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Research Article

Effects of Granulation Parameters on Granule Quality of PDM

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Abstract

This paper presents the study of the effects of granulation parameters like binder concentration, drying time, drying temperature & granule size on the granule quality like crushing strength of PDM (Potash derived from molasses) fertilizer. Here the granule is made using spent wash ash and bentonite as a binder material. Spent wash is effluent from distilleries. So PDM production works as a boon for farmers and alcohol industries. Experiments were done and an effort was made to analyse the effect on crushing strength of granules with changes in the granulation parameters like bentonite concentration, drying temperature, time & granule size. These experiments show that with an increase in binder concentration, drying time & granule size the crushing strength increases while it decreases with an increase in drying temperature.

Keywords: Potash derived from molasses (PDM), Granulation, Binder, spent wash, Bentonite, Crushing Strength, Fertilizer

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Introduction

There are a total of 17 vital plant nutrients that are required for plant growth, plant metabolism, and other vital mechanisms. These 17 nutrients are nitrogen (N), phosphorus (P), potassium (K), carbon (C), oxygen (O), hydrogen (H), iron (Fe), manganese (Mn), sulphur (S), calcium (Ca), molybdenum (Mo), nickel (Ni). zinc (Zn), magnesium (Mg), chlorine (Cl), boron (B), and copper (Cu). Some nutrients like carbon, oxygen, and hydrogen are absorbed from the air, water, or both whereas other nutrients are absorbed from the soil. Based on the amount required by the plant, soil-derived nutrients can be divided into two categories: macronutrients and micronutrients. Macronutrients are required in larger quantities than micronutrients. Nitrogen, phosphorus, potassium, magnesium, sulphur, and calcium are the macronutrients. Iron, copper, molybdenum, nickel, zinc, manganese, chorine, and boron are the micronutrients [1]. In the absence of these nutrients, plants are unable to complete their typical life cycle. When plants are not getting enough nutrients then fertilizers are used to fill up that particular deficiency [2, 3].

PDM is potash derived from molasses which is a fertilizer that contains potassium. Potash is a name given to inorganic compounds that contain potassium in a water-soluble form. Having potassium in the water-soluble form helps its use as a fertilizer because after application due to its solubility it gets easily available to plants for uptake. It ensures the proper health of plants by improving overall health, and disease resistance. It also increases crop yield and creates a better final product [4]. For potash, the best source is potassium salt deposits which are made after the dried ancient seas. The form of potash that is generally used for fertilizer production is MOP (Muriate of Potash). When no local option for procuring potash is available, it must be imported and that is why PDM provides a great alternative option because it reduces the external liabilities of importing.

Molasses is a thick black syrup that is obtained as a by-product of sugar production. This molasses is fermented to produce alcohol. After the fermentation weak alcohol is obtained, this weak alcohol is then sent to distilleries [5]. Distilleries use distillation operations where a liquid is purified by the process of heating or cooling. So, during the distillation, pure concentrated alcohol is obtained, and spent wash is also produced as liquid waste. This spent wash is highly acidic in nature (pH=4.1-4.5) and BOD, COD is also high means spent wash is highly polluting in nature. But spent wash contains 27.89% potassium as K_2O, 1.06% phosphorus as P_2O_5, calcium, magnesium, sulphur, and carbon. Despite having great fertilizer properties spent wash cannot be applied to the soil directly due to its toxicity, because if applied it can pollute the soil. That is why it must be first treated to make it an applicable fertilizer. For this process, it is first concentrated in a multi-effect evaporator (MEE) and then it is burned in an incinerator to produce spent ash. MEE uses a series of vessels to heat the solution and remove the impurities by using the difference in the boiling point of the associated components. In MEE, the pressure is reduced from vessel to vessel, as the pressure progressively reduces the boiling points of every component in the solution is also reduced and the solution can be evaporated at low temperature. The spent ash is then sent to a granulation plant to produce PDM granules [6]. The granulation plant consists of a granulator for making granules from powder, a dryer for removing moisture and for strengthening the granules, a cooler for cooling, and screens for separating the granules of the desired size.

For fertilizers, granulation is used because granular fertilizers have the advantages of slow-release, no constant application, and are also a cheaper option than liquid fertilizer. Slow-release from granules is possible due to its binder and shape, the binder does not allow nutrients to get easily dissolved in soil due to bonding and as it has a spherical shape it has the least surface to volume ratio means it has the least surface area for the same volume than any other shape, it gives less area to contact with soil means less chance for nutrients for dissolving. As nutrient is released slowly plants get them in a timely manner and no constant application is hence required, slow-release is also important because if a particular nutrient is made available to the soil in a large quantity at a time it dilutes the other nutrients and plants can suffer its deficiency. For granulation, a binding material is required so that it can hold the material in a granule form [7]. Here bentonite is used as a binding material because it has the ability to absorb large quantities of water and when wet it increases its cohesiveness [8].

This paper focuses on the effects of change in the granulation parameters on the granule quality of PDM. Here mentioned granulation parameters are bentonite concentration, drying temperature, drying time, and granule size. The granule quality is characterized based on the granule crushing strength. The crushing strength and spherical shape obtained from the granulation are important because it only helps granules to maintain their structural integrity during transportation and the slow release of nutrients at the time of application. This research aims to provide a better understanding of the granulation process and granule quality through experiments on PDM granules. although some studies are done on NPK fertilizers for influence of time parameters of granule formation [9], and on pharmaceutical samples for influence of binder properties [10], studies of the kind discussed in the current manuscript is scarce.

Material and Methods

Lab experiments were conducted at the R&D department, GSFC Ltd., Vadodara to produce PDM granules and measure their crushing strength. To start the experiment first the required amount of spent ash which contained 20% potash and bentonite was taken in a beaker and a homogeneous mixer was made by proper mixing. After proper mixing granules were made by spraying water during granulation. Three sets of PDM granules were produced based on different bentonite concentrations of 15%, 20% & 25%. After these granules are produced it is then separated into three different size ranges of oversize, undersize, and preferred size between 2 mm – 4.75 mm by sieving. Now as there are several samples available of different concentrations and sizes it is then sent for drying in a hot air oven. Samples were kept at different drying temperatures of 80^{0}C, 100^{0}C, & 120^{0}C and at different drying times of 1,2 & 3 hours.

Crushing strength measurement

After granule samples with different parameters are obtained, they are then used to measure the crushing strength. For crushing strength measurement, the equipment shown in **Figure 1** is used. First, the granule is placed on the support and it is confirmed that it is placed at the centre precisely.

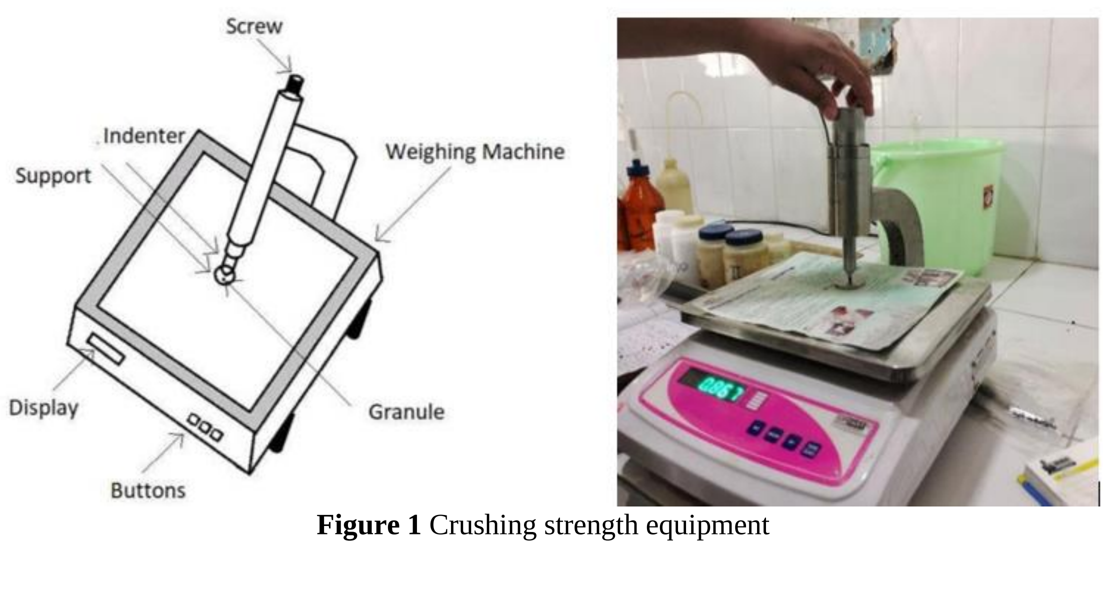

Figure 1 Crushing strength equipment

Next, the granule is slowly pressed with help of the screw and the weight reading increases on the display as the indenter presses the granule it is done till the granule clearly breaks or the reading achieves a peak and it decreases rapidly means the granule is crushed and that is why the load is released. Here the peak was the reading & its unit will be Kg/granule. Multiple readings are taken from a sample and the average crushing strength is considered as the result.

Result and Discussion

Results are obtained from the average crushing strength of all different samples and they are categorized into four sets based on four granulation parameters. All these sets of results are shown below in a graphical manner.

Crushing strength V/s Binder concentration

Figure 2 shows an increase in binder concentration increase crushing strength and it follows the exponential trend. 10% increase in binder concentration from 15% to 25% results in an increase in crushing strength of 121.49% in the 1-hour sample, 159.54% in the 2-hour sample & 163.79% in the 3-hour sample. All these samples were maintained at 100^0C for drying.

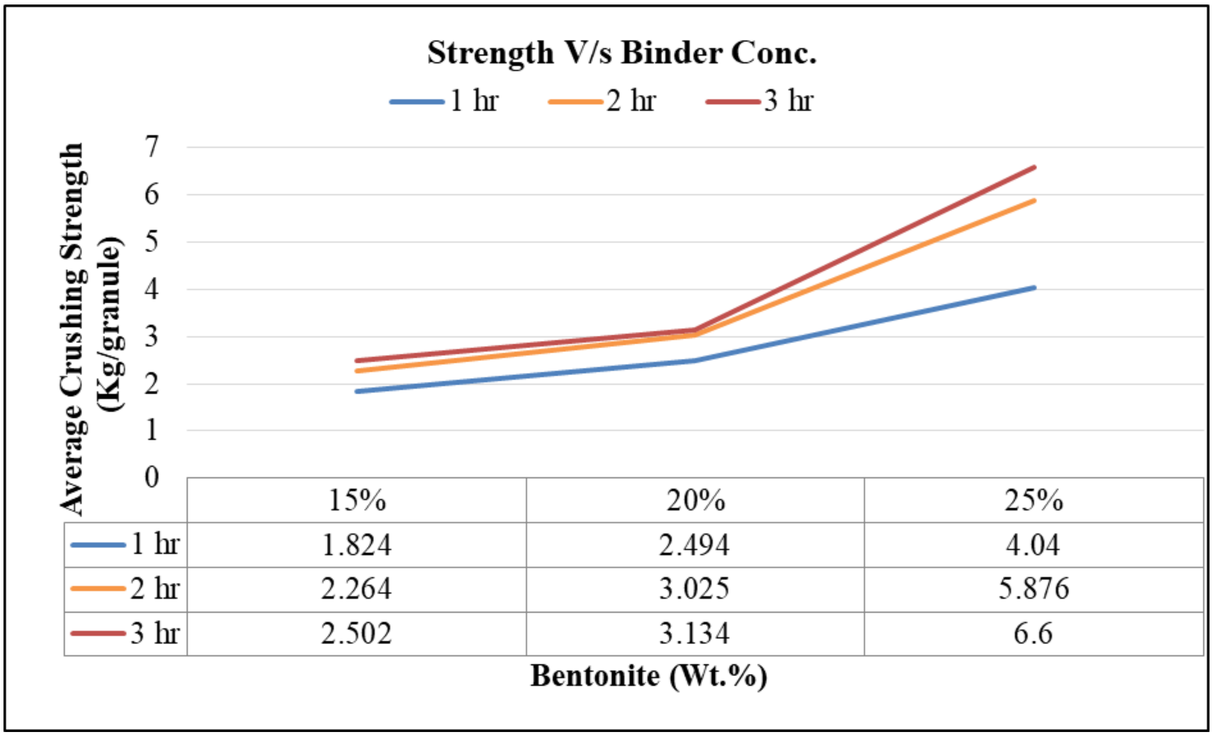

Figure 2 Crushing strength V/s Binder concentration

Crushing strength V/s Temperature

Figure 3 shows an increase in drying temperature decreases crushing strength and it follows a logarithmic trend. Increase of 40^0C in drying temperature from 80^0C to 120^0C results in a decrease of the crushing strength of 7.57% in the 2-hour sample and 31.99% in the 3-hour sample.

Crushing Strength V/s Drying time

Figure 4 shows an increase in drying time increases crushing strength and it follows a logarithmic trend. An increase in drying time by 2 hours from 1 hour to 3 hours results in an increase in crushing strength of 37.17% in the 15% sample, 25.66% in the 20% sample, and 63.37% in the 25% sample. All these samples were maintained at 100^0C for drying.

Crushing strength V/s Granule size

Figure 5 shows an increase in granule size and increase crushing strength and it follows the logarithmic trend. An increase in granule size from a range of below 2mm to above 4.75mm results in an increase in crushing strength of 88.35% in 15% and 120^{0}C samples.

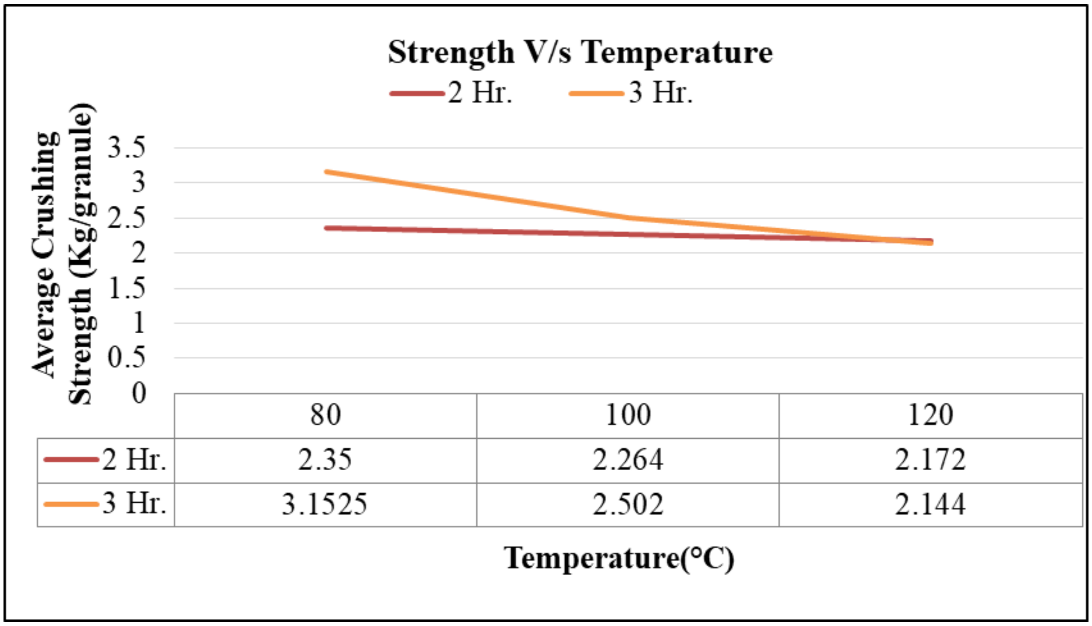

Figure 3 Crushing strength V/s Drying temperature

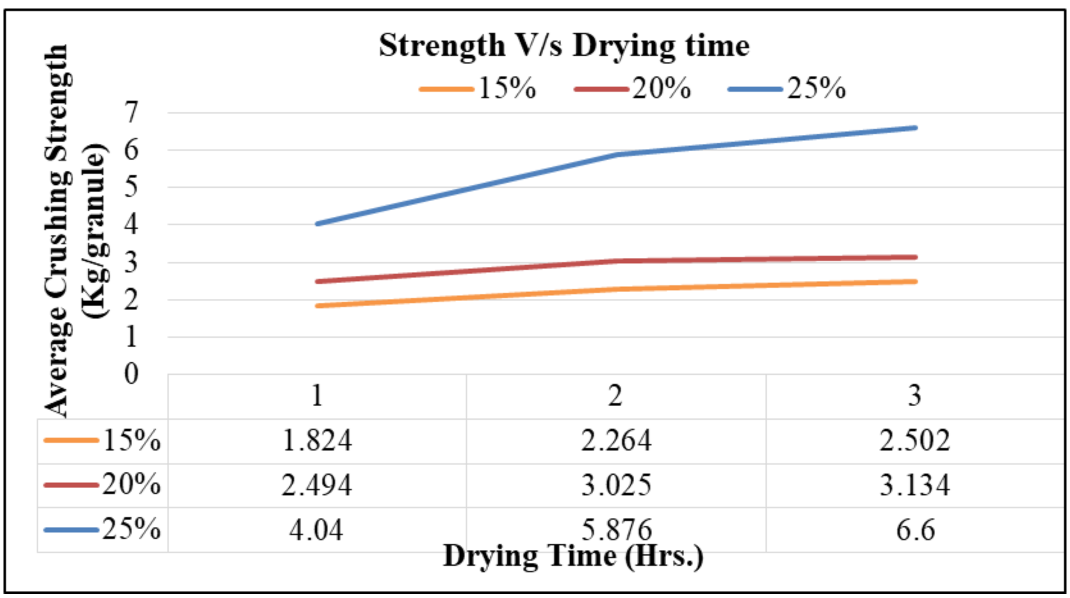

Figure 4 Crushing strength V/s Drying time

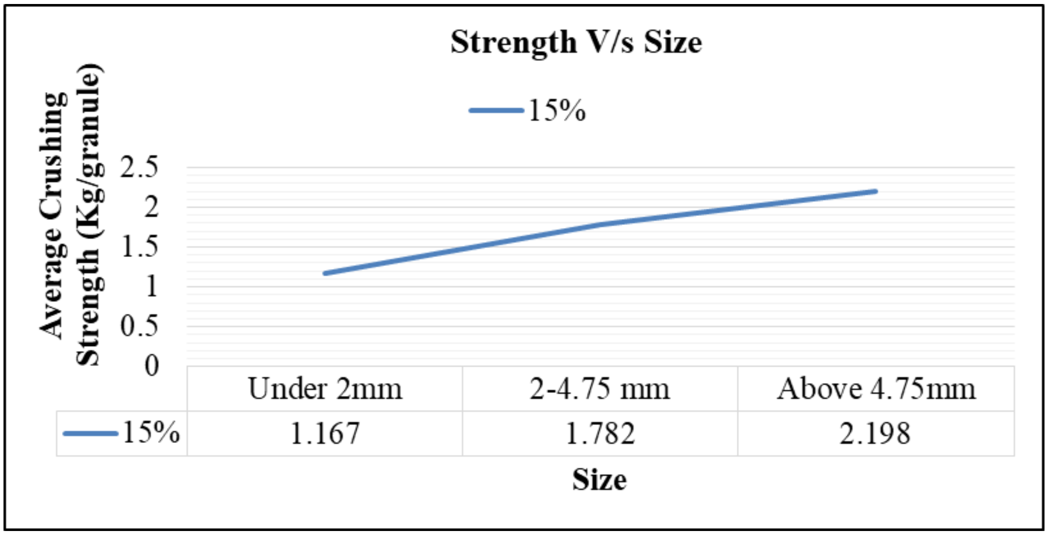

Figure 5 Crushing strength V/s Granule size

Conclusion

The use of bentonite as a binder material for the PDM granulation process produces granules with desired crushing strength and quality. As the Bentonite concentration, drying time, and Granule size increase the granules crushing strength also increases but when drying temperature is increased the crushing strength decreases. This happens because wet bentonite's cohesiveness provides granules its strength, it happens because as the granules are made the nodes are formed between particles and these nodes grow and expand until it links up to the next bentonite particle or adjacent spent ash particle. An increase in Bentonite concentration, drying time, or Granule size provides an opportunity to increase the amount of these nodes or nodes growth that is why an increase in these properties increases crushing strength. But increase in drying temperature means rapid drying of granules and it decreases the chance of node growth that is why the increase in temperature reduces granules crushing strength.

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