Chapter VI

DISCUSSION

6.1 Equipment Construction and System Mechanism

The fluidized-bed column designed and constructed was well suited for the work. The distributor, with three layers of metal ball on sieve plate selected, resulted in less fluctuation in density of bed, less channelling and slugging, and low pressure drop across bed. The contacting between hot air and paddy was nearly uniform for the entire bed. The mechanism of present work system designed, worked quite well. However, there are some points needed to be improved which are as follows:

1) In batch operation; sampling of paddy was done by drawing paddy out of the column by using a simple tool, a long beam with a small can connected on one end, this method is unconvenient. Before this; another method had been tried by drilling a hole, 1.5-cm. diameter, at about 15-cm. above the distributor. This hole was closed with a metal plate which was able to open at the time of sampling. Unfortunately, this method was unpractical, since the air flow rate during the operation was high and resulted in excessive paddy pouring out of the column. Excessive sample was against the objective of sampling that paddy sampled had to be drawn at the least possible amount to keep the bed's weight constant. At tempering stage,

using the simple tool described above in transfering all paddy to equalize moisture outside the column is also unconvenient and time consuming. Nevertheless, those two disadvantages were conquered, when the continuous operation was applied, since it was equipped with paddy feeder and exit aperture which made it easier for sampling and tempering.

2) When the continuous operation was applied, it still needed to be improved. The point is, at the exit of column should be connected with a dust separator (e.g.cyclone) to collect fine fractions produced during the drying process or is already present in the original charge. The dust separator will also capture some portion of paddy which flown out of the colum during the operation.

3) Insulation of the column was not well acheived since there were many points that heat loss occured, such as, glass window, aperture for inserting thermometer and manometer, and screw feeder.

6.2 Experimental Results

1. From the experimental results in determining Minimum Fluidizing Velocity (Umf) which are shown in Table 5-1 and Figure 5-1, pressure drop varied with the increasing flow rate of air through the bed until air velocity had reached a certain value. At this point, the pressure drop decreased slightly and remained constant onwards. At this value of air velocity, which was the Umf, the

bed began fluidizing. The value of constant Δp increased as the height of bed increased, which agreed with the equation (2-2). For the values of Um_f obtained from the experiment (see Appendix B) were almost the same, except the first two values which differed. This was because of few data taken during the fixed bed stage which were not enough to yield an accurate straight line on the graph. The values of Umf from experimental data and calculation by using equation (2-4), were almost the same and constant values as shown in Table 5-1. This confirmed that changing bed height had no effect on the value of Umf and supported the equation (2-4) which showed that Umf is only the function of particle diameter , type of particle and void fraction.

The value of Umf obtained was used in selecting the flow rate of hot air that would be used in drying which was 1.5-2 times of air flow rate at Um_f. This air flow rate was the minimum value to obtain homogeneous bed.

2. In drying period determination, the initial moisture content which was at about 55-60% (dry basis) was reduced down to 16-20%. From the experimental data, almost the entire drying process occurred in the falling-rate period. Due to the low moisture content on surface of paddy, because after steaming paddy was still hot and most of the surface moisture evaporated rapidly before it was transferred to the column to be dried. Therefore, the moisture of paddy left to be dried in the fluidized-bed column was the moisture inside the grain, which migrated from

the center of the grain to its surface, and thenevaporated by hot air. This was the diffusion process. The graphs shown in Figures 5-2 to 5-9 agreed with the falling-rate period shown in Figure 2-5, this confirmed that the drying process in the present study occurred in the falling-rate period.

From Tables 5-2 to 5-11 and Figures 5-2 to 5-9, moisture content decreased as drying time increased. At the beginning, the moisture content decreased very rapidly (rate of drying was high), and then gradually slow down as times passed by (rate of drying was low).

In comparison,when dryings were performed at many air inlet temperatures, it was found that as the temperature increased, the rate of drying increased, and resulting the moisture content decreased faster. Therefore, a short drying time was used in drying to reduce the moisture content down to the level required. This implied that the change of moisture content depended upon the drying temperature, since the rate of diffusion of water vapor in grain depended upon temperature. Hence, we can conclude that higher drying temperature will yield a better drying. Nevertheless, there are some other factors that should be considered in selecting drying temperature, such as, economics reason and results obtained from milling.

In comparison when dryings were applied at different air inlet flow rate, it was found that drying rate varied very little when air flow rate changed, and the same period of drying time resulted in nearly the same moisture content. On the other hand, the flow rate of air inlet had very little effect on drying. This was because fluidized bed allowed a more uniform contacting between paddy and hot air than any other types of drying. Therefore, increasing air flow rate made very little change in characteristics and temperature of the bed. As the temperature in bed did not changed, rate of diffusion remained unchanged and resulted in the same rate of drying.

3. For the relationships between rate of heat transfer, temperature difference, and heat transfer coefficient; the experimental results were shown in Tables 5-12 to 5-13 and Figures 5-10 to 5-11. The relationship between rate of heat transfer and temperature difference was a straight-line function, with the slope of the graph equal to $As.h_p$. Therefore; when the value of bed surface area (As) was known, the value of heat transfer coefficient (h_p) could be determined from the graph as shown in Table 5-14 and 5-15.

In batch operation, when the temperature of ait inlet increased the value of h_p (heat transfer coefficient by convection) decreased. This was because, when the air flow rate was fixed the increase in temperature of air would reduce air density and resulted in lower convection and consequently, the value of h_p was reduced. This supported the experimental results which

$Q = Ah\Delta T$

$h = \frac{Q}{A\Delta T}$

the rate of drying increased with temperature (since diffusing of heat from outside into the grain was the heat transfer by conduction, and this diffusion was effected by only the characteristics of grain and the temperature gradient between outer part and within the grain), because the amount of heat which was not convected was forced through the grain to evaporate and carry away the moisture.

As the air inlet flow rate increased, the value of h_p increased which agreed with the fact that air flow rate will influence the heat convection. It will have a strong effect on drying in constant-rate period, but will have very little effect on falling-rate period since the drying occured in this period is the evaporation of moisture from inside the grain.

In continuous operation, when the production rate increased, the value of h_p decreased because the area of contacting between hot air and paddy increased as the feed rate increased and more heat was transfered to paddy which reduced the amount of heat convection and resulted in lower hp.

4. The relationship between Nusselt number and Reynolds number was shown in Table 5-16 and Figure 5-12. According to the experimental results, this present experimental work agreed with the previous studies which displayed in Figure 2-9, that the value of Nup was a direct straight line function of Rep. The empirical constants of the relationship between Nup and Rep. of the present study were calculated from Figure 5-12 and $Nup = 0.2517 X 10^{-4} Rep\ 1.0$

5. The results of milling were exhibited in Tables 5-17 to 5-19, and can be compared as follows:

a) the percentage of husk of parboiled rice acquired from milling did not much differ from the raw paddy. Theoretically, the percentage of husk should had been constant. However, the higher percentage of husk from milling was due to the error during the analysis that there were some husk mixed with paddy. Vice versa, the lower percentage of husk was due to the fact that there was some portion of paddy which its husk split off during the steaming stage and fell off during the drying stage, mixed with the other paddy.

b) the percentage of bran in parboiled rice is much lower than those of raw paddy. This was because of two reasons. First, bran which stuck with the grain was very hard and very difficult to be milled since gelatinization occurred during the steaming stage. Second, some portions of vitamins and minerals with in the bran were solubilized into the endosperm during the soaking and steaming stages which made the milled parboiled rice more nutritive and higher in weight.

c) Since the grain was harder after gelatinization occurred, the percentage of broken rice of parboiled rice was much lower than those of raw paddy, also, the percentage of head rice of parboiled rice was much higher. It showed that parboiling pretreatment will give the products which is of good quality and low percentage of broken rice. In turn, the product could be sold at a higher price.

From Table 5-17, it was shown that, in batch drying, when the temperature of air inlet increased, the percentage of broken rice also increased. This was due to the fact that higher temperature in the bed, had increased both the rate of diffusion of water vapor from within the grain and from the surface of the grain to outside. However, the water vapor on the surface evaporated faster than the one within the grain and the total moisture content was reduced down to the required level while there was a substantial difference between moisture content at the surface and within the grain. This nonuniform distribution of moisture content within the grain caused stress to develop and resulting in cracking when paddy was milled. This implied that drying temperature effected the quality of parboiled rice obtained.

From Table 5-18, it was shown that, in batch drying, the change of the air inlet flow rate hardly effected the quality of parboiled rice, since the percentages of broken rice obtained from different flow rates nearly the same, and the reason behind this was the same as those explained in (2).

From Table 5-19, it was shown that, in continuous drying, the change in production rate had very little effect o n the percentage of broken rice. In the matter of fact, production rate should be no effect upon the quality of parboiled rice obtained, since the quality of parboiled rice (% broken rice) only varied with the temperature in bed and rate of heat transfer (as explained in the former paragraphs), but the air flow rate and temperature were fixed when the experiment was conducted at different feed rates. The reason of few difference in % broken rice obtained because of some errors occurred during the experiment. One was the temperature controller which was unsuccessful in keeping the temperature of the bed constant at all time. Another error was the difference in room conditions, since the experiment for each production rate was not conducted on the same day.