AN INNOVATION TOWARDS FUEL AND COST OPTIMIZATION FOR CORN DRYING PROCESS IN FEED INDUSTRY

Muhammad Naufal Hakim
Biological Engineering Study Program, School of Life Sciences and Technology, Institut Teknologi Bandung, Jl. Ganesa No. 10 Bandung, 40132, Indonesia

Abstract:* Feed industries, particularly poultry feed industries use corn as their main raw material, and it has a specific standard in term of corn's moisture content. To reduce moisture content, most industries dry corns until they reach the standardized moisture content, usually by generating heat that utilizes fuel and cost. More drying and storage of rejection corn means increased fuel consumption thus increased production cost. Moreover, there was no process control method that optimize drying process of corn. This research studied drying process of corn, evaluated moisture content data to determine drying model, and found how to control drying process (single or double-stages drying) that works efficiently for fuel and cost optimization. For these purposes, an experiment was conducted to get moisture content data in corn drying process every 10 minutes. Analysis of moisture content value that can be threshold of one or two-stages drying process is based moisture content data that form drying curve. The experiment shows the range of 18-20% (w/w) of corn's moisture content is limitation range to control drying process (single or double-stages drying) based on drying curve. Henderson and Pabis drying model was the fittest model to the experimental data with a correlation coefficient (r2) of 0.98 and validated in confidence interval of 95%. Application of novel process control has tested and proven to optimize fuel and cost usage equal up to US$ 3,699.92 per month economically in addition to maximize feed production.

***Keywords:* Corn; Drying; Industry; Innovation; Optimization**

I. INTRODUCTION

One of the most conventional method of preserving agricultural products is drying. Drying has been done by human beings for over hundred years. Solar drying is the simplest drying method. A massive portion of the world's supply of agricultural products continues to be sun dried in the open without technical aids [1]. Therefore, it does not cost a lot and has a simple techniques. However, practically in industry drying was done by heat that was done by combustion or gasification to achieve mass-scale result in shorter time compared than solar drying. Furthermore, the mass scale production has to be precisely determined, in terms of modeling and process control. Process modeling and control needs to be done to optimize the result and reducing cost. Unfortunately, drying was industrial process that has difficulty to control [2]. The simulation of drying process must be similar with real condition of real situation to get accurate results. Corn is one of agricultural product that has many usage, one of them is for poultry feed industry. Corn that used in further process must meet several requirements, i.e. no mold, no bugs, and standardized moisture content. As industrial process, standardized moisture content was fulfilled by heated-air drying using combustion. Corn drying process in the company was occurred in two mode operation, i.e. single and double-stage drying process. Process selection in earlier method was based on trial in the company by observe the moisture content of corn. Rule of thumb from several experiments at the company shown that corn with initial moisture content above 28% (w / w) had to undergo drying twice before the corn was kept in silos. Moisture content of corn that is still above the standard will cause the corn easily flea and moldy, while if moisture content of the corn is below the standard or too dry will make the feed made is not liked by livestock [3]. Errors in selecting the operation mode may cause corn stored into silo and feed production are not optimal. Therefore, drying model should be explain the phenomenon. Drying model must be shown there should be a point or range of moisture content that limits between constant rate period and falling rate period that make drying process slower than constant rate period in drying process. The discovery of limitation value is related to single and double-stage of drying in the company. Assuming all other factors must be the same, such as grain column temperature, heat exchanger quality, plenty of ambient air capable of heating the grain column, and the incoming hot air flow rate to the grain column. In this research, analyzing of drying unit was conducted to find how it works. After that, the simulation of dryer unit can be done to understand the whole process of drying. Finally, we can conclude the range of moisture content's limitation value between constant rate period and falling rate period to find new method that can control the drying process better than before, optimize the result and reduce the cost.

II. MATERIAL AND METHODS

Materials

Material that used in this research was corn in 30% of moisture content, moisture grain analyzer Kett PM650, and oven Memmert UNB500.

Methods that were used in this research:

Preliminary Study of Drying Unit

Drying unit for corn was analysed, including parts of dryer unit, the operation mode, and drying method that was used.

There were three main parts of drying unit, i.e. the furnace, the heat exchanger, and the grain column. Furnace was used to generate heat for corn dryin using biomass combustion. Usually, biomass that used are palm kernel shell. Biomass combustion results heat and also ash. Drying process only want the heat, not the ash, so after biomass combustion there was a fan that take up the combustion results. Then, hot air flowing over metal pipe that functioned as heat exchanger. The hot air will heat the air in hollow pipe, and then the air is going to grain column to heat the corn by suction fan. Moisture content checking was performed every 15 minutes in bottom of grain column unit. After that, the corn was stored in silo or it will be store in temporary storage unit to be dried again. The process flow diagram of the drying unit shown in Fig 1.

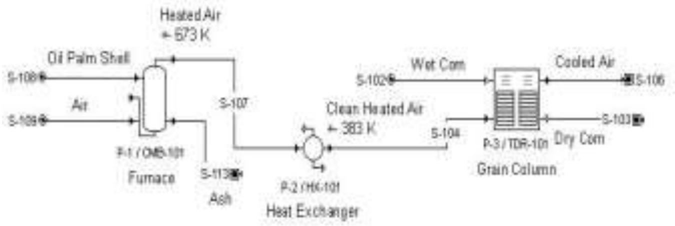

Fig 1. The process flow diagram of drying unit

The Construction of Grain Column

Grain column unit was the place that corn receive the heat, so the search of construction must be performed to get information how the drying method that affect the corn. The construction of grain column shown in Fig. As heat flow from the heat exchanger unit to grain column by suction fan, it can be assumed dominated heat transfer was convection. The tray was only used to put the corn so it can receive the heat. The drying process was set in 1 atm of pressure and 110°C of temperature. The drying process was also assumed as adiabatic process [4]. As abundance and large mass of heat air, the drying process in dryer unit was very quick. Data recording every 15 minutes can not show the whole drying process either. One solution to this problem was using small-scale drying that can show the whole drying
process. Convective drying that used in the dryer unit also similar with oven, so the small-scale simulation was feasible to be done.

Small-scale Simulation

Small-scale drying simulation was done by using an oven to determine drying model and curve that assisted by MATLAB R2014a. Corn was put in alumunium foil container. Moisture content data was measured every 10 minutes until it reached the certain company standard, approximately 180 minutes. Simulation was performed twice to obtain drying model verification. Drying model was used to verify the data, so the drying data can be used to determine the limitation rate of drying process in permitted confidence interval.

III. RESULTS AND DISCUSSION

Drying Model

Based on experiment that was conducted, drying model of corn was obtained. There were some assumptions in built the mathematical model, i.e drying process was adiabatic and heat air amount that corn received was similar. There were some drying model that usually used in agricultural-based product drying, i.e. two terms model, Henderson-Pabis model, and logarithmic model [5-7]. Drying process also one of industrial process that can not replicate easily, so the simulation must be as similar as real operation condition [8]. Data were fitted using Curve Fitting Toolbox in MATLAB R2014a, and based on coefficient correlation (R2), root mean squared error (RMSE), and sum squared error (SSE), Henderson-Pabis model give the best result in accordance of those values are 0.98; 0.01015; 0.00262. Mathematical equation of this model is:= 0.2989 exp −0.006431

With MC is moisture content and t is time in minutes. The data and model are shown in Fig 2.

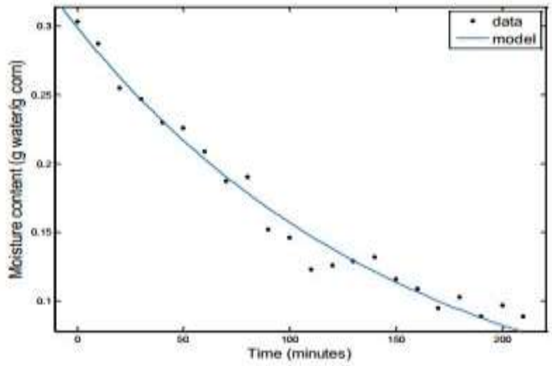

Fig 2. Drying model of corn

The drying mathematical model then is going to verify to ensure the data were correct in confidence interval of 95%. Verification of the model was using parity plot in 95% of confidence interval. Based on statistical parameters in terms of coefficient correlation, root mean squared error, sum square error, and also parity plot it can be concluded the model was verified in confidence interval 95% and can be used in further research in similar operation condition. Importantly, data from the experiment can be used to determine the limitation range of constant rate period and falling rate period in drying process. Parity plot of model and data is shown in Fig. 3.

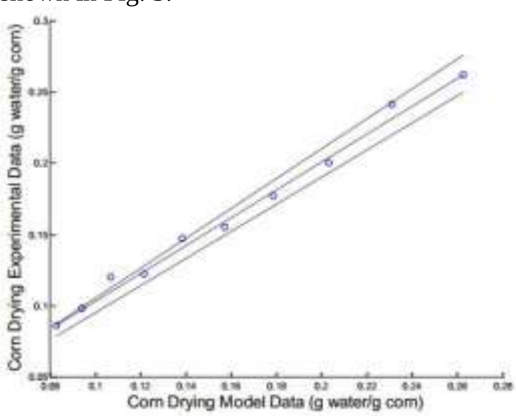

Fig 3. Parity plot of model and data

Drying Curve Analysis

Based on experiment, there is three phase drying process in corn, as stated by Belter and Taufiq [9, 10]. There is constant rate period, falling rate period I and falling rate period II. As company moisture content standard is only 13.5% (w/w), falling rate period II can be neglected. Constant rate period was occurred from the beginning of drying process until (30.3%) until its moisture content 20.9%. Falling rate period I was occurred from 18.7% until 13.2% of moisture content and it has meet the standards of the company. Drying process control only can regulate corn discharge from grain column, or known as discharge feed. Optimization of the drying process is depend on mass flowrate from discharge feed, beside the drying process itself. Analysis of drying curve that shown in Fig. 4 shows limitation rate between constant rate period and falling rate period I were ranged between 18-20% of its moisture content. So, if the moisture content of corn is below 20%, it can be determined easily the corn is dried in single-stage drying, and above the point, it should be dried in double-stage drying. Utilization of these range is to optimize the result and maximize the discharge feed. But, to get threshold value for discharge feed, trial in drying unit is necessary. Other things that must be concerned i.e. hot air temperature, furnace temperature and heat exchanger quality. The consequences as follow this innovation is temporary storage for corn is increasing as effect of discharge feed optimization.

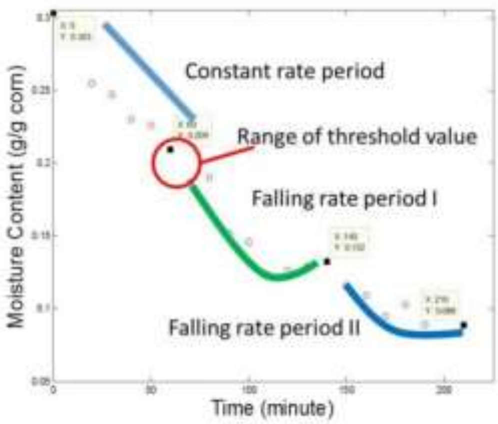

Fig 4. Analysis of drying curve

Analysis of drying curve also can be used to reduce fuel. The method can be used based on the analysis was the drying process only need to reach 18-20% in the higher corn moisture content. After that, second stage of drying was applied to ensure the corn reach the company standard with reducing fuel and cost either. It is often the case that corn with high moisture content is imposed on the first-stage drying to maximize water evaporation, but when second-stage drying was ran, corn becomes too dry. The existence of limitation range also makes the fuel used more efficiently because the heat required to be not too large to reach the corn standard.

Both of the optimization ways are lead to cost reduction, maximize production and shorter operation time. Temperature optimization makes efficient fuel and reduce cost for fuel. Corn that meet company standard in every drying process also can optimize feed production, corn storage, and shorter operation time with innovation methods that noticing natural drying process in agricultural products. Field trial also was successfully done, and the novel method is reported can reduce cost up to 8% or US$ 3,699.92 monthly.

IV. CONCLUSION

Corn drying process can be divided into three steps, i.e. constant rate period, falling rate period I, and falling rate period II. The mathematical model of the drying process was obtained and verified. Limitation value between constant rate period and falling rate period that range between 18-20% can be used to control and optimize the corn drying process, including fuel optimization, cost reduction, and maximize drying result.

Acknowledgments

Thanks for PT Charoen Pokphand Indonesia Feedmill Makassar as place to do the research.

REFERENCES

[1] Szulmayer, W. (1971) From sun drying to solar dehydration: Method and equipment. Food Technology in Australia, 23, 440

[2] Zhang, Q., & Litchfield, J. B. (1991). An optimization of intermittent corn drying in a laboratory scale thin layer dryer. Drying Technology, 9(2), 383-395.

[3] Sauvant, D., Perez, J. M., & Tran, G. (2004). Tables of composition and nutritional value of feed materials: pigs, poultry, cattle, sheep, goats, rabbits, horses and fish. Wageningen Academic Publishers.

[4] Mujumdar, A. S. (1997). Drying fundamentals. Industrial drying of foods, 1.

[5] Henderson, S.M. (1974) Progress in developing the thin layer drying equation. Transactions of the ASAE. 17(6):1167-8

[6] Chhinnan, M.S. (1984). Evaluation of selected mathematical models for describing thin-layer drying of in-shell pecans. Transactions of the ASAE, 27(2) , 610-615

[7] Yağcıoğlu, A., Değirmencioğlu, A., Çağatay, F. (1999). Drying characteristics of laurel leaves under different drying conditions. In 7th Int Congress on Agricultural Mechanization and Energy (pp. 565-569)

[8] Mujumdar, A. S. (2014). Handbook of Industrial Drying (pp. 52-72).. New York: CRC Press.

[9] Belter, P. A., Cussler, E. L., dan Hu, W. (1988). Bioseparations : Downstream Processing for Biotechnology (pp. 302-337). New York: John Wiley & Sons.

[10] Taufiq, M. (2004). Pengaruh temperatur terhadap laju pengeringan jagung pada pengering konvensional dan fluidized bed (Undergraduate thesis). Solo: Universitas Negeri Sebelas Maret.

