ACCELERATED DRYING OF SHELLED MAIZE BY CONDUCTION HEATING

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The investigation was conducted employing sand as heat transfer medium for drying of shelled maize initially at 18.10% moisture content on dry basis (d.b.). A grain dryer was designed and fabricated using locally available material to find optimum operating conditions for drying of the grain. The process was found promising for providing a viable method of rapidly and efficiently drying of grain. For safe storage of maize grain for larger periods without deterioration of grain quality, the required moisture content (12.3%) was achieved with sand temperature of 100 ° C at 4.5 and 6.5 sand to grain mass ratios (SGMR) at 14 and 28 rpm of cylinder respectively. Conversely for drying at 100 ° C, 4.5 SGMR and 28 rpm of cylinder were found suitable for short period storage of shelled maize.

INTRODUCTION

Inadequate drying is one of the main reasons for food grain losses (Hall, 1963). Grain damage may be due to insect infestation and mold growth which are accelerated at high moisture levels. However, proper drying of cereals can reduce losses in storage and promote increased production through strengthening the practicability of double cropping in irrigated areas where crop is harvested in cold weather.

The most common traditional method of grain drying in Pakistan is sun drying. Chaudhry (1970) reported 3.19% grain losses during sun drying in Pakistan. This method is effective only during seasons of relatively warm, clear dry weather, and, therefore, not reliable under humid conditions. One method for drying grain with added heat utilizes air as the heat transfer medium. But the process of air-drying, regardless of the type of dryer used, is an inefficient process (Lapp and Manchur, 1974). Chancellor (1986 ab) also reported that drying rates by conduction drying exceed those by heated air. Keeping in view the importance of drying and ineffectiveness of the other drying methods, a grain dryer using the principle of conducted heat was designed, fabricated and tested for drying of shelled maize. The principle of using a solid heat transfer medium seems technically suitable and economically feasible for grain drying in Pakistan.

MATERIALS AND METHODS

Maize grain with an initial moisture content of 18.10% on dry weight basis (d.b.) was used in the study. Grains were stored in polythene bags to maintain moisture content. The sand texture 20-40 was used to remove the greater amount of moisture and achieve maximum drying efficiency during drying of grain at different temperatures of sand (Mittal and Lapp, 1984).

Description of the dryer: The dryer shown in Figure 1 was used for investigations. The main component of the dryer was a rotary cylinder 61 cm in diameter and 76 cm long. A helix, 15.24 cm high was welded inside the drum for conveying and mixing the hot sand and grains. The conical mouth of the drying cylinder had 30.5 cm diameter. For the fabrication of the drum a 1.92 m x 0.61 m, 15 gauge mild steel sheet was used. At the exit end of the drying cylinder, access ports were provided for discharging hot sand and grain after drying. An iron stand was employed for mounting the drum, electric motor, etc. A 950 rpm, 1 H.P., 3 phase electric motor was coupled to rotate the drum through matched pair of step pulleys and a V-belt.

Experimental procedure: The dryer was evaluated under various sand to grain mass ratios (SGMR) and temperatures of sand. The specific quantity of sand was uniformly heated to desired temperature in an open pan using natural gas as a source of heat. As soon as the desired temperature of sand was obtained, it was quickly transferred into the drum. A temperature drop of 3 °C observed during transfer of hot sand from pan to the drum was compensated by heating sand higher than the required experimental temperature. A 400 g sample of maize grain was selected as a base and the mass of sand was varied to give the desired SGMR.

After the heated sand was transferred to the cylinder, the sample of grain was quickly poured into the cylinder and allowed to mix with sand by switching on the electric motor. As soon as the mixture of sand and grain came out of the dryer, the corn grains were separated from sand by sieving and the final temperature of sand was recorded by a mercury thermometer. The change in temperature of the medium was recorded as T. The grains were allowed to reach room temperature and moisture content of grains was determined by oven drying method at 103 °C for 72 hours (Anonymous, 1971). Two replications were made for each trial. Each trial was followed by laboratory procedures for moisture determination.

Drying efficiency: Drying efficiencies were calculated on the basis of heat utilized to remove water (output) divided by the heat available for drying (input). Sinha and Muir (1973) developed the following relationship for calculation of drying efficiency:

$$n_d = \frac{M_w \, h_{fg}}{M_s \, C_p \, T} \qquad (1)$$

where

n_d = drying efficiency in decimals,
M_w = mass of water removed, kg,
h_{fg} = latent heat of vaporization, J/kg,
M_s = mass of medium, kg,
C_p = specific heat of medium equal to 795.0 J/kg.K (Parry *et al.*, 1969), and
T = temperature change of medium in drying, K

Latent heat of vaporization was calculated as under (Anonymous, 1983):

$$h_{fg} = (73{,}29{,}15{,}59{,}78{,}000 - 1{,}59{,}95{,}964.08\, T^2)^{1/2} \qquad (2)$$

$$338.72 \leq T \leq 533.16$$

where

T = dry-bulb temperature, Kelvin

RESULTS AND DISCUSSION

The data were statistically analysed and the best fit curves were plotted. The analysis of variance on the basis of moisture removed during drying, indicated highly significant differences among different parameters of the study. Interactions between these parameters were also highly significant at 5% level of probability.

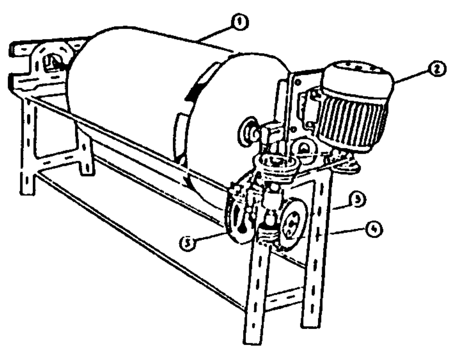

Fig. 1. An isometric view of the dryer.
1. Drying cylinder
2. Electric motor
3. Worm wheel
4. Worm gear
5. Spur gear

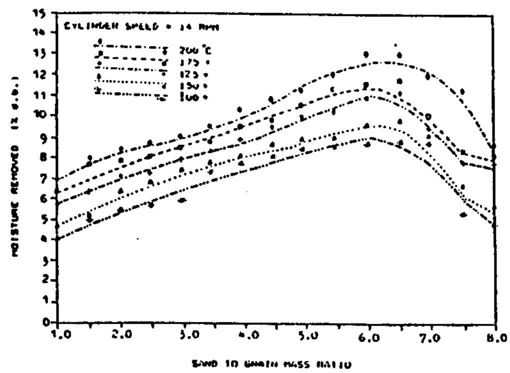

Fig. 2. Per cent moisture removed from corn at different SGMR and sand temperatures.

Figure 2 depicts that at initial sand temperature of 100 ° C and SGMR 1.0, the moisture removed was 4.15% (d.b.). On the other hand, loss in moisture was 12.95% with initial sand temperature of 200 ° C and a 6.5 SGMR. The curves indicate that the moisture removed is proportional to the initial temperature of sand. It can also be seen from the curves that with the increase of SGMR from 1.0 to 6.5, at the same temperature, the quantity of moisture removed increased. At all initial sand temperatures, maximum loss in moisture occurred at a 6.5 SGMR, i.e., 8.91, 9.61, 11.0, 11.55 and 12.95% for 100, 125, 150, 175 and 200 ° C respectively. However, for SGMR higher than 6.5, the curves showed a decreasing trend in the removal of moisture content. The results are in line with those obtained by Mittal and Lapp (1984). The pattern of curves up to SGMR 6.5 may be due to the fact that with the increase in sand volume, the grain contact with sand increased and , hence, resulted in removal of moisture content proportionately. Decrease in moisture removal rate beyond SGMR 6.5 be attributed to the fact that a large volume of sand relative to grain in the moisture resulted in a thick layer of sand surrounding the maize kernels. This created a physical barrier to the escape of moisture from grain to the surrounding air. Figure 2 indicates that the maize grain initially at 18.10% moisture content has undergone moisture reduction from 7.0 to 12.85% at 200 ° C during a residence time of 0.29 minutes.

For one year and five years safe storage of maize grain, 14.94% and 11.11 to 12.36% grain moisture contents are required respectively (Brooker *et al.*, 1974). Depending on the initial moisture content of the maize, suitable temperature and SGMR can be selected from Figure 2, in order to bring the moisture content of the crop to a safe level suitable for short and large term storage. Specifically in this study the initial moisture content of test material was 18.36%, so it required to remove 3.87% and 6.45 to 7.70% moisture content for satisfying

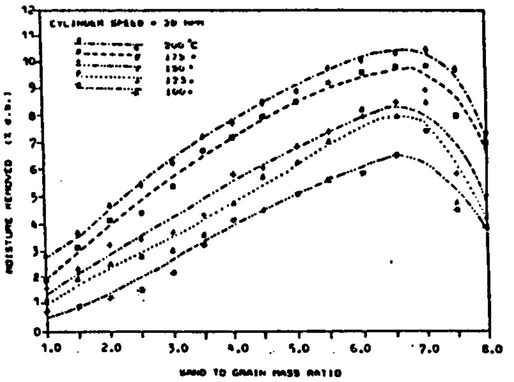

Fig. 3. Per cent moisture removed from corn at different SGMR temperatures.

the condition of safe storage for one year and five years respectively. Since all the treatments at 14 rpm of cylinder resulted in more reduction of moisture content than that required for storing grain for one year, therefore, 14 rpm cylinder speed was not recommended for drying grain to meet the conditions for one year safe storage. However, at 14 rpm of cylinder, five years safe storage conditions were satisfactorily met. The required moisture content of 14.94% was obtained by using initial sand temperatures of 100, 125, 150, 175 and 200 °C at 4.5, 3.0, 2.0 and 1.0 SGMR respectively. Nevertheless, the treatment with initial sand temperature of 100 °C and a SGMR 4.5 was considered more suitable because of less chances of burning the grain at this lower sand temperature. Figure 3 depicts that 28 rpm speed of cylinder can be safely recommended for drying grain to meet one year and five years storage conditions. For safe storage of grains, the required moisture content of 14.94% was obtained with sand at temperatures 100, 125, 150, 175 and 200 °C at 4.5, 3.5, 3.0, 2.0, 2.0 and 6.5, 5.5, 4.5 and 3.5 SGMR for one and five years period, respectively. Nevertheless, Figure 3, provides relevant information for the selection of a suitable treatment in order to bring the moisture contents of shelled maize to a desired level depending upon its moisture contents. Further it is evident that the residence time of grain in the cylinder had a direct relationship with the percent moisture removed. Therefore, the moisture removed at 14 rpm was more compared to that at 28 rpm (Figures 2 & 3). For example at 100 °C and 6.5 SGMR, moisture removed was 9.0 and 6.0% at 14 and 28 rpm of cylinder respectively.

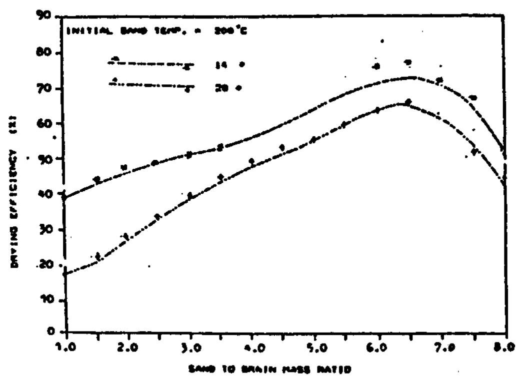

Fig. 4. Per cent drying of corn at different RMP of the drying cylinder and SGMR at 200 °C sand temperature.

Figure 4 shows the results of drying efficiency at different cylinder speeds for various SGMR at 200 °C initial sand temperature. The highest values of drying efficiencies at 14 and 28 rpm of cylinder were obtained at 6.5 and 7.0 SGMR and these values were 78.80 and 67.45 respectively. The results of the study conform to those obtained by Finney *et al.* (1963), but are better than those of Foster (1973) who reported a drying efficiency of 51.2% by drying maize with continuous flow tower type grain dryer using hot air as a heat transfer medium. However, it is possible to improve the drying efficiency further by making the modifications to the prototype. An average drying efficiency as high as 70% was obtained by Finney *et al.,* (1963) when they used this principle to dry shelled maize. Hence, the drying efficiencies achieved by the investigators are close to the results obtained by them.

Conclusions: The following conclusions may be drawn from this investigation:

The results reveal that the higher the initial sand temperature, the faster the drying. The process gives definite promise of becoming a viable method of rapidly and efficiently drying grain that is not to be used for seeding. Sand has semi-fluid flow characteristics which are adaptable to continuous flow process. No difficulty was experienced in mixing sand with the kernels. The operation of the grain dryer using sand as a heat transfer medium appeared feasible. For safe storage of maize grain for five years without burning during drying, the required moisture content was obtained with sand temperature of 100 °C at 4.5 and 6.5 SGMR at 14 and 28 rpm of cylinder respectively. However, drying at 100 °C with 4.5 SGMR and 28 rpm of cylinder was found appropriate to achieve the desired moisture content for one year storage. The separation of sand from grain after screening has been remarkably complete and no sand particles have been noticed in the grain dried by this dryer. The performance of hot sand and a heat transfer medium was found superior to hot air systems in drying efficiency. The increase in cylinder speed affected the drying in terms of residence time, hence less moisture was evaporated at higher cylinder speeds. No change in colour of dried grain was noticed. It is suggested that before the use of investigated parameters, chemical analysis and germination test may be performed to assess the effect of the treatments on dried grain.

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