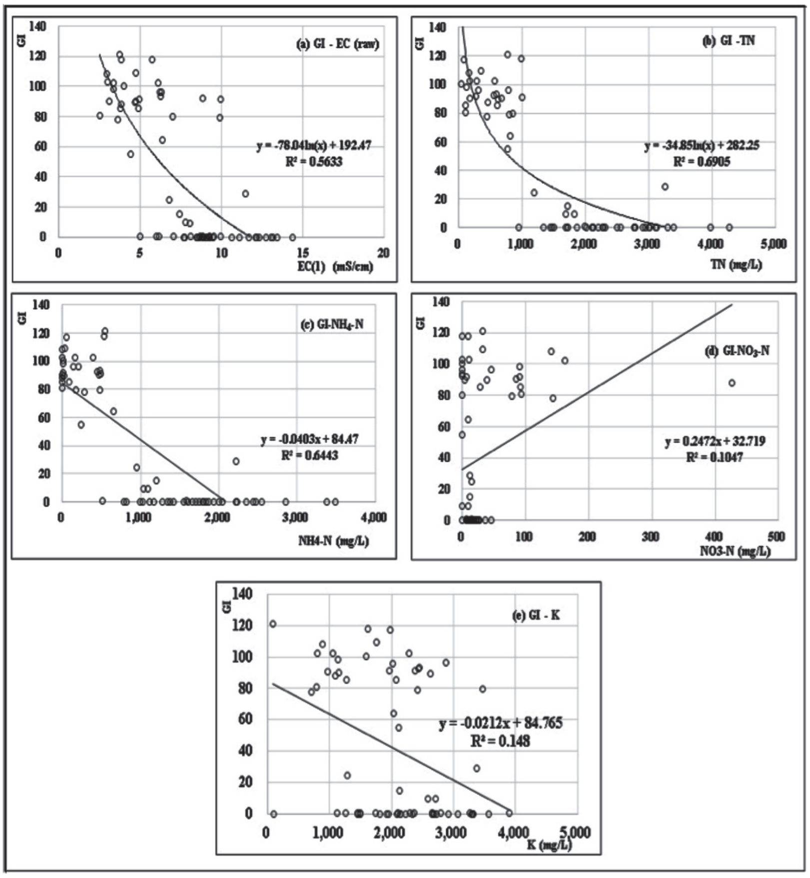

Fig. 3. Relationship between the LFGI and physiochemical properties (EC, TN, NH_4–N, NO_3–N, and K) for the 66 aerobic liquid fertilizer samples.

1,313 mg/L, and 1,752 mg/L in order to mature, semi–mature and immature (Table 5). Fig. 3c shows the interrelation between GI and NH_4–N; the mature specimens showed less NH_4–N than the semi–mature or immature specimens, and the highest to lowest LFGI counts of all 66 samples. The LFGI count reduce with increased NH_4–N concentration. The maximum LFGI count of 121 had a NH_4–N concentration of 539 mg/L, while the maximum 2,228 mg/L NH_4–N concentration showed a LFGI count of 0(zero). Meanwhile, the lowest germinated specimen with a 77 LFGI count (on the scale of 70 GI count) had 286 mg/L NH_4–N concentration, but the minimum NH_4–N concentration of 0(zero)mg/L showed a moderate 1080 LFGI count. Scholars have shown previously that a high NH_4–N concentration with unsterilized condition (Bernal *et al*., 1998) has a negative impact on the growth and germination of seeds (Walch *et al*., 2000; Raab and Terry, 1994). Here, the NH_4–N concentrations of the matured specimens were relatively lower than those of the other maturity classes, which may support the notion of a relationship between a high LFGI count and low NH_4–N.

NO_3–N is the anion form of N (Miller and Donahue, 1990) also NO_3–N is an oxidized form of NH_4–N (Kim *et al*., 2013 and Hooda *et al*., 2000) which may reduce with the stages of maturity, from mature to immature. The respective Mean concentrations of NO_3–N were 74 mg/L, 11 mg/L, and 14 mg/L, as shown in Table 5 and Fig. 2. The Fig. 3d shows the positive but informal relation in NO_3–N and LFGI count. In general the trend of high NO_3–N shows a high LFGI count. Highest NO_3–N concentration 462 mg/L shows 87 LFGI count following, NO_3–N concentration 163 mg/L shows 102 LFGI count relatively low 78 mg/L NO_3–N concentration shows 79 LFGI count, follows 39 mg/L NO_3–N had 89 LFGI count. When the NO_3–N level goes lower relative LFGI also get lower, as several 0(zero) LFGI counts shows with lowest NO_3–N concentration respectively 17 mg/L, 12 mg/L, 9 mg/L, 8 mg/L. This partially supports the previous report that mentioned how NO_3–N stimulates the germination of seeds (Egley, 1986; Bench–Aroled *et al*., 2000). NO_3–N may production or increase when the NH_4–N concentration gets lower and the material gets matured (Finstein and Miller, 1985), Tiquia *et al*. (1996) shows increase of NO_3–N are resulted at a time decrease of NH_4–N are because of the conversation of NH_4^+ to NO_3^- through nitrification processes. Which may support the decrease of NH_4–N and the increase of NO_3–N according to the specimen's maturity level (mature to immature).

Changes of TP and K during the physicochemical evaluation of 66 aerobic samples

Phosphorus (P) is an essential macronutrient that can limit or increase plant growth. Fig. 2 evaluates the states of TP according to the maturity classification. For the mature, semi–mature, and immature stages, the respective Mean TP concentrations were 182 mg/L, 154 mg/L, and 129 mg/L. The range of TP values according to the maturity stages were respectively 608–19 mg/L, 634–18 mg/L and 463–34 mg/L. (Table 5). The decreasing concentration of TP along with LFGI count, from mature to immature specimen fertilizers, supports that the germinated seeds had a sufficient TP concentration to supply high energy (Better Crops/Vol. 83 (1999, No. 1))

The K concentration in manure helps seeds grow up and survive in stressful conditions (Kant, 2002). In this study (Table 5), the average K concentration values were 1,691 mg/L, 2,425 mg/L, and 2,034 mg/L, according to their maturity level, which is not sequential from (Fig. 2). We found from Fig. 3e that the K has a negative relation with LFGI. Meanwhile, the highest K concentration of 3,898 mg/L had a 0(zero) LFGI count followed by 710 mg/L K concentration shows 77 LFGI count(lowest GI count on the scale of 70) and the lowest K concentration of 88 mg/L had the highest LFGI count of 121.

Because of the higher solubility and inorganic form of K found in the liquid phase of slurry (Duthion *et al.*, 1979) or liquid fertilizer (Kim *et al.*, 2013). The proper disposition (Askegaard and Eriksen, 2008, Eichler–Löbermann *et al.*, 2009) and inorganic form of K gave the seeds easy access to uptake K, which may be reflected in matured samples.

CONCLUSION

The SFGI method is not suitable for liquid fertilizers because of the high concentration of nutrients and organic and mineral components. Therefore, when we tried to dilute the samples by following the SFGI method it showed much lower dilutions. This is why we had to make compatible dilution rates, so we multiplied the primary dilution by 1.533.

The germination index of the 23commercial composted solid fertilizers had an average of 137, and the range of their GI was about 99–190, where recommended level of germination is 70. So this clearly proves the efficiency of the SFGI method for solid composted fertilizer. However, when we compared both methods for the 26 anaerobic digested samples, we got a great difference between the SFGI and LFGI results. In this case, the germination happened for both methods but the SFGI method (dilution) never reached 90 (the highest was 81) but when trying the LFGI germination method (dilution), the lowest germination we got was 27 while the same specimen showed 0 (zero) germination for SFGI, in same time the highest LFGI was 99. Furthermore, LFGI made a large difference with SFGI in germination for every sample. This shows us the efficiency of LFGI for liquid manure fertilizers.

The 66 aerobic liquid fertilizer samples were classified based on their color, odor (NH_3 and H_2S), and statistical process and were classified as matured, semi–matured, or immature. When applying the LFGI method to these samples, it was found that the average germination for the 22 "mature" samples was 90, 25 for the 25 "semi–mature" samples, and only 5 for the 19 "immature" samples. Therefore, the germination index followed by LFGI supports the mechanical method, and the inverse, the mechanical method supports LFGI. The physiochemical tests of these 66 samples also support the maturity classifications with GI. The respective average values of the properties and their classifications were 7.9, 8.3, and 8.3 for the pH; slightly increase or decrease were associated with germination. Average EC value was 9.9 mS/cm, 18.4 mS/cm, and 20.6 mS/cm shows the lower values of EC associated with higher germination. As followed average TN 534 mg/L, 1,924 mg/L, and average NH_4–N 238 mg/L, 1,313 mg/L and 1,752 mg/L, shows negative relation with LFGI according with maturity level. The average NO_3–N was 74 mg/L, 11 mg/L, and 14 mg/L and for the TP concentration was 182 mg/L, 154 mg/L, and 129 mg/L decrease with the maturity levels from mature to immature which shows a positive relation with LFGI. From all the statements above, the LFGI method may possibly be used as a maturity testing tool for testing the maturity of liquid manure and liquid fertilizers.

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