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Note

Determination of economic cost, vigour and rate of germination in batch drying of maize seeds

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A b s t r a c t. The most suitable drying parameters in drying corn in bulk by warm air were determined. 250 kg of corn was employed for each test. Air flow rate was kept constant at 1 m s^{-1}. The corn seeds used in the tests were dried at five different temperature values until the moisture of 16.4% was reduced to 10%. The dried corn seeds were examined from the point of view of drying time, germination rate, germination vigour, energy consumption and economic cost.

K e y w o r d s: maize, drying, energy consumption, economic cost, germination rate

INTRODUCTION

Maize or Indian corn (*Zea mays* L.) is a plant of American origin and is consumed worldwide for various purposes. It is not considered as a staple food. Maize in the form of flour is mostly used to make various products *ie* bread, muffins, doughnuts, infant foods, biscuits, wafers, break fast cereals, and as a filler, binder and carrier in meat products (Velu *et al*., 2006). Moreover, corn is an important industrial raw material in the starch industry (Haros and Suarez, 1997). Maize is an important cereal crop in the world (Hossain *et al*., 2003). Drying is one of the processing technologies used in agriculture prior to storage and the ultimate utilization of agricultural products. Costly instruments and lengthy tests are needed to create an exact picture of the drying process and to carry out experiments in order to define the optimum values of the drying parameters (Nemenyi *et al*., 2000). Maize and some other corns are characterized by a high initial moisture content at harvest. Hence, drying becomes an essential operation before storage. Drying is a difficult task due to the variation in harvest moisture, deterioration of corn quality, the environmental, health and safety regulations and the need of energy saving (Hatamipour and Mowla, 2003). Maize usually has to be dried with heated air in order to achieve a safe moisture level for long-term storage (Davidson *et al*., 2000). Before industrial and agricultural usage, drying of food material is the most important method to be used for conservation (Togrul and Pehlivan, 2003).

In this study, the moisture-time plots for maize widely produced all over the world by drying with hot air flow for five different temperatures under a constant air flow were created and the relevant regression equations were formulated. During studies, by determining energy consumption and optimum drying values, the first parameters for commercially available maize dryer machines, were found out. Moreover, for drying under five different temperature values, the physiological properties of maize such as germination vigour and rates were determined and the statistical differences were investigated.

MATERIALS AND METHODS

The dent corn seeds used in the study were obtained from the fields of Agricultural Faculty, Uludag University, Bursa, Turkey. The drying of corn was carried out in a cabinet dryer. The dryer basically consisted of a centrifugal fan to supply the air flow, an electric heater, an air filter, and an electronic proportional controller. The air temperature was controlled by means of the proportional controller. The air flow rate for all drying runs was 1 m s^{-1} and measured by a digital anemometer (Thies Clima, Germany) having a least count of 0.1 m s^{-1}, and the flow was perpendicular to the bed. The air was recirculated by a variable speed fan and heated by electricity. The experimental samples were dried on a mesh tray which had a flow cross-section of 100 x 100 cm. The initial moisture content of the seeds was determined by digital

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moisture meter (Pfeuffer HE 50, Germany) reading to 0.01%. Average humidity of air was recorded with a Penta-type hygrometer. Drying of corn was finalized when the moisture content decreased to 10% from the initial value of 16.4% w.b. A heating element composed of 12 serpentine resistances with 1.5 kW and a radial fan having an electric motor with 5.5 kW were employed in the system. Energy consumption of the dryer was determined using a digital electric counter (Kaan, Type 101, Turkey).

The drying tests were performed in the 45-75°C temperature range and non-heated air were chosen according to information found in the literature. The tests were repeated three times. Moisture of the corn grains, energy consumption values and time values were measured at every 15 min during the tests and they were transferred into the computer for analysing (Trelea *et al*., 1997). Costs of energy consumption were calculated in USD (Jayas and White, 2003). 100 corn seed were germinated in a pot for each temperature sample, for the determination of germination rate (%) and time. Then, they were counted after 3-4 days and the average values were calculated. Average of the counting performed after 7-8 days yielded germination vigour (%) (Kirtok, 1998).

The results were processed by the MINITAB (Version 14, University of Texas, Austin, USA) programs. One way analysis of variance and LSD test MSTAT_C (Version 2.1., Michigan State University, MI, USA) software program were used to analyse the results. Differences were considered significant at $p<0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

Moisture-time plots for maize dried by five different hot air drying are shown in Fig. 1. Maize grain with moisture values of 16.4% was cooled to the moisture value of 10% which is the suitable storage moisture. Depending on drying used, the total drying times are: at non-heated air of 45, 55, 65 and 75°C – 3 120, 970, 715, 528 and 375 min, respectively.

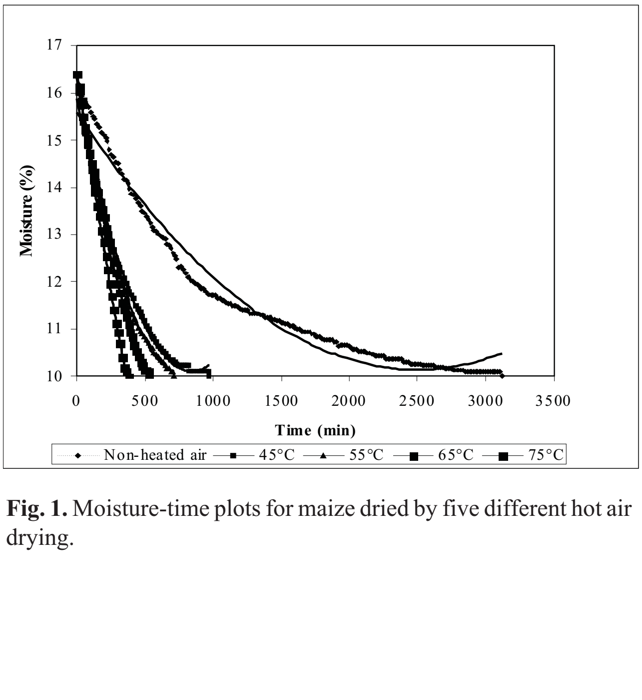

Fig. 1. Moisture-time plots for maize dried by five different hot air drying.

The results are similar to those reported by Trelea *et al.* (1997), Haros and Suarez (1997) for maize, Madamba and Yabes (2005) for rice, and Ghaly and Sutherland (2003) for soybean.

Temperature-air humidity relation for maize dried by five different hot air drying are: at non-heated air, 45, 55, 65 and 75°C – 75, 78, 80, 79 and 82%, respectively.

The relation between moisture (N) and time (t, min) is given by the following equations:

$$N_{\text{non-heated air}} = 9.10^{-7}\,t^2 - 4.4.10^{-3}\,t + 15.559 \quad R^2 = 0.9733 \quad (1)$$

$$N_{45} = 8.10^{-6}\,t^2 - 1.37.10^{-2}\,t + 15.863 \quad R^2 = 0.9942, \quad (2)$$

$$N_{55} = 1.10^{-5}\,t^2 - 16.7.10^{-3}\,t + 16{,}325 \quad R^2 = 0.9986, \quad (3)$$

$$N_{65} = 1.10^{-5}\,t^2 - 17.5.10^{-3}\,t + 16.297 \quad R^2 = 0.9983, \quad (4)$$

$$N_{75} = 1.10^{-5}\,t^2 - 2.10^{-2}\,t + 16.442 \quad R^2 = 0.9989. \quad (5)$$

Statistical analysis results depending on time, total energy consumption and total cost are given in Table 1.

The energy consumption consists of electric power expenditures. Energy consumption values for maize dried by the five different hot air drying are: at non-heated air, 45, 55, 65 and 75°C – 150, 204, 173, 159, and 119 kWh, respectively. The results are similar to those reported by Yildiz *et al.* (1989) for maize seeds and Zhang *et al.* (2007) for wood. The results showed that the energy consumption in 75°C drying is the least and the drying time is the shortest. The concept of instantaneous drying indices makes it possible to trace the variation of energy efficiency in the dryer with time (batch dryer) to identify the most inefficient parts of the dryer and its operating parameters, and to indicate modifications to the dryer design and operation in order to reduce energy consumption.

Energy cost values for maize dried by five different hot air drying are: at non-heated air, 45, 55, 65 and 75°C – 21.460, 29.170, 24.790, 22.753, and 16.990 USD, respectively (Table 1). The results are similar to those reported by Jayas and White (2003) for maize seeds and Cermak *et al.* (2005) for cuphea seeds. The energy cost in the 75°C drying is low, because it has advantages such as mature technology, short drying time, and good adaptability. In the literature, drying of corn kernels has been carried out using different treatments and drying. Ambient air corn drying offers advantages in corn quality compared to high temperature drying. However, the drying process takes place over a much longer period of time (Doymaz and Pala, 2003; Lynch and Morey, 1989). Lowering the grain temperature below ambient temperature or grain cooling has been used extensively to minimize deterioration of grain during storage (Borompichaichartkul *et al*., 2004).

Germination rate values for maize dried by five different hot air drying are: at non-heated air, 45, 55, 65 and 75°C – 74, 74, 72, 68 and 26%, respectively (Table 2). Similar

Table 1. Statistical analysis results depending on time, total energy, consumption and cost

Temperature (°C)	Time (min)	Total energy consumption (kWh)	Total cost (USD)
Non-heated air	3 120 ± (8.66)^{a}	150 ± (5.19)^{b}	21.460±(0.741)^{b}
45	970 ± (84.10)^{b}	204 ± (7.73)^{a}	29.170±(1.110)^{a}
55	715 ± (5.00)^{c}	173 ± (2.45)^{b}	24.790±(0.351)^{b}
65	528 ± (11.70)^{d}	159 ± (3.44)^{b}	22.753±(0.491)^{b}
75	375 ± (15.00)^{d}	119 ± (3.66)^{c}	16.990±(0.523)^{c}

$^{a\text{-}d}$ Means superscript with different letters in the same column differ significantly ($p<0.01$).

Table 2. Statistical analysis results depending on germination rate and vigour

Treatment	Germination rate (%)	Germination vigour (%)
Control	67±(5.81)^{a}	82±(7.13)^{a}
Non-heated air	74±(2.33)^{a}	86±(3.06)^{a}
Temperature (°C)		
45	74±(4.70)^{a}	88±(3.38)^{a}
55	72±(3.06)^{a}	87±(2.03)^{a}
65	68±(7.31)^{a}	83±(5.46)^{a}
75	26±(3.33)^{b}	40±(2.52)^{b}

Explanations as in Table 1.

results of germination rate have been reported for sunflower (Ducournau *et al*., 2004), wheat (Toklu *et al*., 2008) and guayule seed (Jorge *et al*., 2006).

Germination vigour values for maize dried by five different hot air drying are: at non-heated air, 45, 55, 65 and 75°C – 86, 88, 87, 83 and 40%, respectively. Statistical analysis results depending on germination rate and vigour are given in Table 2. Similar results of germination vigour have been reported for maize (Govender *et al*., 2008), *Catharanthus roseus* (Jaleel *et al*., 2007), and a corn (Branco *et al*., 2002).

CONCLUSIONS

1. Optimum results with respect to energy consumption, economic cost and drying time were obtained for seeds dried at 75°C.

2. Optimum results with respect to germination rate were obtained by non-heated air and 45°C.

3. Optimum results with respect to germination vigour were obtained from the seeds dried at 45°C.

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