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PRELIMINARY STUDY ON URINE-COMPOST EXTRACT AS BIO-LIQUID FERTILISER FOR HYDROPONICS

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Abstract: *This work studied on the feasibility on the application of the urine-compost extract as bio-liquid fertiliser for hydroponics. The experiment was divided into two parts: the first part was to produce the compost and compost extract, and the second part was to use the compost extract as liquid fertiliser for hydroponics. The composted corncob-urine was used as materials. The studied parameters for compost were temperature, moisture content, volatile solid content, pH, electrical conductivity, total nitrogen, total phosphorous, total potassium and carbon to nitrogen. The hydroponics experiment was used Nutrient Film Technique (NFT) for comparing between the chemical liquid fertiliser and bio-liquid fertilizer (compost extract) and Lactuca sativa var.crispa L. (Red Oak and Butter Head) were chosen as vegetables for hydroponics. The studied parameters were key plant nutrients (nitrogen, phosphorous and potassium) and heavy metals (lead, cadmium, chromium), and the vegetable characteristics (root length, number of leaves, fresh weight, and dry weight) were also studied. It concluded that the bio-liquid fertiliser had similar the key nutrient plants to the chemical liquid fertiliser and the heavy metals in the bio-liquid fertiliser was less. The vegetable characteristisc from bio-liquid fertilizer were less than ones from chemical liquid fertiliser.*

Keywords: *Urine, Compost extract, Bio-liquid fertiliser, Hydroponics*

Introduction

Human urine is a sterile by-product of human excreta which is mostly combined with water and feces in the flush toilet system, and treated in the sewerage system. The urine separation with dry toilet system can be recycled the plant nutrient in urine recycled to agriculture and farmland which is the food for animal and human, thus, it will be the close loop of plant nutrient (Sene et al., 2012; Johansson and Nykvist, 2001). Kirchmann and Pettersson (1994) stated that stored human urine had pH values of 8.9 and was composed of eight main ionic species (> 0.1 meq L^{-1}), the cations Na^+, K^+, NH_4^+, Ca^{2+} and the anions, Cl^-, SO_4^{2-}, PO_4^{3-} and HCO_3^-". They also informed that "Heavy metal concentrations in urine samples were low compared with other organic fertilizers, but copper, mercury, nickel and zinc were 10–500 times higher in urine than in precipitation and surface waters". For example, human urine can be achieved as a fertilizer at a dose of 180 kg N/ha for cabbage cultivation which compared with industrial fertilizer as the same as in cucumber cultivation, pure human urine was similar or slightly better than the yield obtained from control rows fertilised with commercial mineral fertilizer and also banana cultivation. (Pradahn et al., 2007; Heinonen-Tanski et al., 2007; Sridevi et al., 2009).

Hydroponic is a technique for growing the plant without soil. The inert matrix material is used to support the stem of plant and aerate their root system (Berry and Knight, 1997). The plant adsorbs the solution as liquid fertilizer for nutrients (Marr, 1994). The parameters for hydroponics are the adequate aeration and the environment in the root zone, a known rate and concentration of nutrients (Berry and Knight, 1997). Marr (1994) stated that “The principle of the NFT system is to provide a thin film of nutrient solution that flows through either black or white-on-black polyethylene film liners supported on wooden channels (frequently used with tomatoes and cucumbers) or some form of PVC piping (lettuce production) which contain the plant roots”.

Composting is a biological process which degrades the organic matter with microorganism. The key factors of this process are moisture content, carbon and nitrogen source as nutrient (Epstein, 1997). Urine can be the nitrogen and water source in composting therefore it can also conserve the water for using in composting. The product is compost with plenty of key plant nutrient which nitrogen, phosphorous and potassium in utilized form for plants (Epstein, 1997). In addition compost has the electrical conductivity which can be adjusted for plants. However, the compost is in solid form, it is suitable for growing plants with the soil as supporter. If compost will be applied for growing plants in non-soil, for example, liquid, compost needs to be changed in the liquid form as extracted compost or compost extract. The primary benefit of the extract is to provide a supply of soluble nutrients that can be used as a liquid fertilizer as stated that by Anonymous[a] (2007).

The aim of this work was to study on comparing the characteristics of plant cultivation between extracted compost in solution form, produced from urine as nitrogen source for composting, and commercial chemical solution for hydroponics.

Methods

The experiment was divided into two parts: the first part was to produce the compost and compost extract, and the second part was to use the compost extract as liquid fertiliser for hydroponics. The compost experiment was to use the 34-L polystyrene-insulating plastic reactor for composting. Air was applied intermittently every 15 minutes. The corncob-urine was used as materials. Sampling was collected every week. Temperature was measured every day. The studied parameters for compost were moisture content, volatile solid content, pH, electrical conductivity, total nitrogen, total phosphorous, total potassium and carbon to nitrogen ratio (Anonymous[b], 2005). The compost was extracted by soaking in water like tea bag and the studied parameters for compost extract were total nitrogen, total phosphorous, and total potassium (Anonymous[b], 2005). The hydroponics experiment was used Nutrient Film Technique (NFT) for comparing between the chemical liquid fertiliser and bio-liquid fertilizer (compost extract) and *Lactuca sativa var.crispa L*. (Red Oak and Butter Head) were chosen as vegetables for hydroponics. The studied parameters were key plant nutrients (nitrogen, phosphorous and potassium) (Anonymous[b], 2005) and heavy metals (lead, cadmium, and chromium) by Atomic Absorption Spectrometer, and the vegetable characteristics (root length, number of leaves, fresh weight, and dry weight) by measurement and weight were also studied.

Results and Discussion

The experiments were divided into two parts: composting and compost extract study and plant growth test and heavy metal for Hydroponic study.

Composting, compost and compost extract study

The key parameters of composting which were temperature, moisture contents, volatile solids contents, carbon contents, carbon to nitrogen ratio, pH, and electrical conductivity were studied as shown in Table 1 and the plant nutrients were nitrogen content, phosphorus content, and potassium contents also were studied as shown in Table 2.

Table 1: The key parameters of urine-corncob composting

Parameters	Urine-corncob composting
Temperature, max (°C)	52.60
Moisture contents (%)	74.14-63.69
Volatile solid contents (%)	68.78-42.85
Carbon contents (%)	48.47-34.38
Carbon to nitrogen ratio	40.2:1-9.19:1
pH	4.08-7.79
Electrical conductivity (μS/cm)	925.66-1566.66

Table 1 showed that the key parameters of urine corncob composting which were the maximum temperature, moisture contents, volatile solid contents, carbon contents, carbon to nitrogen ratio, pH, and electrical conductivity. The maximum temperature of the composting was 52.60 °C which affected from the microorganism activity to degrade the organic matter in raw materials and released the heat in the composted materials. Moisture contents was high along the composting process because the characteristics of corncob as carbon source which was a porous material so the water was adsorbed inside the pores besides between the molecules, and the urine as nitrogen and water sources which was more difficult to evaporate than the water because the chemical and salt substances soluble in the water of urine. While volatile solid and carbon contents showed that the volatile organic compounds and volatile organic carbon contents which were degraded by microorganisms for using their cell growth and energy source. The carbon to nitrogen ratio reduced from 40.23:1 to 9.19:1, which the final carbon to nitrogen ratio of this compost, 9.19:1, was suitable for planting because the suitable compost should be less than 20:1 (Epstein, 1997). Electrical conductivity and pH showed that the soluble salt contents in compost when it is dissolved which affect to the each of plant types and the pH in this compost is suitable because the pH between composting should not be more than 8 with high temperature it will lead to nitrogen loss in the ammonia form.

Table 2: The plant nutrients in compost and compost extract

Plant nutrients	Compost	Compost extract
Nitrogen contents (%)	3.74	2.76
Phosphorous contents (%)	0.058	0.045
Potassium contents (%)	1.105	0.034

Table 2 showed that the major plant nutrients which were nitrogen, phosphorous and potassium. The nitrogen in compost was the most contents and the phosphorous was the less because the nitrogen source was urine which had the urea and the ammonia in the major contents. When the compost was extracted by water, the soluble nutrients were dissolved. The results found that the water could be extracted better nitrogen and phosphorous than potassium. This reason was that the nitrogen was in the ammonia (NH_3) and nitrate forms (NO_3^-) in the compost and also in the urine, which nitrate was in the soluble form and ammonia can be changed in the soluble form as ammonium form ($NH4^+$) when it dissolved similarly the phosphorous was in the phosphate form in the compost and also in the urine, which was the soluble form. While the potassium was in the potassium compounds which were depend on the type of potassium compounds as soluble forms in the compost.

Hydroponic study

The plant nutrients were nitrogen content, phosphorus content, and potassium contents were studied as shown in Table 3. The characteristics of plant which were root length, number of leaves, fresh weight, and dry weight were studied as shown in Figure 1-4 and Table 4 and the heavy metals were lead, cadmium, chromium also were studied as shown in Table 5.

Table 3: The plant nutrients in diluted compost extract and commercial liquid fertiliser

Plant nutrients	Diluted compost extract	Commercial liquid fertiliser
Nitrogen contents (%)	0.028	0.034
Phosphorous contents (%)	0.021	0.004
Potassium contents (%)	0.012	0.011

Table 3 showed that the comparing the major plant nutrients in compost extract to commercial liquid fertiliser. The plant nutrients in diluted compost extract were less than the plant nutrients in compost extract in Table 2 because the nutrient solution for hydroponics was controlled by the electrical conductivity and pH, which were 1500–3000 μS/cm and 5.5-6.5, respectively. The nitrogen content of diluted compost extract was less than one of commercial liquid fertilsers but the phosphorous content of diluted compost extract was higher than one of commercial liquid fertilsers. While, the potassium contents of diluted compost extract was not different to one of commercial liquid fertilsers.

The characteristic plant results

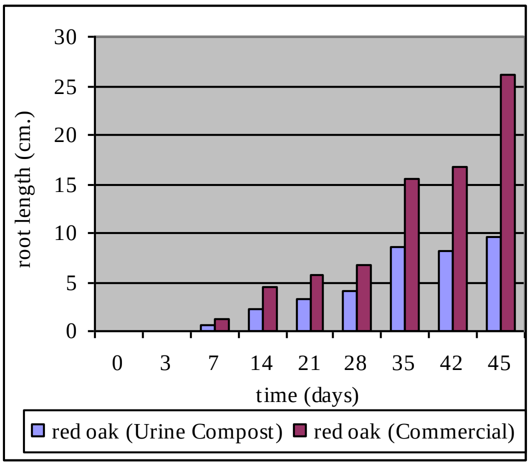

Figure 1: The root length of Red oak

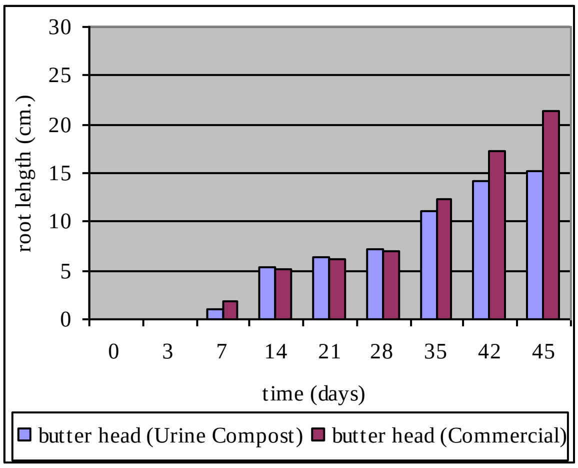

Figure 2: The root length of Butter Head

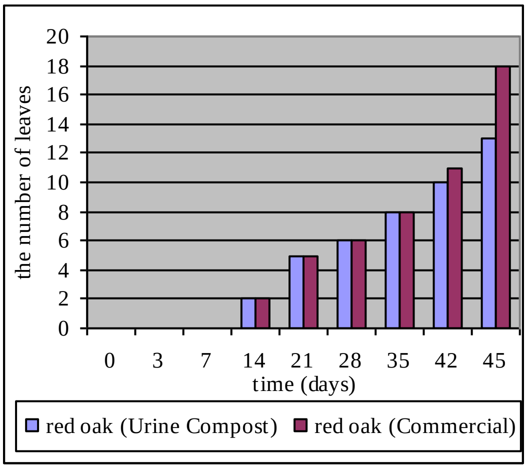

Figure 3: The number of leaves of Red oak

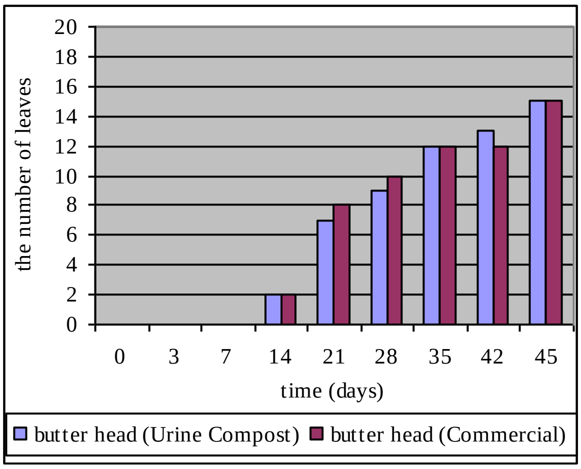

Figure 4: The number of leaves of Butter Head

Figure 1 and 2 showed that the length of roots of Red oak continually increased along the time for 45 days when used commercial liquid fertilizer, but the length of roots of Red oak from the compost extract slightly increased from day 7 to day 28, then increased in day 35, and kept constant until day 45. In comparison, the root of Red oak from commercial liquid fertiliser was significantly longer than one from compost extract in day 45. While, the length of roots of Butter head from commercial liquid fertiliser increased from day 7 to day 14, then slightly increased until day 28, and increased until day 45 as same trend as the length of roots of Butter head from compost extract. In comparison, the root of Red oak from commercial liquid fertiliser was still longer than one from compost extract in day 45.

Figure 3 and 4 showed that the number of leaves of Red oak from commercial liquid fertiliser increased from day 7 to day 14, then slightly increased until day 28, and increased until day 45 as same trend as the number of leaves of Red oak from compost extract, In comparison, the number of leaves of Red oak from commercial liquid fertiliser was significantly much more than one from compost extract in day 45. While, the number of leaves of Butter head from commercial liquid fertiliser increased from day 7 to day 35, then kept constant until day 42, and increased until day 45 but the number of leaves of Red oak from the compost extract continually increased along the time for 45 days. In comparison, the number of leaves of Butter head from commercial liquid fertiliser was equal to one from compost extract in day 45.

Table 4: The dry and wet weight of Red oak and Butter head

Parameters	Red oak		Butter head	
	Compost extract	Commercial liquid fertiliser	Compost extract	Commercial liquid fertiliser
Wet weight (g)	25.02	37.12	36.22	45.64
Dry weight (g)	1.29	1.89	1.79	2.02

Table 4 showed that the wet and dry weight of Red oak from commercial liquid fertiliser was higher than one from the compost extract as same as the wet and dry weight of Red oak from commercial liquid fertiliser was higher than one from the compost extract.

Table 5: The heavy metal in diluted compost extract and commercial liquid fertiliser

Parameters	Compost extract	Commercial liquid fertiliser
Lead contents (mgl^{-1})	NF	NF
Chromium contents (mgl^{-1})	NF	4.67
Cadmium contents (mgl^{-1})	0.027	NF

NB: NF = not found

Table 5 showed that Lead did not investigate in compost extract and commercial liquid fertilizer. However, Chromium investigated in commercial liquid fertilizer but did not investigate in compost extract, while Cadmium investigated in compost extract but did not investigate in commercial liquid fertilizer. In case of Cadmium in compost extract was quite low which was probably from raw materials.

Conclusions

It can be concluded that the bio-liquid fertiliser had similar the key nutrient plants to the chemical liquid fertiliser and the heavy metals in the bio-liquid fertiliser was less. While the most vegetable characteristic from bio-liquid fertilizer were less than ones from chemical liquid fertiliser, except the number of leaves of Butter head was equal. Thus, the bio-liquid fertiliser can use as the liquid fertiliser for hydroponics and the compost extract quality will be improved.

References

Anonymous[a] (2007). Overview of Compost Tea Use in New South Wales. 2nd edition. Recycled Organics Unit, Department of Environment and Conversation, The University of New South Wales, Sydney, Australia.

Anonymous[b] (2005). The manual of the analysis of soil,water, fertilizer, plant and soil conditioner samples, Part 2., 2nd ed., Science for Land Development Institute, Land Development Department, The Ministry of Agriculture and Cooperatives, Thailand.

Berry W. L. and Knight S. (1997). Chapter 8: Plant Culture in Hydroponics. In: Plant Growth Chamber Handbook, edited by Langhans R.W. and Tibbitts T.W., North Central Regional Research Publication No. 340 and Iowa Agriculture and Home Economics Experiment Station Special Report No. 99. Iowa State Technology of Science and Technology.119-131.

Epstein E. (1997). The science of composting. Technomic publishing company, Inc. Lancaster, Brasil.

Heinonen-Tanski H., Sjoblom A., Fabritius H., Karinen P. (2007). Pure human Urine is A Good Fertiliser for Cucumbers. Bioresource Technology, 98, 214–217.

Johansson M. and Nykvist M. (2001). Closing the Nutrient Cycle: Summary from A Unique Research Project in Sweden. EcoEng Newsletter 1, October, Forum#2.

Kirchmann H. and Pettersson S. (1994). Human urine - Chemical composition and fertilizer use efficiency, 40(2) , 149-154.

Marr C. W. (1994). Hydroponic System. Greenhouse Vegetable Production. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, September, 1-12.

Pradhan S. K., Nerg A.-M., Sjoblom A., Holopainen J. K. and Helvi H.-T. (2007). Use of Human Urine Fertilizer in Cultivation of Cabbage (Brassica oleracea)-Impacts on Chemical, Microbial, and Flavor Quality. Journal of Agricultural and Food Chemistry, 55, 8657–8663.

Sene M., Hijikata N., Ushijima K., and Funamizu N. (2012). Adequate Human Urine Application Pattern for Agriculture. International Research Journal of Agricultural Science and Soil Science, 2(1), 038-045.

Sridevi G., Srinivasamurthy C. A., Bhaskar S. and Viswanath S. (2009). Evaluation of Source Separated Human Urine (ALW) as A Source of Nutrients for Banana Cultivation and Impact on Quality Parameter. ARPN Journal of Agricultural and Biological Science, 4, (5), 44-48.

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