SOME PROBLEMS IN DEVELOPING MECHANICAL GRAIN DRYER AND RESEARCH IMPROVEMENT

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ABSTRACT

Mechanical grain drying is not much practiced yet by the farmer for several reasons such as : high initial investment, high operation cost, too large machine capacity, etc. In the following research, it had been designed mechanical grain dryer based on silo form as one of solution to overcome the problem on grain drying.

The objectives of this research were to know the effect of heating temperature and tempering methods on grain drying process and also to evaluate the performance of constructed facilities and evaluate dryeration method.

In this research, it had been designed a mechanical drying machine based on silo form, with the diameter of 175 cm, cylinder height of 195 cm, and hopper slope of 60^o made from steel plate. It had been equipped with pneumatic conveyor, centrifugal blower, gas burner, and using LPG gas as the drying fuel. The research used corn and rough rice as the research materials with initial moisture content of 28.96% (w.b) and 29.30% (w.b) respectively. The treatments applied in this research was the variation of air drying temperature and drying methods ie : conventional and dryeration methods.

The results showed that in the drying of corn, convective heat transfer coefficient was found around 0.446 – 0.572 $W/m^{2o}C$ for temperature range of drying air of 70 – 100^oC, much higher than sun drying which only 0.026 $W/m^{2o}C$. Whereas in tempering process the values were between 0.120 – 0.571 $W/m^{2o}C$. While the values of drying rate constant (k_M) around 0.145 – 0.265 1/hour which also higher than sun drying 0.122 1/hour, while in tempering process around 0.096 – 0.164 1/hour. By using rough rice as the tested material it was found that the consumption of diesel oil and LGP for conventional method were 17 lt and 25.5 kg respectively, while by applying dryeration method they were only 13 lt and 9 kg to dry 2 tons of rough rice. The results showed that Heat Utility Factor (HUF) around 0,80 - 0,93 and Effective Heat Efficiency (EHE) around 0,90 - 0,98.

It could be concluded that silo which was equipped by an aerator could be applied as a grain drying machine with quite good performances. The application of mechanical drying using dryeration was capable to increase drying capacity and decrease fuel consumption largely.

Key words : drying, silo, grain, dryeration, tempering

INTRODUCTION

In Indonesia postharvest handling especially in grain drying are still conducted using solar/sun drying. This method have been known to have so many weaknesses. To improve quality and capacity of grain drying, the goverment of Indonesia has distributed an aid of mechanical grain drying machine to various related institutions and farmer groups which need that machine. However, almost all of those drying machines are not operated for many reason such as high operation cost, fuel cost, drying capacity too large, etc.

High opeartion cost of drying machine is also possibly caused by the choosen method to operate this machine is not adequate. Where generally the grain is dried in the drying machine from high moisture content continuously until desired final moisture content is reached (conevntional drying method). As the results, fuel consumption for drying grain in this method become high, because as the drying procces enter falling rate period the moisture content of the grain become difficult to evaporate, and finally required high fuel consumption. Noyes dan McKenzie (1998), stated that in grain drying removal of 2 – 3 point of final grain moisture content need the largest energy. Using dryeration this final moisture content didn't need to be removed by drying machine, as the result it will increased machine capacity significantly.

The procedure of grain drying using dryeration method is as follow, drying with high temperature is stopped and the hot grains are moved when the moisture content about 2-3% above desired final moisture content. This hot grains are leave for tempering process around 6-12 hours in different container before it is cooled for several hours by using air flow about 0.5-1.0 m^3/min/ton, and after cooling process, the grain are moved into final storage sturctures (Maier, 2003).

The need for energy cost in corn drying about 60% of the total energy needed in grain production (Brooker et al., 1992). This ilustrates that grain drying is an expensive process, this means the change in grain drying cost will be significantly change total cost of grain production. Selection of cheap drying fuel will also decrease overall drying cost. Drying machine from govenment usually use gasoline, which recently the price increased very high, especially for industrial use. According Gely and Giner (2004), grain drying is a process which need intensive energy, the use of method to reduce energy consumption is economicaly very important and save the environment. Beside the possibility in increasing drying capacity and preserve grain quality better, dryeration can be a promising alternative of grain drying method. However, as this method need relative high invesment for the equipment, require good handling and time, it is need technics and economics analysis to find the best knowledge and application method in practices.

The objectives of this research were to find out the effect of several subtanstial parameters in grain drying by applying dryeration method, evaluated the performance of constructed drying facility, and also evaluated the possibility to develop grain drying facility base on silo form.

RESEARCH METHODS

Material and Equipments

Grain sample used in this research were shelled corn and rough rice totally 8,5 tons and 4 tons respectively, with initial moisture content of 28.96% (w.b) and 29.30% (w.b) respectively. The main equipment was a drying machine constructed in the form of silo, made from steel plate with diameter of 175 cm, cylinder high of 195 cm, hopper slope of 60^o, and it could be loaded for 3 tons of shelled corn. For both drying and tempering silo, they were equipped with an aerator made from wire screen installed in the inside of silo with certain shape. The silo drying machine was equipped with pneumatic conveyor, centrifugal blower, burner with LPG (Liquid Petroleum Gas) as the drying fuel for heating drying air.

Procedures

In the following research three different air drying temperature i.e : 70^{o}C, 85^{o}C, and 100^{o}C were used to dry shelled corn, by applying dryeration method. While for rough rice they were 50^{o}C and 70^{o}C by applying dryeration and conventional drying methods to compare the different of those two methods. In dryeration method, drying process was divide into three main processes 1). Heating process in drying silo, 2). Tempering process in tempering silo, and 3). Cooling process by aeration. Heating process was stopped when average grain moisture content reach about 17% (w.b), then the grain was tempered until moisture content decreased to about 14% (w.b) without heating, and finally the grain was cooled using aeration. In the following research, it was also investigated three different tempering method i.e : tempering in the silo, tempering in the sack equipped with an aerator, and tempering using pile equipped with an aerator.

RESULTS AND DISCUSSION

Figure 1 is an example of grain temperature curves during heating (left) and tempering (right) processes respectively.

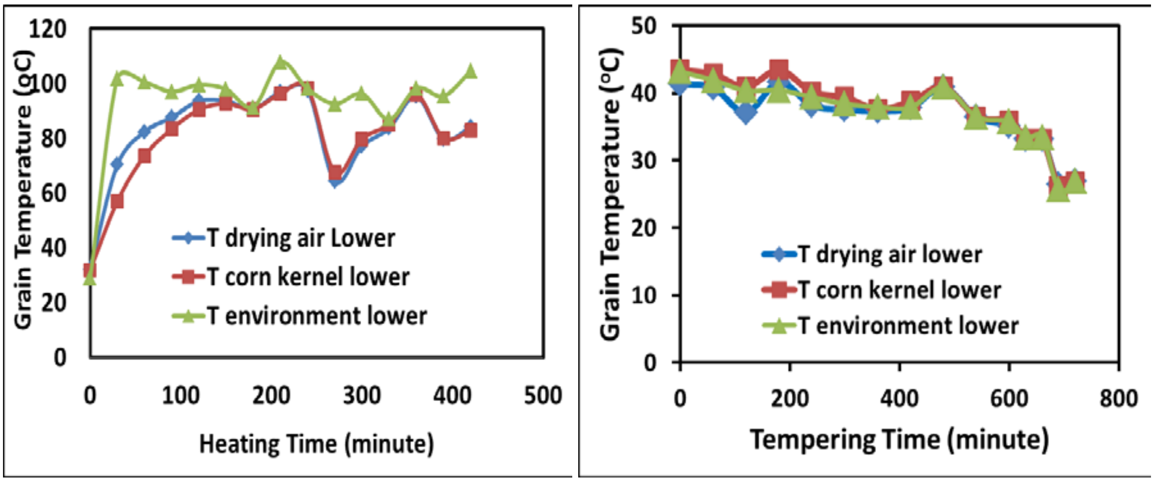

Fig 1. Example of corn grain temperature change during heating in the drying silo (left) and tempering in the sack (right)

In heating process, grain temperature increased as heating time increased, then reached almost constant values, while in tempering process grain temperature decreased along with increasing tempering time, and drastically decreased at the end of tempering time as the result of cooling (aeration) process. Using Newton law of cooling it could be calculate the values of constant of grain temperature increment rate (k_T) both for hetaing and tempering processes.

Tabel 1. Constant of grain temperature increment rate (k_T)
for heating and tempering processes

Drying Temp (^oC)	Heating (1/jam)	Tempering (1/jam)		
		Silo	Sack	Pile
70	0,074	0,169	0,168	0,176
85	0,255	0,183	0,175	0,181
100	0,393	0,154	0,150	0,176
Sun Drying	0,018			

It can be seen that the value of k_T for heating roughly higher than tempering process, this indicated that grain temperature increment was faster than its reduction. When drying air 100^{o}C, k_T reached more than 20 times sun drying, it indicated that grain heating process in mechanical drying much faster than sun drying. During tempering the values of k_T nearly same for the three methods, where the values were quite low. This was possibly caused by the condition where during tempering process the different between grain (corn) temperature and surrounding air temperature was low, as the results heat transfer from the grain to the air run slowly as the absent of flowing air. This also meant that tempering process for dryeration method could be done both using tempering silo, sack equipped with an aerator, or pile equipped with an aerator with almost same results, this could elimanate the need for tempering silo and so it could reduce capital invesment.

Figure 2 shows an example of corn grain moisture change during heating in the drying silo (left) and tempering processes in the sack (right).

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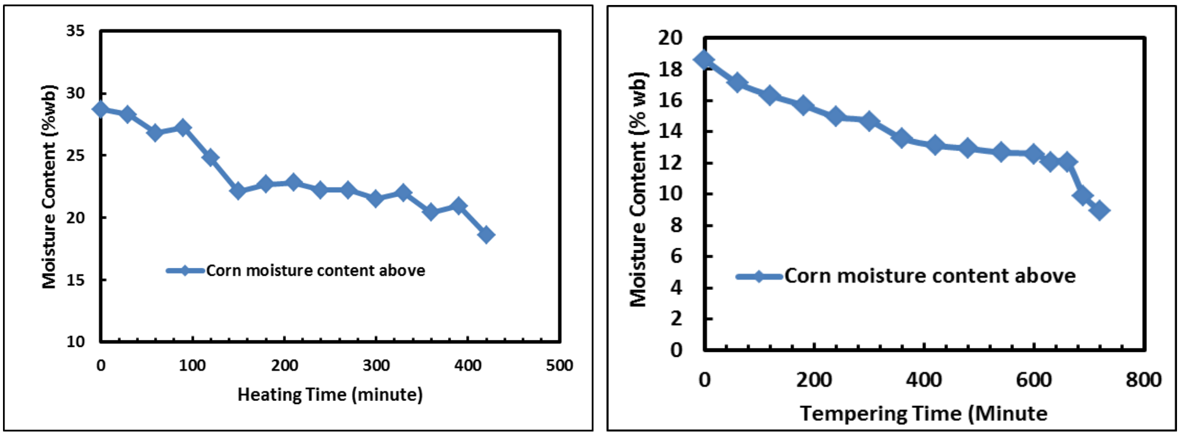

Fig 2. Example of corn grain moisture change during heating in the drying silo (left) and tempering in the sack (right) processes

Using the same analogy as calculating k_T, it could be determined the value of constant of grain moisture content reduction rate (k_M) for heating and tempering processes as shown in Table 2.

Tabel 2. Constant of grain moisture content reduction rate (k_M) for hetaing and tempering processes

Drying Temp. (^oC)	Heating (1/jam)	Tempering (1/jam)		
		Silo	Sack	Pile
70	0,242	0,164	0,156	0,164
85	0,145	0,096	0,110	0,132
100	0,265	0,146	0,158	0,162
Sun Drying	0,122			

As for k_T, the values of k_M were also higher than sun drying, which roughly almost twice except at air drying temprtarure 85^o. This indicated that reduction of grain moisture content in mechanical drying much faster than sun drying. For drying temperature of 85^{o}C, the low value of kT was probably caused bay the fact that grain sample had lower initial moisture content (23% w.b) than in air drying temperature of 70^{o}C and 100^{o}C which were 34.67% (w.b) and 28.80% (w.b) respectively. Commonly the values of k_M in tempering process were relatively low, even lower than k_M of sun drying. This indicated that water removal from the grain took place very slowly, slow water release from the grain wolud prevent grain cracking and fissuring to occur, so that it could retain better grain quality. Ezeike and Otten (in Maier,

2003) sated that tempering of corn grain is the most pactical method in retaining grain quality while increasing higher drying capacity. Further it was also stated that the best tempering process took place in still air.

By applying lump capacytance method it could be determained the value of convective heat transfer coefficient for heating and tempering processes (h) as can be seen in the folloowing table.

Tabel 3. Convective heat transfer coefficient for heating and tempering processes (h)

Drying Temp. (^oC)	Heating ($W/m^{2o}C$)	Tempering ($W/m^{2o}C$)		
		Silo	Sack	Pile
70	0,572	0,298	0,219	0,571
85	0,446	0,433	0,130	0,120
100	0,558	0,214	0,309	0,249
Average	0.525	0.315	0.219	0.313
Sun Drying	0,026			

In heating h indicated the heat transfer from heating (drying) air to the grain, while in tempering process it indicated heat transfer from grain to the surrounding air. During heating process, the average value of h almost 20 times higher than sun drying, while during tempering process around 8.4 to 12.1 times higher than sun drying. This indicated that the rate of heat transfer both entering or leaving the grain considerably faster than sun drying. Early (1983), gave the table of h values, where for still air was 6 $W/m^{2o}C$ and moving air at 3 m/s (10,8 km/hour) was 30 $W/m^{2o}C$. However, in drying process grain in the bulk condition, air mass in the bulk was lower, this condition restricted contat between grain kernel and surrounding air, this caused the value of h was lower for both mechanical and natural darying. Although the values of h in tempering process were higher than sun drying, they were only 54% of h values of heating process. As for the values of k_M, lower value of h during tempering process meant favourable for drying process, as it colud prevent good grain quality. According to Proctor (1994), dryeration which firstly developed for corn grain, was a combination between drying with a hot air and aeration cooling. In this method tempering process was determined which was between hot air drying period and cooling period. Further it was also stated that grain damage could be reduced and drying efficiency could be increased by using remaining heat in the grain kernel to evaporate water during cooling process. The three methods of tempering evaluated in this research had almost same values of h, indicated that the three methods performed almost the same speed of grain heat reduction, and so would need almost the same time in tempering the grain.

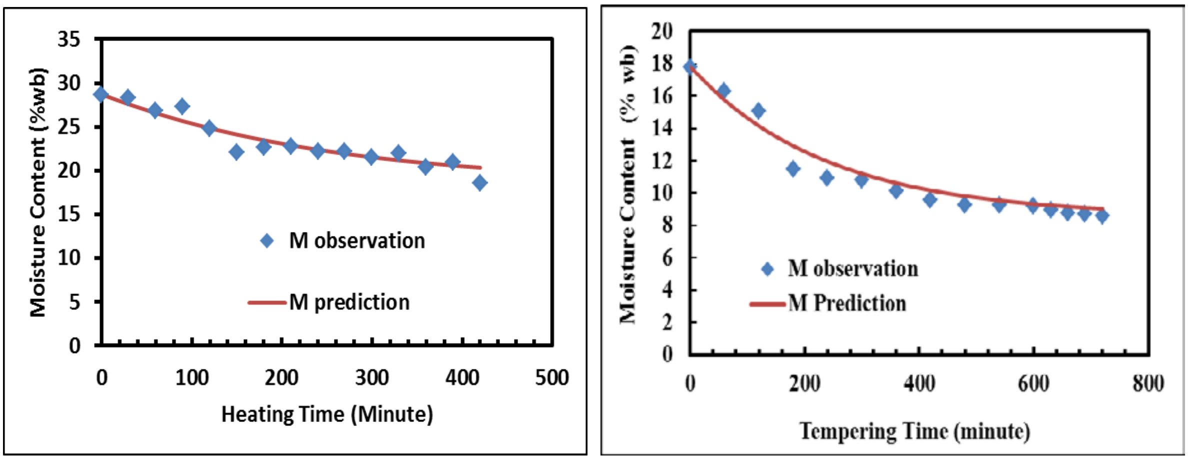

Figure 3. Example of prediction vs observation curve for moisture reduction during heating (left) and tempering (right) processes

Figure 3 shows an example of curve fitting of corn grain moisture reduction between prediction equation and observation results. It can be seen that the prediction results closed to the observed data (R^2 = 0,92), it showed that the analogy of Newton law of cooling could be used to derived prediction equation. In heating process, applying Arrhenius Theory the values ok k_M could be related to drying temperatures (T), so that it could be found a mathematical equation (1). This equation could be used to estimate moisture content of the grain during heating process in dryeration.

$$M_{(t)} = e^{\left(-0,743044 . e^{-\frac{-884,1}{T}} . t\right)} \left(M_{(in)} - M_{(eq)}\right) + M_{(eq)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From analysis it was found that the values of HUF(Heat Utilization Factor) which was the comparison between utilized heat to supplied heat lied between 0.8 – 0.9 for corn and 0.84

– 0.87 for rough rice. While EHE (Effective Heat Efficiency) indicated the sensible heat in the drying air as the effective heat which could be utilized for drying process. This value was the comparison between the difference of dry bulb temperature of the drying air and leaving air divided by the difference between dry bulb and wet bulb of drying air, and in the following research lied between 0.90 – 0.98 for corn and 0.91 – 0.98 for rough rice. This showed that the utilization of heat during drying process was very effective or heat loss was very small, indicated that constructed drying machine could work very good in conserving heat of drying air.

In drying shelled corn using dryeration, diesel oil consumption to drive blower to push drying air and blower of pneumatic conveyor was around 4.6lt/ton. While LPG cnsumption to heat drying air about 9.1 kg/ton depend on drying air temperatur used.

The comparation of drying method between conventional and dryeration could be evaluate from the results of rough rice drying process which had been performed. Drying rough rice using dryeration method needed 6.5 lt/ton diesel oil, while for conventional method needed 8.5 lt/ton, dryeration decreased diesel oil consumption almost 25%.

While the need of LPG was 4.5 kg/ton for dryeration and 12.75 kg/ton for mechanical conventional drying methods, this was decreased about 65 %. This indicated that drying applying dryeration could save fuel consumption quite large, especially the consumption of LPG to heat drying air. Maier (2003) stated that dryeration could decrease fuel consumption about 15-30% and increased grain dryer capacity up to 50% or more. So many years, many researchers had confirmed the advantage of dyeration and in-bin drying.

In conventional rough rice drying, drying machine capacity was 0.190 ton/hour, while using dryeration method, there was an increased of machine capacity of 50.5%. The results of research conducted by Montross and Maier (200), showed that drying using hot air followed by dryeration or cobination drying, could reduce the cost of drying about 10% compared with continuous drying or drying with cooling process in the machine. The highest advantage could be found for the increase of drying capacity of 72% and 159% when dryeration and combination drying were applied compared to conventional drying or drying with cooling process in the machine.

CONCLUSIONS

1. A silo equipped with an aerator could be applied as mechanical grain drying machine which showed quite good performances.
2. Reduction of grain moisture content during heating process could be predicted using equation which was formed based on Newton law of cooling and Arrhenius.
3. Heating rate constants, drying rate constants, and convection heat transfer coefficients in this drying process showed relatively high values and far more than sun drying.
4. The application of dryeration method could increase drying capacity of the machine more than 50%, reduced fuel consumption more than 23%, and reduced LPG consumption more than 64%.

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