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Physical and engineering properties of urea briquettes relevant to design of ICAR-NRRI urea briquette applicator

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Abstract
Fertilizer deep placement technology is one of the effective measures to levitate fertilizer use efficiency. The physical and engineering properties of urea briquettes were studied for designing the urea briquette applicator. Metering mechanism is considered to be the heart of developed urea briquette applicator to place the urea briquettes at recommended dosage. The diameter of cup and cup depth were decided based on the maximum length and thickness of urea briquette. The mean length, breadth and thickness of urea briquettes were found to be 16.59 mm, 14.54 mm and 9.30 mm, respectively. The mean size and sphericity of urea briquettes were found 13.10 mm and 0.79, respectively. The angle of repose of urea briquettes was found as 33.6°. The average bulk density of urea briquette was found as 0.78 g cc^{-1}.

Keywords: Urea briquette, bulk density, size, shape and metring mechanism

Introduction

Production of paddy is input intensive, particularly, the modern high yielding varieties of paddy, consume large quantity of inorganic fertilizers and irrigation. Nitrogen (N) plays a key role in rice production and is required in large amount. It is also the most limited nutrient in rice production and suffers from heavy system losses when applied as inorganic sources in the puddled field. In wetland paddy cultivation, only 30-40% of nitrogen applied is successfully utilized (Datta *et al*., 1978) [3]. There is a need to improve nitrogen use efficiency of paddy crop to decrease the excessive application of chemical nitrogen and also minimize nitrogen emission to atmosphere. The most widely used nitrogen fertilizer is urea, which contains 46% N, the highest of all solid fertilizers. Nitrogen fertilizer is usually broadcasted as prills in paddy fields prior to transplanting, followed by one or more top dressing in the flood water within the period from transplanting to flowering. The nitrogen fertilizer production is 13.41 MT and consumption is about 17.37 MT during 2015-16. (Anonymous, 2017)

Solid fertilizers can be applied by four different methods viz. broadcasting, placement, band placement and pallet application. Broadcasting is done in two ways spreading of fertilizers prior transplanting (basal application) and spreading of fertilizer prior to flowering (top dressing). Deep placement of nitrogenous fertilizer (N) is one of the alternatives for increasing the nitrogen use efficiency of rice crop. Different forms (granular, urea briquettes, liquid) of nitrogenous fertilizer and their application technologies have been introduced for deep placement. Transplanting and deep placement of fertilizer were done simultaneously, coated fertilizer showed slow dissolving of N granules at 3-5 cm deep into soil and 4-5 cm away from seedlings. (Nayak *et al*., 2017) [7].

Materials and Methods

The experiments of the measuring the physical and engineering properties of urea briquette were carried out in the laboratory of Agricultural Engineering, ICAR-National Rice Research Institute, Cuttack.

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Making of urea briquettes
The prilled urea was used for making briquettes. The prilled urea contains N-46% of fertilizer. Making of good quality briquette, the prilled urea should be free from foreign matter. The briquettes were made by compaction process. The prilled urea feed in the hopper of briquette making machine. The machine has two opposite rotating rollers with reduced spacing for making briquettes. The opposite rotating roller had pockets on its periphery. The urea briquettes were collected at discharge end. The good quality, broken, uneven briquettes were separated manually. The prepared urea briquettes were white in color and odourless.

Size and shape of urea briquettes
The shape and size were very important parameters to design the metering mechanism and placing briquette according to the recommended dosage in rice crop per hectare. The size of briquette was specified by length, width and thickness. The length, width and thickness were measured by digital vernier caliper, which having least count of 0.01 mm. For measuring the dimensions twenty urea briquettes were randomly selected. The size of urea briquette was determined by following formula.

$$size = \sqrt[3]{(length \times breadth \times thickness)}$$

Sphericity and surface area of urea briquette
The sphericity is a measure of shape character, compared to a sphere of the same volume. Sphericity affects the flow characteristics of briquettes in hopper and delivery tube also. The twenty urea briquettes were selected randomly from sample and measured. The degree of sphericity and surface area were calculated as follows (Mohsenin, 1986) [6].

$$surface\ area = \frac{13}{11}(breadth + thickness) \times length$$

$$spericity = \frac{size}{length}$$

Weight of urea briquette
Measuring of urea briquette weight was important to design and develop the size of hopper of applicator. To modify the weight of urea briquette some biodegradable materials can be used. This helps to attain the desirable application rate. The weight of individual urea briquette was measured using electronic weighing balance, having least count of 1 mg.

Bulk density of urea briquette
Bulk density of urea briquette was measured to determine the capacity of hopper. Bulk density of urea briquette was measured using a cylinder of known volume. The test sample was poured gently into cylinder. The point of pouring was moved around to keep the surface approximately level during filling. An excess was allowed to pile on the filled cylinder and then was removed by carefully passing a straight edge across the top of the cylinder. The cylinder with the test sample was then weighed, and the weight of the empty cylinder was subtracted to give the weight of the test sample. The procedure was repeated ten times and the average bulk density of the briquette was calculated. Bulk density was calculated as follows

$$BD = \frac{SW}{V}$$

Where,
BD = Bulk density, g/cm^3,
SW = Weight of the test sample, g, and
V = Volume of cylinder, 1000 cm^3.

Angle of repose of urea briquette
Angle of repose of urea briquette was important parameter to be measured for design the slope of the applicator hopper. The angle of repose was determined by free fall method. The briquettes were dropped from certain height on floor. The dropped briquettes form a cone. The diameter and height of the cone was measured. The experiment was repeated ten times to determine mean angle of repose of urea briquette. The angle of repose was calculated using the following relationship:

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right)$$

Where,
θ = Angle of repose, degree,
h = Height of the cone, cm, and
d = Base diameter, cm.

Results and discussion
Size, shape, sphericity and weight of urea briquette
Physical properties of urea briquettes relevant to design of urea briquette applicator viz. size, shape, surface area, sphericity, weight were determined. These properties were used for developing the urea briquette applicator. Depth and diameter of cup of metering mechanism would be influenced by the maximum length and thickness of urea briquette. The size, sphericity, surface and weight were determined as per methodology. The mean length, breadth and thickness of urea briquettes were found to be 16.59 mm, 14.54 mm and 9.30 mm, respectively. The mean size and sphericity of urea briquette were found to be 13.10 mm and 0.788, respectively. The mean weight of urea briquette and surface area of urea briquette were found to be 1.13 g and 470.44 mm^2.

Bulk density and angle of repose of urea briquette
The bulk density and angle of repose of urea briquettes were determined as per methodology. Angle of repose affects the flow characteristics of urea briquettes in the hopper. The average bulk density of urea briquette was found to be 0.78 g cc^{-1}. The angle of repose of urea briquettes was found to be 33.6˚.

Table 1: Engineering properties of urea briquettes taken for design of metering unit

Parameters	Value
Length (mm)	16.59±1.284
Breadth (mm)	14.54±0.575
Thickness (mm)	9.30±0.249
Size (mm)	13.10±0.521
Surface area (mm^2)	470.44±49.419
Sphericity (%)	0.788±0.042
Weight (g)	1.13±0.105
Bulk density (g/cc)	0.78±0.009
Angle of repose (˚)	33.65±0.429

Conclusions
Design values for urea briquette applicator metering unit
All the engineering properties of urea briquettes were measured and average values were presented in Table 1.

Based on the values, metering unit was designed. Diameter of cup was selected as 20 mm on the basis of maximum length (16.59±1.284) of urea briquette and some allowance was also given for smooth picking and delivery. Depth of cup was selected on the basis of thickness (9.3±0.249) of urea briquette, which was taken as nearly 50% of depth of cup. With different depth of cup was taken and tested for missing and multiple droppings. Depth of cup of 5.5 mm was found finalized which work satisfactorily and giving minimum missing and multiple droppings. If the depth of cup was more briquettes will sit deeper in the cup and if depth of cup was less the briquette fall early resulted in more missing percentage. Mean angle of repose was measured for mild steel surface and was found 33.65±0.429. The angle of repose of cup, picking the urea briquette was selected based on the calculations.

Table 2: Design values for urea briquette applicator metering unit

Parameters	Values
Diameter of cup, mm	20
Depth of cup, mm	5.5
Distance between two cups, mm	19.6
No. of cups per unit	4

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