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Strength and disintegration characteristics of compost pellets produced from urban waste in Sri Lanka

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Introduction

Recovering resources from urban waste streams can serve agricultural production while closing the nutrient loop. The relevance of resource recovery from both liquid and solid urban waste streams is well recognized and encouraged in developing countries. However, related practices are only emerging in low-income countries, although the agricultural value of these resources is known and adjusting the value proposition to suit the local setting would enhance market demand and price. Strengthening sanitation–agriculture interface is a necessity, but has its own challenges.

As in other developing countries, solid and liquid waste generation steadily increases in urban areas also in Sri Lanka whereas resources recovery from municipal waste streams remains low. At present, the 338 municipalities in the country collect around 7,500 tons of solid waste every day. Although more than 110 municipalities established municipal compost projects with governmental support in the meantime, overall resources recovery remains low and majority of collected waste ends up at waste disposal sites, resulting in adverse impacts on the environment. Likewise, majority of generated fecal sludge is stored in on-site sanitation systems that lack regular desludging and proper treatment. Often, when septic tanks or pits are filled, fecal sludge from tank desludging is disposed into the environment, which creates adverse impacts on water resources, biodiversity, and human health. To overcome these challenges, the International Water Management Institute (IWMI) developed a resource recovery option that showcases how urban waste can be treated and reused through co-composting of nutrient-rich fecal sludge (FS) and the organic fraction of municipal solid waste. FS is rich in nutrients and by integrating it into the co-composting process, a nutrient-rich final product can be obtained (Nikiema et al., 2013; Cofie et al., 2016). It is assumed that new approaches towards processing of these urban waste streams are beneficial in several dimensions; (a) in view of treating two major urban waste streams with high pollution potential, (b) through recovery of high nutrient agricultural inputs and c) for soil amelioration. The reuse of organic rich co-compost would offer various benefits for tropical soils that commonly suffer from organic matter deficiency such as increased water retention capacity and soil microbial life. Besides, making nutrients and organic carbon from waste streams available for agriculture assists to reduce chemical fertilizer use and related imports into the country. To add value to the co-compost, a pelletizing process was introduced and tested that enhances organic fertilizer density and other properties (Cofie et al., 2016; Grau et al., 2016). Pelletizing is also beneficial for storage and handling of the co-compost product whereas this process especially influences physical properties such as strength, density, disintegration time and nutrient release (Nikiema et al., 2014). Previous studies indicated that pelletized fertilizer are of interest for farmers, and could offset various drawbacks related to bulky nature of compost products. The presented study gives insight into selected aspects of compost pellets, especially its disintegration behavior and pellet strength/durability that are relevant to promote the proposed innovative organic fertilizer pellets for agricultural use.

Main objectives

This research addresses major drawbacks that affect the use and promotion of compost products from urban waste streams with a) bulky nature and low density of compost products, b) low nutrient density of organic municipal waste derived compost, c) quality concerns and d) options to add value to co-compost products through pelletizing.

Material and Methods

Main input materials used to test co-composting and pellet production were organic solid waste from the municipal collection (MSW) and dried fecal sludge (DFS) from on-site sanitation systems. Specifically, the following waste treatments were performed to enable the co-composting of FS:

- drying of FS in sand-drying/filtration beds for 14-21 days,
- mixing of input materials DFS and MSW in ratio 1:10 for co-compost production,
- screening of final co-compost to separate the material fraction of 0-5 mm as input material for pellet production,
- adjustment of moisture content to 25% of co-compost product prior to pelletizing,
- use of three (3) binders added to the co-compost with: rice flour (RF), Eppawala Rock Phosphate (ERP), and lime (L) in concentrations of 1%, 2%, and 3% respectively,
- pellet production using Die and Roller pelletizing method.

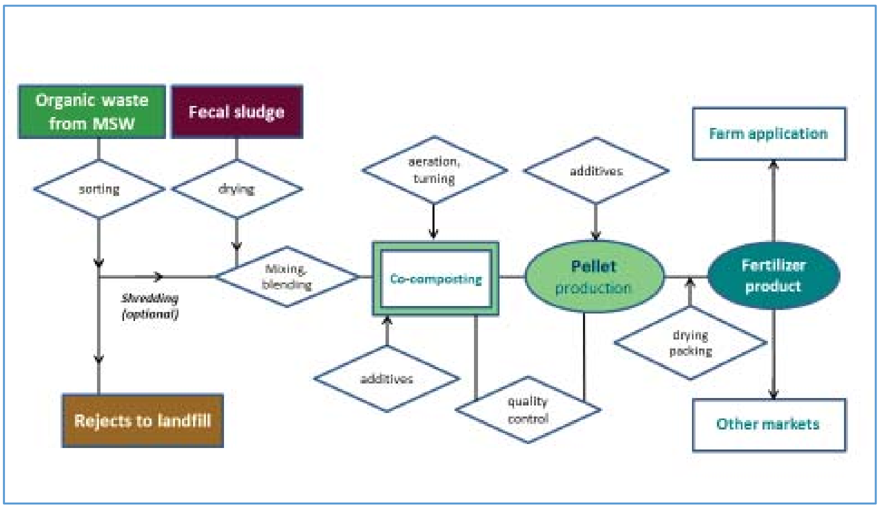

Figure 1: General process flow on co-composting and pellet production

The main steps of waste treatment applied for co-composting and pellet production are shown in Figure 1. The disintegration behavior of pellets was tested under laboratory conditions with a) placement of 50 g of pellets into 200 ml of distilled water in plastic cups and b) disintegration for 30 days without disturbance under laboratory conditions.

Results and Discussion

For pellet production, compost drying and pulverization is usually performed prior to pelletization. Within this research, compost drying and pulverization was replaced by compost sieving and adjusting the water content to 25% as input material for pellet production. This technology adjustment reduced the work and energy inputs for the production process. The graphs below show the trends of strength and disintegration properties of pellets as observed during laboratory testing. Pellet strength is considered as relevant parameter to assess product quality for storage, transportation, handling, and application of pellets. Disintegration may be linked with nutrient release, which is an important parameter for soil amelioration and plant growth. The overall trend for pellet strength for the tested 3 binders is displayed in Figure 2.

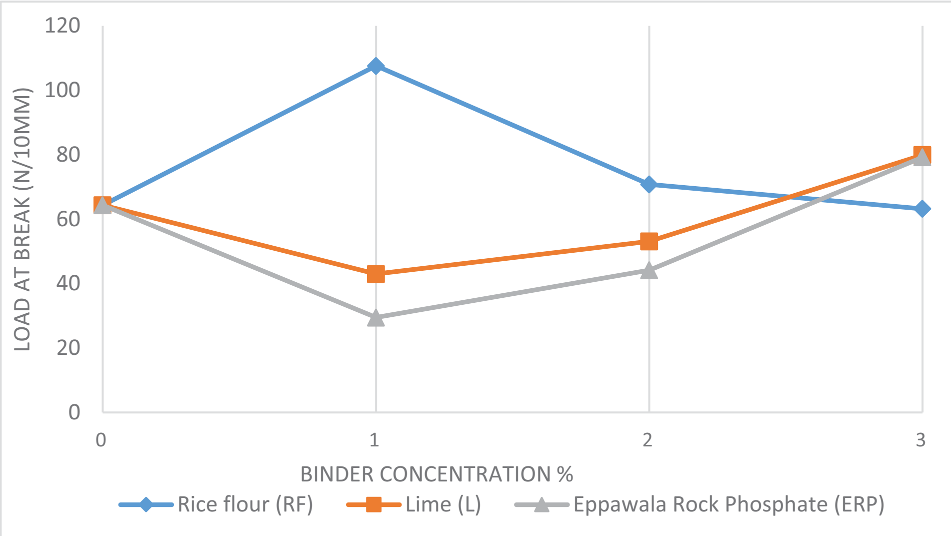

Figure 2: Trends of pellet strength for the tested binding agents in pellets

The three binders were selected by considering their local availability, cost, soil benefits, nutrient values, and organic respectively inorganic nature. Eppawala Rock phosphate (ERP) is an available natural resource in Sri Lanka, while Lime (L) is a soil amendment agent commonly used in all parts of the country. Rice flour (RF) is one of the organic binding agents available at low cost in Sri Lanka, which may react differently towards disintegration if compared to inorganic binders. Figure 3 summarizes the observed disintegration trends for the various binders during the laboratory tests.

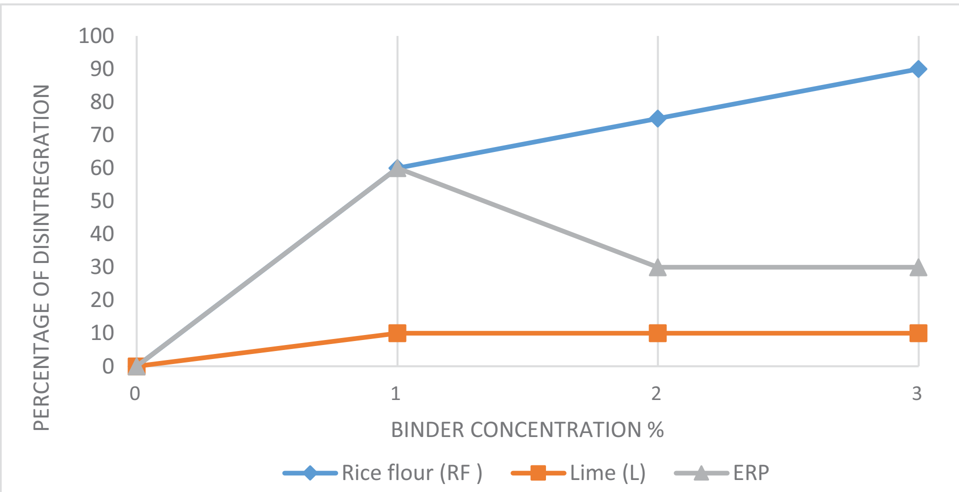

Figure 3: Trends of disintegration behavior for the tested binding agents in pellets

Pellets with RF as binding agent showed the highest disintegration ability under laboratory conditions whereas disintegration increased with binder concentration. Adding RF in concentrations of 1%, 2%, and 3% resulted in pellet disintegration of 60%, 75%, and 90% respectively. For ERP it was found that by increasing the concentration of the binding agent, the disintegration ability will decrease; i.e. concentration of 1% resulted in disintegration of 60% of the pellet, but a much lower disintegration of only 30% was achieved with 3% ERP concentration. Addition of lime resulted in the lowest disintegration with less than 10% in all concentrations. The findings indicate that ERP and Lime binder result in low disintegration of pellets that may only be suitable for medium- and long-term crops. However, the relatively quick disintegration of pellets produced with rice flour binder makes it suitable for short-term crop application. This trend may be due to, (a) expansion of rice flour with moisture absorption and/or (b) increased biological activities on rice flour due to higher moisture content. It is assumed that organic waste materials (such as expired starch or flour) can substitute rice flour in commercial pellet production. The laboratory tests performed also indicate that pellet strength properties are enhanced with increasing concentrations of ERP and Lime. In contrast to the behaviour of these two inorganic binding agents, the pellet strength of pellets that were produced with organic binder RF decreased for higher binder concentrations, whereas the addition of 1% RF showed highest strength of all tested binding agents. An additional test to evaluate transport impacts on product quality revealed that the transport of pellets that were produced with 3% RF binder did not change or harm the products over a transport distance of 50 km. Pellets strength may be a useful parameter to assess handling and transportation, whereby the minimum strength characteristics of pellets to serve its purpose is yet to be determined.

Conclusions and Outlook

Based on the findings of this study it appears that pelletizing can increase the compost material density >30%, whereas ongoing research aims to further enhance product and storage properties, e.g. for packaging and to optimize value and properties of fertilizer pellets. Other research indicates that higher density increase was accomplished by using a similar Die pelletizing machine (Lawong et al., 2011). Although compost pellets can be produced without a binding agent under certain pressure and moisture adjustments, application of binding agents proved useful and increased pellet strength and disintegration characteristics. Whereas the two tested inorganic binders resulted in low disintegration, the further tested organic binder showed a much faster disintegration response. This confirms that certain binding agents can act as de-binders when water is added later on (e.g. rice flour). Lastly, this research also revealed that commonly applied processes prior to pelletizing, namely compost drying and pulverization, can be eliminated while reducing energy consumption and work efforts for pellet production. Additional research is needed to verify the findings, to test alternative binders and to analyze disintegration properties under field conditions.

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