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Performance analysis of chicken manure coated slow-release urea fertilizer (CM-CSRUF)

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Abstract. Slow-release fertilizers (SRFs) are developed, to halt the nutrient loss to the environment, either by coating the urea or by infusing the urea in a hydrophobic material. SRFs reduces the nutrient release to that point where a single application of fertilizer can meet the nutrient demand of the plants. Diverse range of materials have already been utilized to produce SRFs, however several disadvantages such hydrophilicity, non-biodegradability and crystallinity limit their scale up. Herein, we reported the production of coating of urea using chicken manure with paraffin wax as a binder. Nitrogen release test of the coated urea revealed that only 11.8% of total nutrients were released in first 12 h whereas uncoated urea released ≥99.9 % nutrients. Ritger-Peppas model was found to best fit the nutrient release kinetic data with an R^2 value of 0.97.

Introduction

With the global population dramatically growing to reach the estimated number of 9.5 billion by 2050, the worldwide food demand has also risen and thus the anticipated apiece food requirement is likely to be doubled by that year [1,2]. Asynchrony between the release of nutrients (ammonium (NH_4^+) and nitrate (NO_3^-)) from urea and the crop demand has resulted in losing surplus nutrients due to the leaching, volatilization, and nitrous emission, provoking a ineffective plant nutrient uptake efficiency (NUE) and also serious environmental problems [3,4]. Only 30% of the applied urea applied is absorbed by the plants [5–7].

Slow-release fertilizers (SRFs), a purposefully engineered manure that delays the release of nutrients following the sequential nutrient requirement of plants, are usually used to improve the nutrient use efficiency (NUE) [8]. SRFs are produced by encapsulating the urea granule using hydrophobic materials, which reduces the nitrogen release to that point where a single application of fertilizer can meet the nitrogen requirement of crops [9]. Diverse range of materials have already been synthesized to coat the urea which includes synthetic (methacrylic acid copolymers [10], inverse vulcanized copolymers [11–13] Polyacrylic acid latex [14], polyurethane [15], waste polystyrene (thermocol) [16], Ca-Mg phosphate polyolefin, polyolefin plus dicyandiamide, poly(lactic acid-co-ethylene terephthalate) [17]) and natural (starch [18], lignin [19], ethylcellulose [20], and bio-based polyurethane) polymers. These materials have shown encouraging lab results in term nutrient release, however, the nonbiodegradability of synthetic polymers contaminates the soil and on the other hand the poor mechanical and physical properties of natural polymers requires

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modification using plasticizers or crosslinkers increasing the overall cost. These disadvantages arise the need to look for other sustainable and biodegradable materials.

Malaysia being the 3rd largest chicken consumer in the world produces chicken manure in abundance [21]. Chicken manure compared to other manures is a nitrogen, phosphorous and potassium (NPK) enriched organic fertilizer but its direct application to soil leads environmental pollution such as greenhouse gas (GHG) emission, soil acidification and water contamination due to leaching [22]. Therefore, proper treatment process is needed for its application to soil. Our lab recently treated the chicken manure to produce biogas after which chicken manure does not any harmful gases and safe to be use. Herein, we reported the production of slow-release fertilizer by coating chicken manure using paraffin wax as a binder on urea. Then nitrogen release test was conducted on coated urea in distilled to evaluate its slow-release properties.

Materials

Urea was procured from PETRONAS Fertilizer Kedah Sdn. Bhd. Malaysia. Diacetyl monoxime (DAM), thiosemicarbazide (TSC), and O-phosphoric acid (85%) were purchased from Sigma-Aldrich, USA. Paraffin wax was purchased from Kinetic chemical Sdn Bhd Malaysia. All materials were used as received without purification.

Methods

Coating of Urea

First of all, a coating solution was prepared, by melting 5 g of paraffin wax at 80 ºC and mixed with 8 g of chicken manure under continuous mixing to obtain homogenous mixture. After this, 10 g of urea was coated using a dip coating method and allowed to cool at room temperature.

Nitrogen Release Test

DAM calorimetry method was used to estimate the nitrogen release from coated urea. This method includes the preparation of color reagent by mixing the acid reagent (460 ml), TSC (15 ml) and DAM (25 ml) solution which were prepared by dissolving 0.25 g Thiosemicarbazide and 2.5 g of Diacetyl monoxime in a 100 ml of distilled water, separately and for acid reagent phosphoric acid (250 ml), sulfuric acid (10 ml) and distilled water (240 ml) were mixed. In order to analyze the nitrogen release properties of the coated urea, 2.0±0.1 g of the developed fertilizer was immersed in 200 ml distilled water in an Erlenmeyer flask sealed with cling wrap. After every 12 h the homogenously mixed 2.5 ml of sample was taken out and mixed with 7.5 ml of color reagent and placed in water bath heated at 85 ºC and allowed to react for 30 mins after the sample was allowed cool at room temperature. The resultant solution was then analyzed using UV-vis spectrophotometer.

Kinetics of Release

First-order, Parabolic diffusion, Ritger-Peppas and Elovich models were used to investigate release kinetic data to understand mechanism of release from the newly developed fertilizer. Models used are given in Table 1. R^2 value was used to evaluate these models.

Table 1:Models used for describing nitrogen leaching kinetics data.

Model	Equation	Ref
First-order	$\ln(N_o - N_t) = \ln(N_o) - kt$	[23,24]
Parabolic diffusion	$N_t = b + kt^{0.5}$	[25,26]
Ritger-Peppas	$\ln\left[\frac{M_t}{M_o}\right] = \ln k + n \ln t$	[27,28]
Simple Elovich	$N_t = b + k \ln t$	[29,30]

Where t is the release time, N_o is the highest release rate, N_t is the cumulative release rate of nitrogen in time t, the ratio of M_t to M_o is the rate of Nitrogen release in time t, K is the constant of diffusion (which depends on the type of material and osmotic medium), and n is the diffusional exponent which indicates the transport mechanism.

Results and Discussion

Nitrogen elease in Distilled Water. Figure 1 shows the nitrogen release performance of coated and uncoated urea. The slow-release properties of coated urea were evaluated in distilled water at room temperature. The integrity of the coating film is reflected by the initial nutrient release rate. Thoroughly coated urea releases less nutrient compared to uncoated urea. The uncoated urea released almost 99.9 % of its total nutrient in first 12 h. In case of the coated urea, only 11.8 % of its nutrient in first 12 h. Results are almost similar to the biopolymers [31], which demonstrate that chicken manure can be used as a effective coating material.

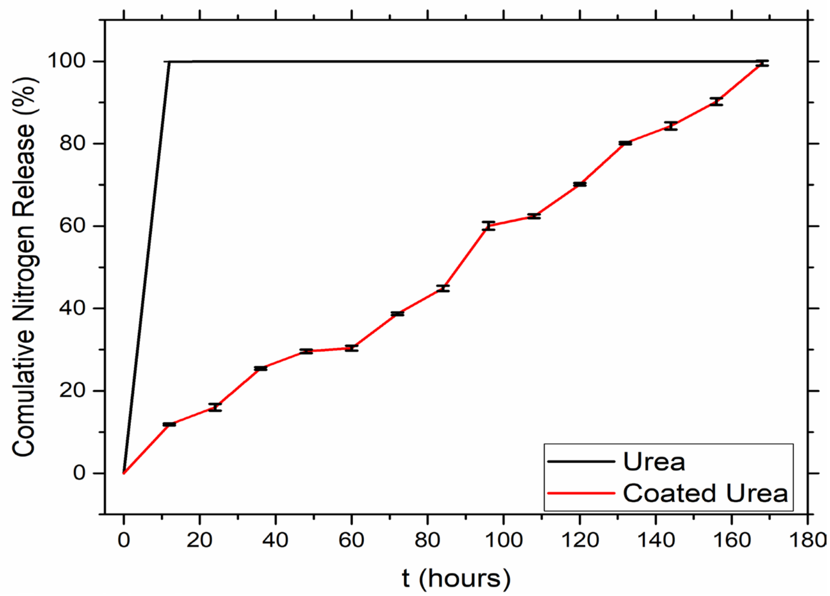

Figure 1: Cumulative nitrogen release percentage as a function of time for coated and uncoated urea.

Release Kinetics

Few models were used to elucidate the functioning of the newly developed coated fertilizer and to get the parameters of release kinetics. Kinetic of release of nutrient from coated urea based on four different models are presented in Figure 2. The kinetic data best fit the Ritger-Peppas law with very high coefficient of determination (R^2) value which is more than0.97. This is due to the fact that the nutrient releases follows both Fickian and Non-Fickian as indicated by the mass transport indicating number n =0.85 which is known as anomalous phenomena [13].

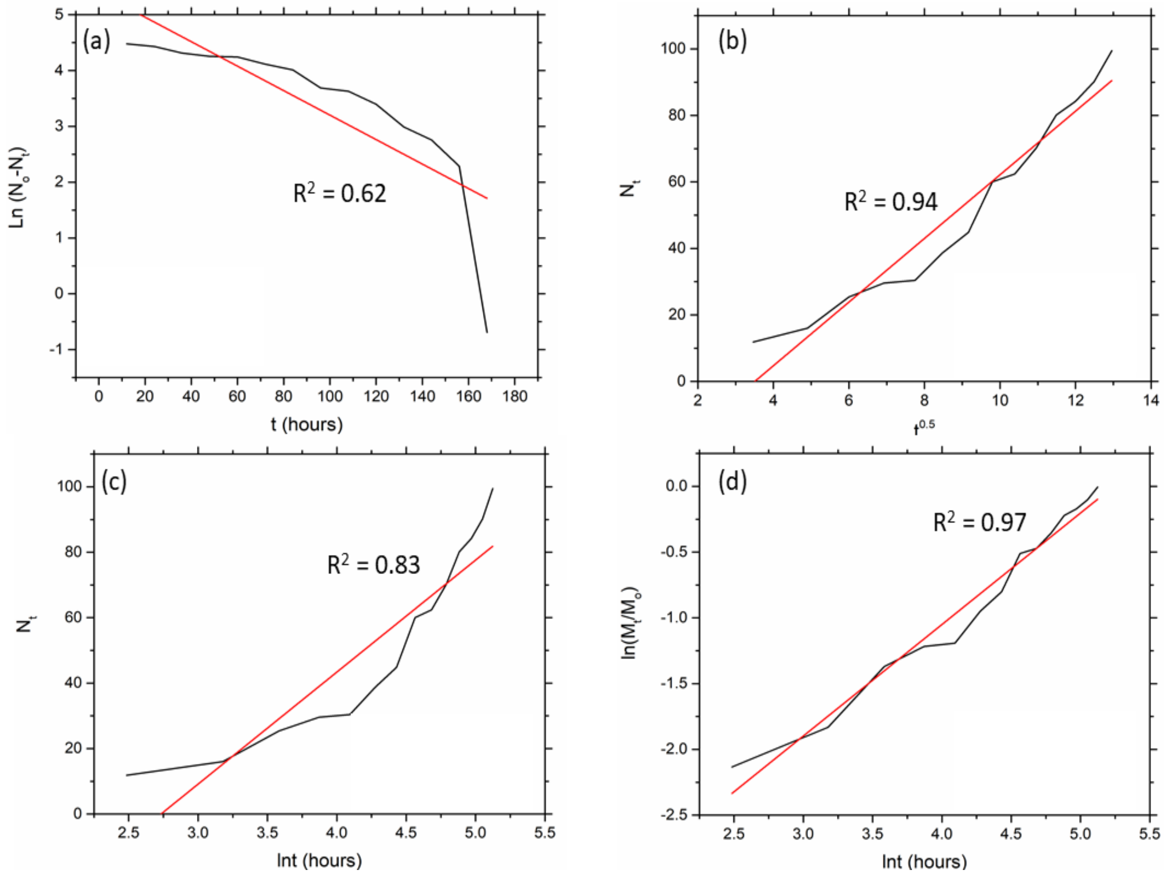

Figure 2: (a) First order, (b) Parabolic, (c) Simple Elovich and (d) Ritger-Peppas models.

Conclusion

Using paraffin wax as a binder urea granule were dip coated with chicken manure to produce novel slow-release coated urea (SRCU). Slow-release properties of the developed fertilizers were examined using nitrogen release test in distilled water. Pristine urea releases more than 99% of its total nutrient in less than 12h, whereas it took almost 680 h in case of SRCU to release ≥99% nutrients. R^2 value of 0.97 for Ritger-Peppas model suggested that the kinetic release data best fir this model.

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