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Research paper

Optimizing the Urea Granule Size by Taguchi Approach

Norhidayah. Mohamad[1]*, A. Shaaban[2]

[1]*Faculty of Engineering Technology, Multimedia University, Jalan Ayer Keroh Lama, 75450, Melaka, Malaysia*
[2]*Advance Manufacturing Center,*
Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Melaka, Malaysia
**Corresponding author E-mail: norhidayah.mohamad@mmu.edu.my*

Abstract

Urea granule fertilizer was produced by using lab scale fluidized bed granulator through the wet granulation process. This experiment was conducted to determine a dominant factor of few parameters used in producing urea granule. The Taguchi method was utilized to address these three factors which later were analyzed by using Analysis of Variance (ANOVA). The obtained results were analyzed by Signal-to-Noise ratio and ANOVA. Based on the Signal-to-Noise ratio analysis, indicates that spraying rate and viscosity are insignificance in determining the output. The mass of starch is the significant factor. The ANOVA results reveal the cassava starch contribute major influences on urea granule size formation, meanwhile spraying rate was indicated as minor contributor.

Keywords: *Granulation, Urea, Cassava starch, Fertilizer, Taguchi*

1. Introduction

Fluidized bed technology is the most economic technology used to produce high volume urea granules. Granules can be produced from solid-containing liquids as solutions, suspensions or melts by means of Fluidized Bed Spray Granulation (FBSG). The final output granules brought value added with solubility, control release of active ingredients and else. M. Börner et al. made an optimal adjustment of liquid binder atomization into the fluidized bed system. His research focused more to analyzed the variation of nozzle parameters [1]. There are different utilizations of the granulation process. Previous researchers [2-3] e.g. used melt agglomeration to produce their granules. In the spray agglomeration process granule growth is realized through a binder agglomerating existing particles.

This research was conducted to investigate the parameters of binder, binder viscosity and spray rate performance that will give more influence on UG agglomeration by using conventional top spray fluidized bed granulator (TSFBG). Cassava starch was used as a main source of binder for this experiment [4-6]. The binder solution reinforces the bond between urea powder particles in the formation of urea granule (UG). Proper mixed binder ratio preparation will produce strength of covalent binding from oxygen-hydrogen bonding at physical adsorption [7]. This condition would be reduced at high temperature more than 80 °C whereby binder possible transform back to liquid state affected by OH released as H2O state [8]. Therefore, temperature was controlled and monitored first in previous study to ensure the effectiveness of granulation process [9]. Viscosity was frequently related to the study of hardness of the obtained granule. Hu et.al found that high concentration and viscosity would cause solidification binder and tube blockage in the feeding channel. The binder solution was heated up in range of 65 °C. The temperature should be controlled not more than 65 °C in order to avoid loss of nitrogen (N) content which was needed to fertilize in paddy growth. Thus, in the evaluation of agglomeration of granule size, viscosity contributes less but still has significant especially in term of force of spraying required to ensure broad droplets distribution to achieve uniformity of granule size production at hyper kinetic condition.

D.M. Morkhade made a comparison of impact for different binder addition methods. Binder addition by spraying increased fines, blend segregation potential, granule friability, tablet tensile strength and tablet disintegration time. Findings from their research, binder spray method increased granule size and density [10-12]. The research conducted by Martin Schmidt et al. proven that, the spray rate parameter does not give significant effect to enlargement of granule. The overspray rate denotes the amount of spray droplets which solidify before being spread on the particles. Thus the overspray does not contribute to particle growth but directly forms dust particles. It is contradict with other researchers [13]. U. Vengateson and R. Mohan conducted the experiments and the results proved that increasing the binder flow rate caused the formation of bigger granules while increasing fluidizing air velocity leads to a decrease in average granule diameter. Granule growth rate and the size of the end granules increase with the binder flow rate, however, increased binder flow rate causes earlier defluidization. Increase in fluidizing air velocity led to a reduction in growth rate and delayed defluidization [14].

2. Experimental Work

A series of preliminary data from binder ratio consist of starch (S): urea powder (UP): distillate water (DW) as mixing ingredient used to prepare a binder solution. At this stage, the concentration of binder then was determined accordingly based on amount of starch powder mixed into these three combination element. The accumulated data were screening by using one-factor-at-a time (OFAT) and then the binder viscosity was measured by using viscometer (V200002 Smart Series, Fungilab).

2.1. Screening using one-factor-at-a time (OFAT)

Table 1 indicates series of data obtained based on preliminary screening using OFAT to reveal the optimum amount of starch required in binder preparation to ensure the binder flows smoothly in silicon tube which size 1-meter length and 0.5 cm inner diameter. Binder C was selected as an optimum ratio used in binder preparation according to the viscosity flows through the silicon tube in condition between liquid-solid states at 65 °C.

Table 1: Binder ratios listed after OFAT screening.

Binder	Ingredients Starch: Urea: Water (W/W) %	Spray rate (ml/mi)	Binder Solution (feeding line) 65 ^{0}C
A	1 : 50 : 49	300 ± 5	Liquid
B	2 : 50 : 48	250 ± 5	Semi-liquid
C	3 : 50 : 47	200 ± 5	Semi-Solidified
D	4 : 50 : 46	150 ± 5	Solidified
E	5 : 50 : 45	100 ± 5	Solidified

2.2. Taguchi Analysis

In this study, the Taguchi analysis has been used to optimize the factor of UG size agglomeration. This technique provides a special design to set the process parameters with minimum number of experiments by saving time and resources. For this Taguchi's experimental design, a L4 (2×3) orthogonal array was selected in this work to determine the effect of all of these factors, cassava starch, and binder spray rate and binder viscosity to the agglomeration of UG size. The factors and their levels considered in conducting the experiments are displayed in the table below.

Table 2: Control Factors and Levels

Symbol	Factors	Unit	Level 1	Level 2
A	Starch	Gram	1	5
B	Spraying Rate	ml/min	5	10
C	Viscosity	$Kgm^{-1}s^{-1}$	0.05	0.25

Symbol A represent for starch, while B is for spraying rate of fluid spread out from nozzle tip and C for viscosity from the prepared binder. Thus, the optimum levels of the parameters (A2, B2, and C2) were selected to perform the experiment using TSFBG to verify the optimum of UG size.

3. Results and Discussion

3.1. Image Segmentation by Agglomeration

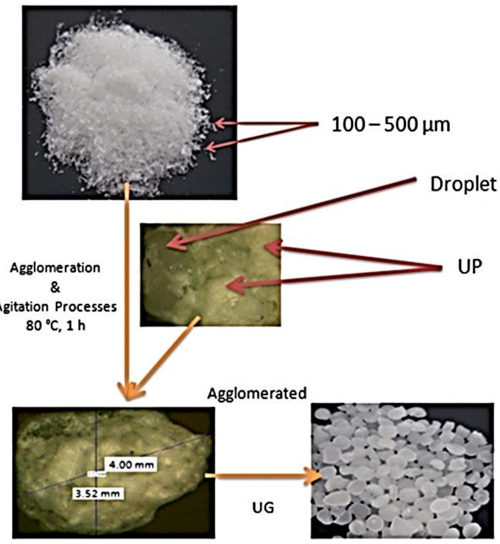

Fig. 1: Stages of the agglomeration of UG observed by digital microscope.

Figure above shows the granule images shoot by using digital microscope (Eclipse LV150N Nikon). The UG size and image surface were verified for granule surface identification. These images show the rough of agglomeration mechanism between UP and binder. These images also used as a hypothesis to understand the mechanism of agglomeration process between droplets and powder.

3.2. A Signal-to-noise Ratio

In the Taguchi approach, Signal-to-Noise (S/N) ratio, was used to measure the quality characteristics which deviate from the desirable value. For the Signal-to-Noise ratio, the term 'Signal' represents the desirability of response parameters and the term 'Noise' represents the undesirability for the response parameters. The objective of the S/N ratio was to identify the factors and their combination that influence the UG agglomeration. For the result, the larger Mean S/N ratio (dB), the better quality of characteristic was used to calculate the S/N ratio and it was is determined by:

$$S/N = -10 \log \sum(1/yi2)/n \quad (1)$$

Where n is the number of experiments in a trial/row, in this case, n = 2 and yi is the ith measured value in a run. Results of the experiments are shown in Table 3.

Table 3: Minimum and maximum readings of three factors effect on UG size formation.

No	A	B	C	Granule size (mm)				Mean SN (dB)
				1st trial	2nd trial	3rd trial	Average	
1	1	5	0.05	2.20	2.40	2.80	2.47	7.714
2	1	10	0.25	2.40	2.60	2.60	2.53	8.055
3	5	5	0.25	3.60	3.20	3.40	3.40	10.599
4	5	10	0.05	3.80	3.00	3.60	3.47	10.663

The experiment was performed according to process parameters at the different levels as tabulated in Table 3. The experimental results were converted into signal/noise (S/N) ratio. In this measure, the larger output is the best for UG optimum size. Data from table 3 shows that experiment 4 gave highest Mean SN value compare than other experiments conducted.

3.3. Analysis of Variance (ANOVA)

The purpose of the analysis of variance is to find the parameter's significance on the quality characteristics. The ANOVA results developed for this experimental work are summarized in Figure 2 and Table 4. It indicates that the optimum levels obtained are starch at maximum level (5g), spraying rate at maximum level (10ml/min) and viscosity at maximum level (0.05 kgm-1s-1

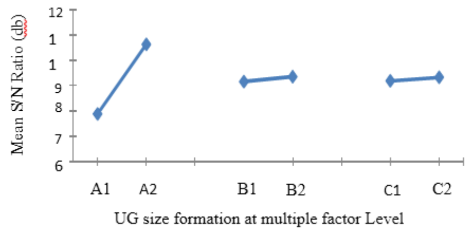

Fig. 2: ANOVA assessments on three factors influence onto UG size formation.

Figure 2 shows that the maximum level of the all the three factors (A2, B2 and C2) have higher means S/N ratio, implying that it gave influence on UG size agglomeration.

Table 4: ANOVA for the UG Agglomeration Size Factor

Parameters	Contribution (P, %)	Rank
Starch	99.209	1
Spraying rate	0.537	2
Viscosity	0.252	3
Error	0.002	
Total	100	

The significant factor was further obtained using ANOVA result as shown in Table 4. The cassava starch was the major parameter (99.209%) influences on UG size formation, meanwhile spraying rate was indicated as minor contributor as 0.537 % solely whereby this parameter was totally affected by condition of inlet air pressure.

4. Conclusion

The following conclusions are drawn from this study: according to Taguchi optimization, for UG sizing output, the quantity of binder solution was 0.05 kgm-1s-1, spray rate at minimum level 10ml/min and the cassava starch amount of 5 grams are found to the best the parameter on producing the optimum size. The data obtained by repeating the experiment using selected series of factor level (A2, B2 and C2). Thus, the binder of cassava starch concentration had highest influence in the UG formation and behaves as a good binder at optimum granulation duration. The range of UG sizes from the Taguchi assessment was vindicated by supported images captured using digital microscope. The obtained result will be used for next research to determine the dominant factor in the agglomeration mechanism and hardness of the UG.

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