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Evaluation on Drying Temperature of Grain Corn and Its Quality using Flat-bed Dryer

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The drying performance of grain corn was investigated using a pilot scale flat-bed dryer. The shelled grain corn (variety Dupont 30T60 , P4311 and P4546) were selected and the study was carried out at MARDI Pendang, Kedah. Effect of various temperature (50°C, 60°C and 70°C) on the drying time and moisture reduction profile were investigated. The initial moisture content of grain corn in average 26-30% wet basis was dried down to about 12-14% of final moisture content. This reflected to the drying rate of 1.2-1.8% moisture removed/hour with drying operation cost of RM0.16/kg of dried grain corn. The quality of dried grain corn was determined using stress cracking analysis. The results have shown that the quality of dried grain corn obtained from three different temperatures used in this study was acceptable.

Keywords: drying; grain corn; moisture; flatbed dryer

I. INTRODUCTION

(Zea mays L.) is among of the crucial cereal grains grown worldwide because of its greater adaptability (Kogbe and Adediran, 2003). Over 80% of world production of corn is located in the Americas and Asia with 51.6% and 30.6% respectively (FAO, 2016). Pimentel and Patzak (2005) has reported that corn become the most important raw material for animal feed. Beck's Hybrid (2014) reported harvest corn best at 20-25% moisture content. Drying is an industrial preservation method which water content and activity of crops are decreased by heated air to minimize biochemical, chemical and microbiological deterioration. The aim in drying food products is to reduce the moisture content to a level that represented a safe storage over an extended period (Walde *et al.*, 2006; Doymaz and Pala, 2003). Grain corn drying has a significant effect to its quality since incomplete drying and uneven drying will resulted in qualitative and quantitative losses. Improper drying contributes to the loss in overall yield caused by the high temperature and re-wetting of grains. Furthermore, it can cause damage since the microorganism activity occurs at high moisture level. Traditionally, grain corn is dried in an open area under the sun. However, this method may contaminate the grain corn with soil, sand particles and other matter from the drying environment (Oztekin, Bascetincelik and Soysal, 1999). Sun drying method also contribute to the development of aflatoxins, which is harmful mycotoxin for animal and also to human health. So far, there has been various studies of drying technique for processing dried corn. Kouskhaki *et al.* (2017) has investigated on thin layer drying of corn using vibratory bed dryer instead previous report by Lynch and Morey (1989) suggested that ambient air corn drying provides good quality of product compared to high temperature drying in corn drying using thin layer drying. Li and Morey (1984)

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has studied thin-layer drying of yellow dent corn and found the relationship of drying air temperatures, air flow rate, initial moisture content and relative humidity to the drying process. Meanwhile, Eke and Arinze (2011), has dried corn using solar energy from the direct mode natural convection mud type solar dryer and it resulted the dryer achieved 55% saving in drying time against open sun drying. Comparing the efficiency between that dryer and open sun drying has resulted 45.6% and 22.7% respectively.

Flat-bed dryer (FBD) is a mechanical dryer with simple design and operation feature. It is easy to construct using available and inexpensive materials with easy to operate without skilled labour. The floor of drying chamber usually constructs from fine wire mesh, suitable supported structure, or perforated metal. FBD typically required 1.5 to 2.5 kW per tonne of grain for a belt-driven fan using petrol or diesel engine as power source. As reported by Basunia and Abe (2008) and Soemangat *et al.* (1973), operation of flat-bed dryers invariably results in a moisture gradient between the lower layers and the higher layers of the bed. To overcome this problem, careful selection of drying parameter to achieve effectiveness and uniformity of the drying processes should be done. For that reason, this study is to look into the effect of temperature on drying performance, quality and physical characteristic of dried grain corn using flat-bed dryer.

II. MATERIALS AND METHODS

A. Grain Corn Drying

The study of grain corn drying using flat-bed dryer (FBD) was carried out at MARDI Pendang, Kedah. The FBD dimension are 3.7m long, 2.6m width and 1.2m height with holding capacity of about 3 ton per batch. Two dryers were used in this study and schematic diagram of the FBD is shown in Figure 1.

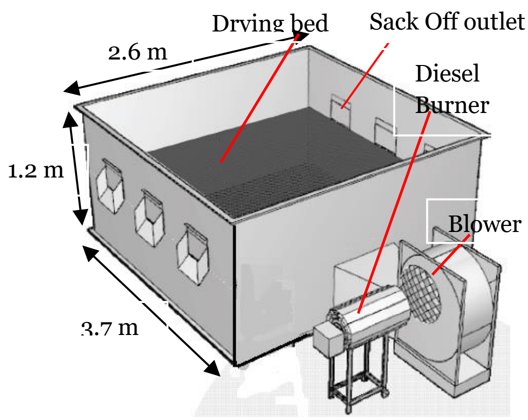

Figure 1. Isometric view of flat-bed dryer in MARDI Pendang, Kedah

Corn of variety Dupont 30T60, P4311 and P4546, freshly harvested from research plot located in MARDI Seberang Perai, Penang. The harvested corn packed in jumbo bag, its weight was recorded and then transported to MARDI Pendang, Kedah for drying process. The drying experiments were performed at 3 different sessions upon harvesting of grain as shown in Table 1.

Table 1. Date, temperature and weight of harvested grain corn for each drying experiment

Number of experiment	Date	Operation drying temperature (°C)
1	20th March 2017	70
2	29th-30th March 2017	50
3	3th May 2017	60

The drying experiments were carried out in two flat-bed dryers that ran concurrently. The temperature and relative humidity of ambient air were recorded throughout the drying process using EBRO Data Logger (EBI 20 TH1) with precision of ±0.5°C. For each FBD, the samples were collected at 2 spots which were the middle and corner edge of FBD as shown in Figure 2. The samples were taken from the surface and at a depth of the flat-bed by using a self-made scoop from PET bottle. The parameter involved in this experiment such as inlet air temperature, initial and final moisture content and diesel consumption for drying process were measured. The moisture content of corn was analysed using moisture analyser SATAKE SS6 (Japan) with ±0.5% accuracy with range of measuring of 10-40%. The amount of moisture content was designed on the basis of the mass of water as equation that represents moisture content in dry basis and wet basis has shown in Equation 1 and 2 respectively.

$$\% MC_{db} = \frac{W_w}{W_d} \times 100 \quad (1)$$

$$\% MC_{wb} = \frac{W_w}{W_w + W_d} \times 100 \quad (2)$$

$$\% MC_{db} = \frac{MC_{wb}}{100 - MC_{wb}} \times 100 \quad (3)$$

where MC_{db} is the moisture content dry basis, MC_{wb} is the moisture content wet basis, is the weight of water (g), is the weight of dry matter (g).

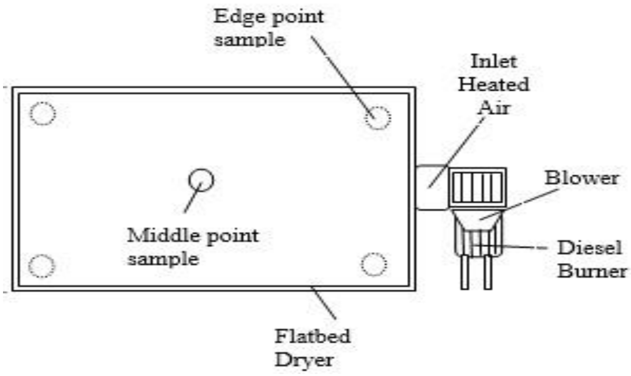

Figure 2. Flat-bed dryer top view and sampling point position during drying process

B. *Stress Cracking Test*

Stress cracking analysis was done on randomly selected of 100 flat-grains of corn. The grain corn kernels were visually inspected for stress cracks using a light board and have done for 3 replications. Each kernel was classified into one of three stress crack classes: undamaged, single, and multiple. The results for each stress crack class were calculated by dividing the number of kernels in each stress category by the total number 100 flat-grains corn selected.

C. *Economical and cost operation calculation*

Engineering economical and cost operation has been calculated based on factors such as cost and rate of fuel consumption, electricity and its rate of consumption, coast of manpower, concern of investment capital, drying capacity and durability of the dryer. Then all of the cost from these factors has summarized as cost drying per/hour, cost drying per/ha, cost drying per/tonne and cost drying/kg

III. RESULTS AND DISCUSSION

A. *Drying Performance and Moisture Reduction of Grain Corn in Flat-Bed Dryer*

Table 2 summarized the result obtained from each drying experiment. It can be seen that highest load of harvested grain corn was during drying experiment at 50°C with initial moisture content 33.58%. Meanwhile for 60°C and 70°C, harvested grain corn load of 3019kg and 3080kg with moisture content 31.23% and 28.73% respectively. However, the optimum moisture content for harvesting grain corn is 20-25% as reported by Beck's Hybrid (2014). High moisture content of the harvested grain corn for each experiment session was due to unpredictable factor such as climate change that affected prediction made based on annual rain distribution data. Drying temperature of 50°C exhibited longest drying time of 16 hours to reduce moisture content into acceptable value of 12-14%. This was due to high initial moisture content and grain corn load (Table 1) compared to 60°C and 70°C. Inlet temperature 50°C also exhibited lowest drying capacity of 205.3 kg/hr hence the drying rate of 1.2%/hr. For drying experiment at 60°C, it showed that the drying process completed after 10 hours. Its drying capacity is 242.2 kg/hr and drying rate of 1.6%/hr which was higher than drying at 50°C. For drying experiment at 70°C, it showed that the drying process only took 6 hours to reduce from initial 26% moisture to optimum level 13%.

Effect of using higher drying temperature of 70°C also contributed to the highest drying capacity and drying rate with 245.2 kg/hr and 1.8%/hr respectively. However, it can be seen that drying temperature of 50°C exhibited the highest recovery with 79.9%, followed by 60°C (76.4%) and 70°C (74.2%). This is considered the recovery is obtained based on initial weight of harvested shelled grain corn and can be seen that the sequence of recovery for each inlet drying temperature as followed this sequence: effect 50°C>60°C>70°C. This could be influenced by plenum temperature during drying of grain corn which is 54.44-60°C is the best and allowable plenum temperature instead of 37.78°C is the maximum grain temperature. (Dupont Pioneer, 2017).

Table 2. Results of grain corn drying experiment

Inlet temperature for drying (°C)	Initial weight of harvested shelled grain corn (kg)	Final weight of dried shelled grain corn (kg)	Initial Moisture Content (%)	Drying time (hours)	Drying capacity (kg/hr)	Drying rate (%/hr)	Drying Recovery (%)
50	4860.0	3881.0	33.58	16	205.3	1.2	79.9
60	3080.0	2352.0	31.23	10	242.2	1.6	76.4
70	3019.0	2240.5	28.73	6	245.2	1.8	74.2

B. *Stress Cracking Analysis*

Stress cracking test was done to evaluate physical quality of the dried grain corn. Based on Table 3 and Figure 3, at higher temperature, the grains are more susceptible to cracking as shown by the increased in percentage of multiple cracking. The results also revealed that drying temperature effect on the quality of dried kernel which as drying temperature increased, the percentage of kernel in the single and multiple crack categories also significantly increase instead undamaged categories has declined (Shoughy *et al.*, 2009).

Table 3. Stress cracking analysis of different drying temperature

Temp (°C)	Crack Type		
	Undamaged (%)	Single (%)	Multiple (%)
50	68.33±4.04	18.33±2.08	13.33± 3.21
60	48.33±10.12	38.00±8.70	13.67±1.53
70	38.33±3.51	45.67±5.51	16.00±2.00

It can be seen that drying with 70° C displayed highest single and multiple crack and followed by 60°C and 50°C being the lowest. This phenomenon is in agreement with Kirleis and Storshine (1990) that reported stress cracking in maize, which are not visible externally, increased consistently with drying temperature up to 60°C. This stress cracking also considered caused by excessive compressive or tensile stress that occurring during or after drying and cooling process as reported Shoughy *et al.* (2009). The reduction of stress crack formation could be suggested due to the relaxation of internal stresses facilitated by a more pliable endosperm or possibly could be starch gelatinization within the kernels drying, which contribute more resistant for endosperm to stress failure.

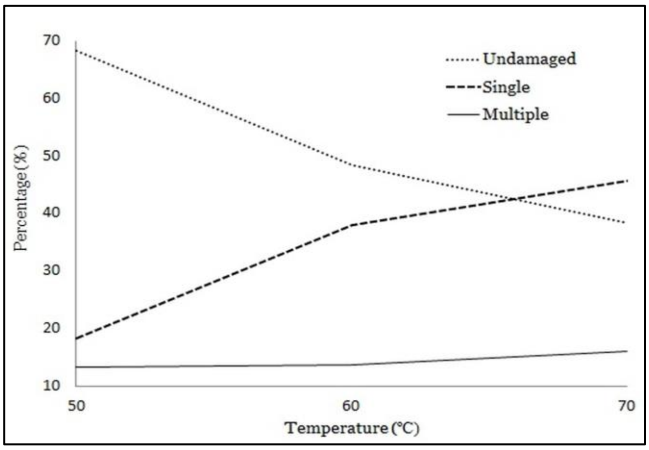

Figure 3. Stress cracking analysis of different drying temperature

C. Economical and Operation Cost

Drying capacity of 3-3.5 ton per batch is the minimum capacity for an economy scale for small farmers. Table 4 has summarized the factor that necessary to consider for operation cost of corn drying using flatbed dryer.

Table 4. Factors involved in corn drying using flatbed dryer (using optimum temperature of 70°C)

Factors	Cost/unit
Cost of diesel, RM/L	2.40
Diesel consumption, L/t of wet grain	24.00
Cost of electricity, RM/Kwh	0.33
Electricity consumption, kW	4.54
Wage rate for labor used to operate the dryer, RM/hr	8.00
Investment rate, %	6.00
Labour rate, RM/hour	8.00
Dryer capacity, ton per hour	0.30
Total tonnes to dry per hectare	7.00
Initial investment in drying system, RM	100,000.00
Useful life of the dryer (years)	15
Expected days usage/yr	30

This included the cost of diesel consumption, electrical power, and wage of manpower. These factors based on the durability or shelf life of the dryer for 15 years. The average drying cost per hour, cost per hectare, cost per ton and cost per kg harvested shelled corn resulted in total cost of RM49.00, RM1149.65, RM164.00 and RM 0.16 respectively as summarize in Table 5. Flat-bed dryer has a drawback of high labor cost when increase in drying capacity for loading and unloading of dried shelled corn.

Table 5. Summarize on cost of corn drying using flatbed dryer

Parameter	Cost per hour	Cost per hectare	Cost per ton	Cost per kg
Depreciation cost per unit production (RM/hr)	8.70	202.90	28.99	0.03
Repair and maintenance cost (RM/hr)	5.80	135.27	19.32	0.02
Diesel cost (RM/ha)	17.28	403.20	57.60	0.06
Electricity cost	1.50	34.96	4.99	0.00
Labor cost	16.00	373.33	53.33	0.05
Total drying cost	49.00	1149.65	164.00	0.16

IV. CONCLUSION

The effects of temperature on drying performance, physical quality of dried grain corn and also economical on operation cost involved in grain corn drying was studied. Other than determination of optimum drying temperature, other factors such as height and uniformity of bed thickness should also be taken into consideration. It was found that drying shelled corn using flatbed dryer was achievable to provide the parameter of inlet temperature, which set at optimum level has contribute to higher drying rate of shelled corn. Grain corn drying is considered a major factor in maintaining good quality of grain. Improper and high drying temperature will result in stress cracks in kernel especially if corn is cooled instantly after drying process. This would lead to further breakage during handling and storage thus lower the value of grain.

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