

A STUDY OF UNCOATED AND COATED UREA CRYSTALS DISSOLUTION IN STIRRED VESSEL

M.H. Ismayanda ^{*)} and M. Zakaria ^{**)}

Abstract

An immersing and spray coating process has been developed for the continuous production of tapioca starch and silica coated urea. The coating thickness and quality of coated urea was produced in a laboratory-scale unit. The dissolution rates of urea uncoated and coated urea crystals were studied in a stirred vessel. Coated urea crystals generally shows low dissolution rates compared to uncoated for all coating materials. The effect of coating was best with tapioca starch and silica combination baked at 70 °C. This coating material of tapioca starch coated urea the dissolution time was in the range of 300 to 360 second, mass transfer coefficient in the range of between 8.08×10^{-3} to 8.78×10^{-3} cm/s and diffusion coefficient in the range of between 3.63×10^{-6} to 2.91×10^{-5} cm²/s. And for the silica coated urea coating material, the dissolution time was in the range of 300 to 380 second, mass coefficient in the ranges of 1.65×10^{-2} to 3.30×10^{-2} cm/s, and diffusion coefficient in the ranges of 3.57×10^{-6} to 3.30×10^{-5} cm²/s. The dissolution ranges from about 87 % for a product containing 10.5 % tapioca starch to the dissolution range of about 85 % for a product containing 9.5 % silica.

Key words : urea crystals, coating, dissolution, stirred vessel

Introduction

Urea ($\text{CO}(\text{NH}_2)_2$) a white crystalline solid containing 46 % nitrogen, 0.40 % biuret, 0.31 % moisture of water and 0.50 ppm iron is widely used in the agricultural industry as an animal feed additive and fertilizer (Salman, 1989 ; Lu and Lee, 1991). Nitrogen from urea can be lost to the atmosphere if fertilizer urea remain on the soil surface for extended periods of time during warm weather. It may also be blended into the soil with irrigation water.

A rainfall of as little as 0.25 inches is sufficient to blend urea into the soil to a depth at which ammonia losses can not occur (Lee and Melsen 1983). Urea is among the most important and widely used fertilizers in the cultivation for a wide variety of crops. In Indonesia about 5 million tons of urea is produced per year for use in rice growing. The need continues to rise with the increase in demand for rice.

In general the paddy farmers sprinkle urea prill across the field at regular intervals. It is assumed that the prills settle for the bottom of the soil and dissolve in the course of time. However, it has been found that only 25-40 % of the nitrogen contained in urea is used by the paddy plants (Lee and Melsen, 1983; Savant, 1983). Controlled release of active agent is important not only for attaining the most effective use of the agent but also for prevention of pollution. Different types of slow release fertilizers have been studied by various investigators (Lu and Lee, 1991).

The pretreatment of urea by coating or binding help reduce the rate dissolution of crystals,

thus allowing more time for the plant to absorb the nutrient. In this study the dissolution of urea crystals was studied, using a stirred vessel to simulate the movement of irrigation water in paddy fields. (Jarrel and Boesma, 1979; Kurihara, 1970; Salman, 1989).

Material and Methods

The urea used are white crystals with a specific gravity of 1.3350. Materials used to coat the crystal are tapioca starch and silica. The original urea crystals was first sieved before being covered with coating materials in powder form, tapioca starch coated and silica coated by spray and immersing coating then the materials was gently mixed in order to aid the coating process with minimal breakage of the particles. The particles were then baked at temperatures of 30°C, 50°C. and 70°C. The particles were sieved before baking to remove the dust. They were sieved again after baking and the individual screen fractions were collected in polyethylene bags.

The dissolution studies were carried out in distilled water in a cylindrical Perspex tank with a diameter of 12 cm. The tank was filled to about 7 cm. Agitation was achieved with a 6-blade disc turbine of diameter $D=T/3$, rotated at 120 rpm.

The concentration of urea in the water was determined over a period of time using a pre-calibrated conductivity meter

The conventional method for determining the dissolution of urea in which is 50 g of the sample is by placing it in a bottle and then add 500 ml of

^{*)} Department of Chemical Engineering University of Syiah Kuala (Unsyiah)
Darussalam- Banda Aceh-Indonesia

^{**)} Institute of postgraduate studies University of Malaya (UM) Kuala Lumpur , Malaysia

distilled water. The refractive index of the solution is measured as a function of time. The urea dissolved in water (gram) can be calculated from equation 5.

Table 1 shows the effect of various coating material on the dissolution rate of a multi particle. It was observed that for the same mixing time the concentration of urea was high for silica coated and tapioca starch coated at 70 °C. For multi particle uncoated crystal experiments, the particle size was about 0.15 cm in diameter and the multicoated urea size was about 0.153, 0.160 and 0.166 mm in diameter and a baking temperature of 30, 50 and 70 °C was used. The dissolution was carried in a beaker filled with 500 ml water, with a disc turbine rotating at 120 rpm

a. Substrate: urea prill, Average diameter 0.15 cm

b. Coating, Sodium silicate and tapioca starch.

These correlations may be useful in determining the mass transfer coefficient for diffusion controlled processes. Alternatively the diffusional step can be characterized by performing the dissolution experiment.

The equation for diffusion coefficient of the dissolution and release of urea is as follows :

$$D_e = \frac{7.4 \times 10^{-8} (\psi B M B)^{0.5} T}{\mu B V_A^{0.6}} \quad (1)$$

Where ψB is factor dissolution, MB is molecular weight of solvent, T is temperature, μB is viscosity of solvent and V_A is volume specific of solvent. The urea dissolved in water (grams) can be calculated from the following equation :

$$\%Diss = \frac{(N_D - 1.3322)(744000(N_D - 1.3322) + 141000)}{100\% \text{ total coating}}$$

N_D is the refractive index of the solution is measured as function of time

Results and Discussion

The release of urea from uncoated and coated urea prill depends on many factors such as the quality of coating film, temperatur, water content, microbial activity, organic matter, cation-exchange capacity, pH, and metode of application.

Figure 1 shows the effect of various coating on the dissolution rate of a multiparticle. It was observed that for the same mixing time the concentration of urea was high for multiparticle uncoated was best baked at 50 °C and 70 °C.

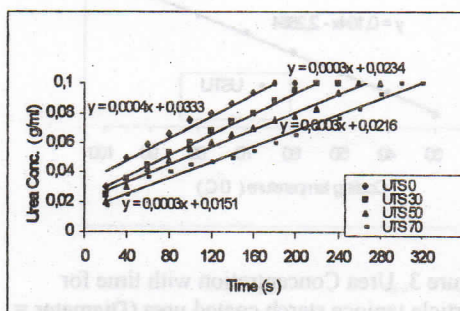


Figure 1. Urea concentration with time for a ,multi particle uncoated urea prill (Diameter = 0.15 cm, T = 30, 50 and 70 °C, Impeller Speed = 120 rpm)

Figure 2 shows the effect of temperature and component of water, biuret, nitrogen, ammonia and iron difference on coating material weigh for difference coated material coating, material coating temperature and flow rate. As seen from figures 2, the coating weigh was found to decrease linearly with material coating of tapioca starch temperature at approximately 0.72 to 8.03 % w per degree in the range of 30 to 100°C

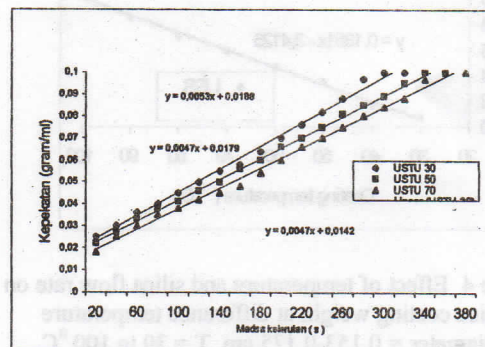


Figure 2. Effect of temperature and tapioca starch flow rate on tapioca starch coating weight at difference temperature (Diameter = 0.153-0.175 cm, T = 30 to 100 °C, Impeller Speed = 120 rpm)

Figure 3 shows the effect of various coating on the dissolution rate of a multy particle coated urea. It is observed that for the same mixing time the concentration of urea was high for tapioca starch coated urea which ranges between 50 °C - 70 °C

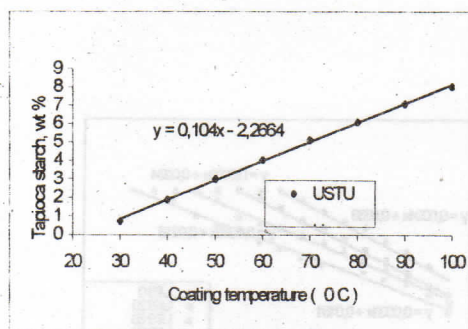


Figure 3. Urea Concentration with time for multiparticle tapioca starch coated urea (Diameter = 0.153, 0.160 and 0.167 cm, $T = 30, 50$ and 70°C , Impeller Speed = 120(rpm))

The coating weight was found to decrease linearly with tapioca starch temperature at approximately 0.8 persen per degree in the range of $30\text{--}100^{\circ}\text{C}$. The contact time between urea and tapioca starch consisted of two parts with a short period of about 0.3 s. The primary dependent variable in the coating process is the coating weight.

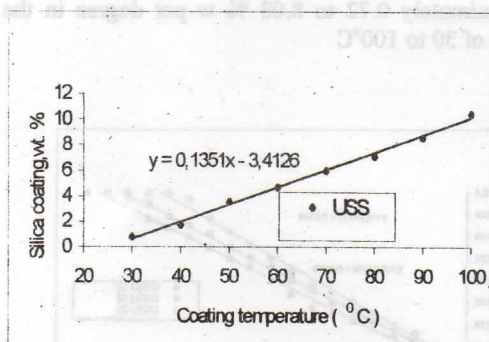


Figure 4. Effect of temperature and silica flow rate on silica coating weight at difference temperature (Diameter = 0.153-0.175 cm, $T = 30$ to 100°C , Impeller Speed = 120 rpm)

Figure 4 shows the effect of temperature and component of water, biuret, nitrogen, ammonia and iron difference on coating material weight with different coating material, materials coating temperature and flow rate. As seen from figures 2, the coating weight was found to decrease linearly with material coating of silica temperature at approximately 0.82 to 10.42 % w per degree in the range 30 to 100°C . The dissolution of urea in water decreases with an increasing coating percentage. In addition to reducing urea release rates, silica coating film improves the physical properties of the fertilizer which are very important for storage and handling characteristics.

The primary dependent variable immersing-coating is based on the rate of heat transfer from the melt to the urea prills the independent variables are those parameters which effect this rate of heat transfer, contact time, silica temperature and flow rate, urea temperature and flow rate, urea type and size.

Figure 5 shows the effect of various coating on the dissolution rate of a single particle. It was observed that for the same mixing time the concentration of urea was high for silica coated at 50°C and silica coated at 70°C .

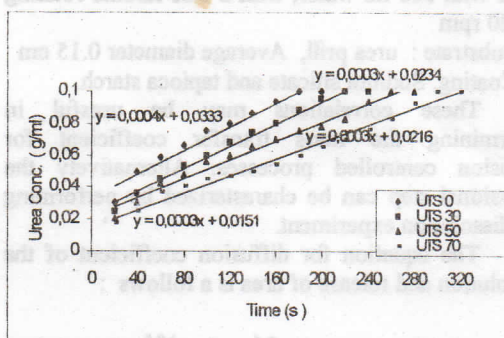


Figure 5. Urea Concentration with time for silica coated urea (Diameter = 0.153, 0.160 and 0.166 cm, $T = 30, 50$ and 70°C , Impeller Speed = 120 rpm)

When the urea prills are coated with silica, the release can be controlled by changing the total amount of coating materials. As shown in Figure 5, the dissolution of urea in water decreases with an increasing coating percentage. This is due to the reduction in the number of pinholes which are the primary path for urea release from silica coated urea. In addition to reducing the urea release rates, silica coated urea film improves the physical properties of the fertilizer which are very important for storage and handling characteristics.

Dissolution of uncoated and coated urea as shown from table 1, the conventional method for determining the dissolution of urea is water. Dissolution was carried out in a beaker filled with 500 ml water, with a disc turbine rotating at 120 rpm. The refractive index of the solution is measured as a function of time. The urea dissolution in water (grams) can be calculated from the following equation (2).

Table 1. Effect of temperature coating on % dissolution at difference materials coating

| Production Urea prill | Baked (°C) | Dissolution (°C) | % Dissolution |
|----------------------------|------------|------------------|---------------|
| Uncoated urea | 0 | 30 | 98.40 |
| Uncoated urea | 30 | 30 | 87.39 |
| Uncoated urea | 50 | 30 | 96.51 |
| Uncoated urea | 70 | 30 | 96.29 |
| Tapioca starch coated urea | 30 | 30 | 87.58 |
| Tapioca starch coated urea | 50 | 30 | 85.27 |
| Tapioca starch coated urea | 70 | 30 | 82.29 |
| Silica coated urea | 30 | 30 | 85.95 |
| Silica coated urea | 50 | 30 | 84.89 |
| Silica coated urea | 70 | 30 | 83.06 |

Coating temperature plays an important role in determining the coating thickness of urea, where the urea was coated with various coating materials such as tapioca starch and silica. The solubility of coated urea observed were in the ranges between 81.15-93.65 %.

This coating material of tapioca starch coated urea the dissolution time was in the range of 300 to 360 second, mass transfer coefficient in the range of between 8.08×10^{-3} to 8.78×10^{-3} cm/s. And for the silica coated urea coating material, the dissolution time was in the range of 300 to 380 second. mass coefficient in the ranges of 1.65×10^{-2} to 3.30×10^{-2} cm/s.

Diffusion coefficient in the range of between 3.63×10^{-6} to 2.91×10^{-5} cm²/s. And for the silica coated urea coating material, the dissolution time was in the range of 300 to 380 second. diffusion coefficient in the ranges of 3.57×10^{-6} to 3.30×10^{-5} cm²/s. The dissolution ranges from about 87 % for a product containing 10.5 % tapioca starch to the dissolution range of about 85 % for a product containing 9.5 % silica.

Conclusions

This study looks into the effects of various coating, a process the effect of various coating materials baking temperatures this work. Among the various coating materials employed in controlling the release of urea, tapioca starch and silica coated urea appears to be the most effective due to low cost of application. The temperature does not have a strong influence on the dissolution rate of urea. Perhaps 50 and 70 °C are an acceptable baking temperature. For all practical purposes, farmers can coat the urea prill with tapioca starch, silica and dry them in sun for slow release of urea. The contact time between urea and tapioca starch, silica consisted of two parts : a

short period of about 0.2 -0.4 s in the coaxial tube feeder and a longer period. The coats consisted of a single tapioca starch and silica layer. Due to infections in the tapioca starch coats, immersing and spray- coated urea exhibited higher urea release than that manufactured by spray-coating processes. However, it is hoped that the pinhole problem, can be overcome by the addition of suitable additives.

Acknowledgment

The authors wish to thank Asean Aceh Fertilizer Company and the University of Malaya, Kuala Lumpur for financial support of this work

Reference

- Jarrel, W. M. and Boesma, L. (1979), "Model for the release of urea by granules of sulfur coated urea applied to soil", *Sci. Soc. Am J.*, pp.1004-1068
- Kurihara, K. (1970), "Coated Fertilizer For The Controlled Release of Nutrient Chief, Laboratory of Fertilizer Improvement", Division of Fertilizer, Department of Soil and Fertilizer, Nalt. Inst. Agr. Sci., pp.22-23
- Lee, Akk and Melsen, A. (1983), "Freeze- Coating process for producing sulfur-coated Urea", *Ind. Eng. Chem. Process. American. Chemical Society.*, pp. 503-609.
- Lu.SM. and Lee, S.F., (1991), "Slow Release of urea though latex film. *Journal Controlled Release*", Chemical Engineering Department, National Taiwan University, Taipei Taiwan, R.O.E., pp. 171-181.
- Murray, T.P. (1985), "Reaction of Molten Urea With Formaldehyde", *Ind. Eng. Chem. Prod. Res. Dev.* pp.420-425
- Narajan. S. Tavaré (1995), "Industrial Crystallization", *The Plenum Chemical Engineering series*, University of Manchester Institute on Science and Technology, Manchester, United Kingdom., pp.397-401
- Savant, N. K., Craswell, E. T., and Diamont, R. B., (1983), "Use of supergranules for wet land rice", International Fertilizer Development Center, Murcle Shoals, Alabama- USA., pp.27-35.
- Salman, O. A., Hovakeemian, G., and Khraishi, N., (1989), "Polyethylene-Coated Urea and Urea Release As Affected by Coating Material and Temperature", *Ind. Eng. Chem. Res.*, 28, pp. 633-638
- Yoho, N. (1992), "Slow release fertilizer-will practice fulfill hope", *Fertilizer International.*, pp. 51-55