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Utilization of waste from a milk cake factory to produce liquid organic fertilizer for plants

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Abstract

The aim of this study was to assess the suitability of utilizing waste from a milk cake factory to produce liquid organic fertilizer with high organic matter and nutrient content. The raw materials for liquid organic fertilizer production were waste water, sewage sludge, molasses and microorganisms. The liquid organic fertilizer fermentation process was completed in 12 weeks. The suitable concentration of liquid organic fertilizer was determined in trials with chinese kale (*Brassica alboglabra* L.H. Bailey) and marigold (*Tagetes erecta* L.). A fertilizer produced at a ratio of 10 : 2 : 1 : 30 [wastewater (L) : sewage sludge (kg) : molasses (kg) : effective microorganisms (mL)] sprayed every other day at concentration of 0.002% (v/v) to foliage of chinese kale, and at a ratio of 20 : 2 : 1 : 30 applied at 0.003% concentration to roots of marigold showed the best growth response.

Key words: liquid organic fertilizer, milk cake, chinese kale, marigold.
Abbreviations: EM, effective microorganisms; T, treatment.

Introduction

Liquid organic fertilizers are natural materials of either plant or animal origin. They include crop residues, livestock manure, household waste, and food industrial waste. Liquid fertilizers are more uniform in mixture of nutrients compared to a solid form. Since there is a good relationship between water content and nutrient availability, the use of liquid organic fertilizer may be an efficient way of enhancing nutrient uptake. Continued use of liquid organic fertilizers results in increased soil organic matter, reduced erosion, better water infiltration and aeration, and higher soil biological activity, as the materials decompose in soil, and increased yields are obtained after one year of application (Riddech et al. 2009). Also, use of organic fertilizer may lead to control of some soil borne bacterial and fungal pathogens (Ndubuisi-Nnaji et al. 2011).

Milk cake or Mochi milk cake is a classic cake of the Nakhon Sawan province, Thailand. It is made from red bean, soybean, coconut, taro, and chocolate filling. There are more than 20 milk cake factories in the Nakhon Sawan province. High volume of milk cake factory production creates large quantities of solid and liquid waste. Treatment of milk cake factory wastewater generaly involves removing wheat flour and soybean meal before the remaining water is discharged to the environment. However, most of these factories have no control and treatment facilities and waste discharge can cause serious problems to the environment due to high biological oxygen demand, and total nitrogen and total phosphorus content in the waste water: 1 920 ± 26 mg L^{-1}, 216 ± 11 mg L^{-1} and 180 ± 21 mg L^{-1}, respectively (Netpae 2010). Recently, a new concept for sludge and wastewater management involving its use as a fertilizer for production of field and vegetable crops was developed (Sermviriyakul 2004).

The aim of this study was to assess the suitability of utilizing wastewater from milk cake factory to produce liquid organic fertilizer, as this may decrease the use of chemical fertilizers and help lower production costs and environmental hazards on a long-term basis.

Materials and methods

Preparation of fertilizer

Wastewater and sewage sludge in different proportions plus equal amounts of molasses and effective microorganisms (EM) were used to prepare 12 types of fertilizer (Table 1). The EM used in this study were produced by Nongbour-Ubon. The fertilizer production conditions were adapted from Larptansuphaphol and Jitjumroonchokchai (2009).

The following physicochemical characteristics were determined according to the procedures by Peverill et al. (1999): temperature, pH, electrical conductivity, total nitrogen, total phosphorus, total potassium, C/N ratio, calcium (Ca), magnesium (Mg), copper (Cu), ferrous (Fe), and zinc (Zn). Liquid organic fertilizer samples were analyzed every five days until liquid organic fertilizer fermentation was complete. The composting process depended on physicochemical parameters and the frequency and degree of turning it over (Punsak, Pampasit 2001).

Table 1. Ratio of various liquid materials used to produce different types of organic fertilizer. Molasses 1 kg and EM 30 mL were added to all fertilizer types

Material	Fertilizer types											
	1	2	3	4	5	6	7	8	9	10	11	12
Waste water (L)	10	15	20	10	15	20	0	0	0	10	15	20
Sewage sludge (kg)	1	1	1	2	2	2	0	1	2	0	0	0
Distilled water (L)	0	0	0	0	0	0	10	10	10	0	0	0

Plant trials

Plant trials were conducted in Thailand from April to July of 2010 in an artificial greenhouse (5 × 6 × 25 m) with a plastic roof. Corrugate iron and blue net were used as a border around the greenhouse. A separate, randomized completely block design with 27 treatments, three replications was used in this study. The treatments (T) were as follows: foliar fertilizer from milk cake factory waste (T1 to T12), soil fertilizer (T13 to T24), control without fertilizer (T25), chemical fertilizer NPK 20-10-10 foliar fertilizer (T26) and soil fertilizer (T27).

The soil used in all treatments was obtained up to a 25 cm depth from an undisturbed area at Nakhon Sawan Rajabhat University, Thailand. The soil was oven dried at 60 °C for 24 h and sieved through a 2 mm mesh before use (Kasim et al. 2011). Commercially available seed of chinese kale (*Brassica alboglabra* L.H. Bailey) and marigold (*Tagetes erecta* L.) from Chia Tai Co., Ltd., Thailand was used. The seeds were sown in seed-beds with subsequent application of fertilizers. The seedlings were transplanted after 20 days into pots containing soil (Sangwan et al. 2010; Raichontara 2011). Plastic pot size was diameter 30 cm and height 25 cm. All pots were filled to field capacity with distilled water, and maintained in this condition during the experiment. If leakage occurred, the lost solution was brought back to the soil to avoid nutrient loss. The pots were placed inside a greenhouse within the experimental field and maintained at temperature 29.2 ± 2.7 °C and sunlight period 12 h. All treatments were watered for 30 seconds twice daily. Foliar and soil fertilizer concentrations of the milk cake factory waste were 0.002% (v/v) and 0.003% (v/v), respectively. Fertilizer was applied every two days until harvesting (Punsak, Pampasit 2001). Harvesting was conducted at transplanting and at 45 and 70 days after planting chinese kale (Raichontara 2011) and marigold (Sangwan et al. 2010), respectively. Number of leaves, fresh mass, and height of chinese kale and flower size of marigold were recorded.

Mean (X) and standard deviations (SD) were calculated for each treatment. F-test and Post Hoc. Duncan test ($p < 0.05$) were applied to determine the significant differences between treatments.

Results and discussion

Physicochemical and nutrient properties of fertilizer

Liquid organic fertilizer fermentation was complete at 12 weeks. The obtained liquid compost was brown color and had a wine-like smell. The fertilizer composition remained stable after production until the end of the observation period at week 16th. At the initial stage of fermentation, pH of the mixture was low, and laterincreased and became stable at a level of pH 4 to 4.8. During the process of fermentation temperature was changing between 24 to

Table 2. Physicochemical characteristics and nutrients from liquid organic fertilizer after 12 weeks of processing

Type of fertilizer	Characteristics				Nutrients (mg L^{-1})							
	pH	Temperature (°C)	Conductivity (mS cm^{-1})	C/N ratio	N	P	K	Ca	Mg	Fe	Cu	Zn
1	4.10	31.0	772	10.14	0.07	0.11	0.17	410.66	610.42	14.98	0.03	4.95
2	4.20	30.5	767	10.61	0.07	0.10	0.14	359.06	557.67	10.31	0.02	3.52
3	4.60	29.0	623	11.87	0.07	0.07	0.11	295.17	383.35	10.27	0.02	3.34
4	4.60	30.0	782	6.72	0.10	0.13	0.19	308.37	601.15	13.83	0.04	3.95
5	4.60	31.0	625	8.73	0.09	0.10	0.12	265.77	483.13	10.80	0.03	4.96
6	4.00	31.0	648	7.98	0.10	0.08	0.10	260.27	381.13	7.06	0.02	6.03
7	4.70	29.5	737	16.10	0.03	0.05	0.15	288.69	395.62	9.65	0.02	6.35
8	4.50	29.0	770	11.24	0.07	0.09	0.12	309.30	425.35	9.19	0.03	5.58
9	4.30	30.0	814	7.81	0.08	0.13	0.16	329.25	450.14	16.04	0.03	2.33
10	4.60	31.0	810	17.61	0.04	0.10	0.11	335.87	385.84	15.07	0.04	3.37
11	4.80	31.0	782	18.47	0.04	0.09	0.13	352.51	410.21	11.97	0.02	2.70
12	4.50	31.0	769	18.66	0.04	0.09	0.12	419.38	422.54	14.06	0.04	4.71

Table 3. Fresh mass of plants, number of leaves, and height of chinese kale after treatment with liquid organic fertilizer and chemical fertilizer as foliar or soil fertilizer. Means in the same column with different superscript letters are significantly different at $p < 0.05$

Type of fertilizer	Foliar fertilizer				Soil fertilizer			
	Treatment	Fresh mass (g)	Height (cm)	Leaves (number)	Treatment	Fresh mass (g)	Height (cm)	Leaves (number)
1	T1	5.2 ± 0.5^{bc}	12.6 ± 1.1^{c}	6.3 ± 1.2^{abcd}	T13	4.2 ± 0.4^{b}	10.6 ± 1.1^{c}	5.7 ± 0.6^{ab}
2	T2	6.9 ± 1.7^{cd}	$14.6 \pm 0.7e^{f}$	5.7 ± 0.6^{ab}	T14	4.6 ± 0.5^{bc}	11.6 ± 1.2^{cd}	6.0 ± 0.0^{abc}
3	T3	6.9 ± 1.6^{cd}	14.5 ± 0.8^{def}	7.3 ± 0.6^{cd}	T15	6.0 ± 0.2^{de}	15.0 ± 0.6^{g}	6.0 ± 0.0^{abc}
4	T4	7.1 ± 0.9^{d}	16.2 ± 0.3^{g}	6.3 ± 0.6^{abcd}	T16	5.6 ± 0.4^{cde}	13.5 ± 1.0^{f}	5.7 ± 0.6^{ab}
5	T5	6.8 ± 0.7^{cd}	15.4 ± 0.4^{fg}	7.7 ± 0.6^{d}	T17	6.0 ± 0.7^{e}	15.2 ± 1.7^{g}	7.7 ± 0.6^{e}
6	T6	5.9 ± 0.2^{cd}	14.3 ± 0.6^{def}	6.0 ± 0.0^{abc}	T18	5.1 ± 0.1^{c}	12.8 ± 0.2^{bdef}	6.7 ± 0.6^{cde}
7	T7	2.1 ± 1.0^{a}	5.8 ± 1.2^{a}	5.0 ± 1.0^{a}	T19	3.1 ± 0.2^{a}	7.9 ± 0.4^{a}	6.3 ± 0.6^{abc}
8	T8	4.0 ± 0.3^{b}	9.9 ± 0.5^{b}	6.7 ± 0.6^{bcd}	T20	4.7 ± 0.2^{bc}	12.0 ± 0.5^{de}	6.0 ± 0.0^{abc}
9	T9	6.2 ± 1.0^{cd}	13.9 ± 0.4^{cde}	6.0 ± 1.0^{abc}	T21	5.2 ± 0.2^{c}	13.0 ± 0.5^{def}	7.0 ± 1.0^{de}
10	T10	5.6 ± 0.7^{bcd}	15.0 ± 0.8^{efg}	6.0 ± 0.0^{abc}	T22	5.3 ± 0.1^{cde}	13.4 ± 0.4^{ef}	8.7 ± 0.6^{f}
11	T11	5.2 ± 0.2^{bc}	13.2 ± 0.5^{cd}	5.0 ± 1.0^{a}	T23	5.2 ± 0.3^{cd}	13.1 ± 0.6^{ef}	6.3 ± 0.6^{abc}
12	T12	5.4 ± 0.6^{bcd}	13.9 ± 1.3^{cde}	6.0 ± 1.0^{abc}	T24	5.1 ± 0.2^{c}	12.8 ± 0.6^{def}	6.7 ± 0.6^{cde}
Control	T25	1.9 ± 1.2^{a}	6.4 ± 0.2^{a}	5.3 ± 0.6^{ab}	T25	1.9 ± 0.1^{a}	6.4 ± 0.2^{a}	5.3 ± 0.6^{a}
Chemical fertilizer	T26	10.6 ± 0.8^{e}	18.9 ± 0.8^{h}	6.3 ± 0.6^{abcd}	T27	10.7 ± 1.1^{f}	17.3 ± 0.4^{h}	6.3 ± 0.6^{abc}

32 °C. The physicochemical characteristics and nutrient contents of liquid organic fertilizer are presented in Table 2.

Content of macro nutrients in liquid organic fertilizer was lower than that in the chemical fertilizer, but it contained micronutrients that were not found in chemical fertilizer. Macro nutrients (Ca and Mg) and micronutrients (Fe, Cu and Zn) are important materials in plant growth and survival (Zhao et al. 2007). Previously Sangwan et al. (2010) showed increased macro- and micronutrient concentrations in liquid organic fertilizer produced from sesame oil cake and rice bran.

Experiment with crop plants

The application of liquid organic fertilizer produced from milk cake factory waste resulted in an increase of chinese kale and marigold production when compared with the untreated control. For chinese kale, application of liquid organic fertilizer as foliar fertilizer showed better results in comparison with soil fertilizer. A fertilizer produced from compost with ratio wastewater 10 L : sewage sludge 2 kg : molasses 1 kg and EM 30 mL and applied at 0.002% resulted in the best chinese kale growth and potential productivity (T4; Table 3 and Fig. 1). Soil fertilizer produced

Table 4. Flower size of marigold plants after treatment with liquid organic fertilizer and chemical fertilizer as foliar or soil fertilizer. Means in the same column with different superscript letters are significantly different at $p < 0.05$

Type of fertilizer	Foliar fertilizer		Soil fertilizer	
	Treatment	Flower size (cm)	Treatment	Flower size (cm)
1	T1	5.0 ± 0.3^{bcd}	T13	5.7 ± 0.2^{c}
2	T2	5.0 ± 0.2^{bcd}	T14	6.0 ± 0.2^{cd}
3	T3	4.9 ± 0.1^{bc}	T15	6.4 ± 0.5^{de}
4	T4	5.0 ± 0.2^{bcd}	T16	6.9 ± 0.3^{ef}
5	T5	5.9 ± 0.5^{ef}	T17	7.1 ± 0.2^{f}
6	T6	6.5 ± 0.3^{f}	T18	7.4 ± 0.3^{f}
7	T7	5.3 ± 0.6^{bcd}	T19	4.8 ± 0.3^{b}
8	T8	5.7 ± 0.5^{de}	T20	6.5 ± 0.2^{de}
9	T9	5.7 ± 0.4^{de}	T21	6.2 ± 0.3^{cd}
10	T10	4.8 ± 0.6^{bc}	T22	4.9 ± 0.4^{b}
11	T11	4.5 ± 0.4^{b}	T23	5.0 ± 0.3^{b}
12	T12	5.3 ± 0.5^{cd}	T24	6.1 ± 0.4^{cd}
Control	T25	3.8 ± 0.2^{a}	T25	3.8 ± 0.2^{a}
Chemical fertilizer	T26	7.5 ± 0.3^{g}	T27	8.0 ± 0.2^{g}

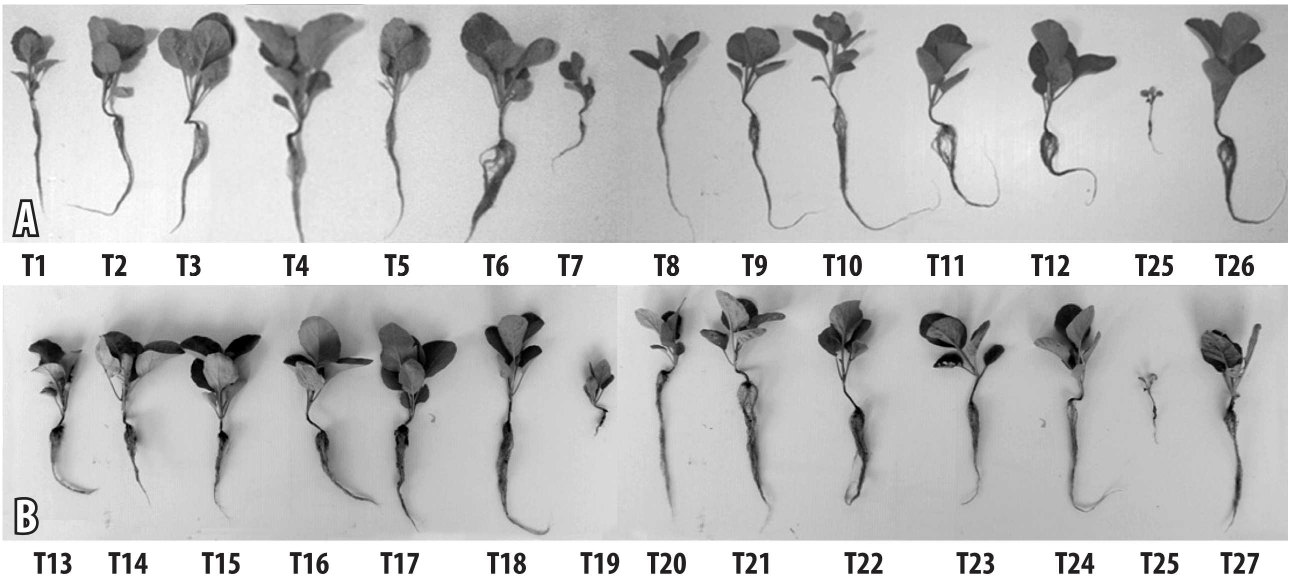

Fig. 1. Chinese kale after treatment with foliar (A) and soil (B) liquid fertilizer from milk cake factory waste and chemical fertilizer.

from compost at ratio of 20 : 2 : 1 : 30 [wastewater (L) : sewage sludge (kg) : molasses (kg) : EM (mL)] and applied every other day at 0.003% (v/v) was optimum for marigold production (T18; Table 4 and Fig. 2). The present results are similar to those obtained by Lee (2010) and Perera et al. (2007) who reported that vegetable (onion, chinese flowering cabbage and chinese cabbage) growth and development was positively affected by macro and micro nutrients from organic fertilizer.

However, applying chemical fertilizer to chinese kale was more effective in stimulation of growth than the liquid compost from milk cake factory waste. It should be noted that liquid organic fertilizer produced from waste was much cheaper compared to chemical fertilizer. Besides this advantage, liquid organic fertilizers from milk cake factory waste are easily available and have almost no adverse effect on the environment, while chemical fertilizers might cause nitrogen loss to groundwater streams and lakes causing pollution (Li et al. 2009). Moreover, liquid organic fertilizers can boost microbial activity in the soil while chemical fertilizers kill the active microorganisms (Kong et al. 2008). Organic compost fertilizer is a means to achieve fast results in a more natural and environmentally friendly way, as organic fertilizers can help to restore soil properties. Bokhtiar (2008) reported that organic manure, when applied with chemical fertilizers, gave better yield than application of individual components. The use of environmentally-friendly organic fertilizers is of special importance, because consumers are demanding higher quality and safer food and are highly interested in organic products (Ouda, Mahadeen 2008).

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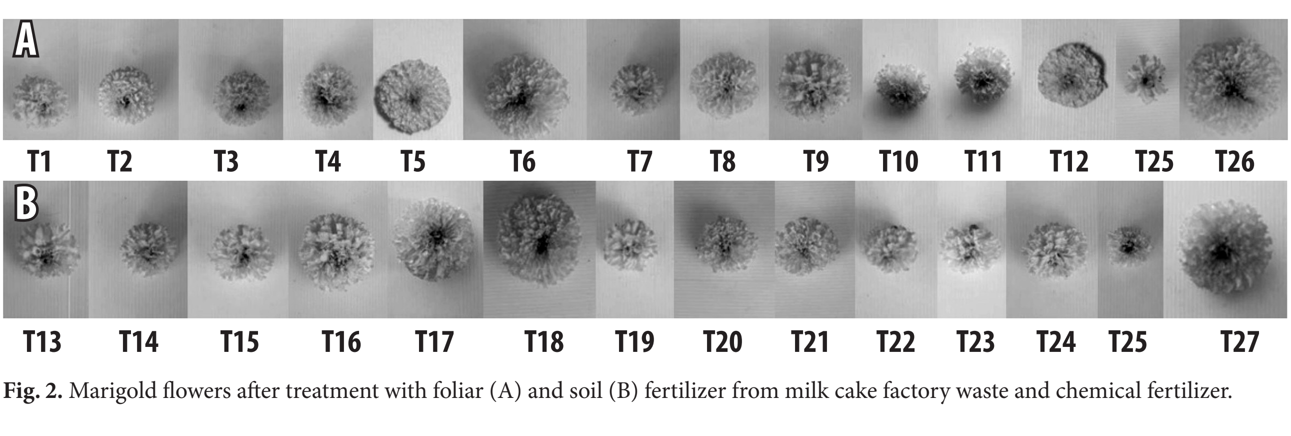

Fig. 2. Marigold flowers after treatment with foliar (A) and soil (B) fertilizer from milk cake factory waste and chemical fertilizer.

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