Operational behavior of an ear corn seed dryer

Evandro Kolling[1], Valdecir Antoninho Dalpasquale[2] and Décio Sperandio[1]

*[1]Programa de Pós-graduaçao em Agronomia, Universidade Estadual de Maringá. [2]Departamento de Agronomia, Universidade Estadual de Maringá, Av. Colombo, 5790, 87020-900, Maringá, Paraná, Brasil. *Autor para correspondência. e-mail: vadalpas@wnet.com.br*

ABSTRACT. This work aimed to analyze the operational behavior of a fixed-bed ear corn dryer in commercial scale. It was carried out by controlling the variables involved in the process, such as: ambient and drying air conditions, airflow, product temperature, and fuel consumption (corncobs). Data were collected at the high season of harvesting, following the operational procedures adopted by the owner. The whole process indicated that the dryer operates in the recommended levels of temperature, an average of 41.7ºC.The highest product temperature during drying process was 42.0ºC. The total drying time (over 100 hours) is too high for commercial drying. *Exhausting drying* consumed more than 85% of the total drying time, and it is only effective when moisture contents are above 18%. Fuel consumption in *effective drying* varied from 295 kg to 365 kg of corncobs (fuel source) per point of moisture removed, which means more than 16,000 kJ/kg.

Key words: drying, seed, efficiency.

RESUMO. Comportamento operacional de um secador de sementes de milho em espigas. Objetivou-se, neste trabalho, analisar o comportamento operacional de um secador de camada fixa, empregado para secagem de sementes de milho em espigas, em escala comercial. O objetivo foi atingido pelo levantamento de variáveis envolvidas no processo, tais como: condições do ar ambiente e de secagem, vazão de ar, temperatura do produto e consumo de combustível (sabugo de milho). Esses dados foram coletados em plena safra, seguindo procedimentos operacionais adotados pela empresa. O acompanhamento de todo o processo permitiu verificar que o secador opera dentro dos níveis recomendados de temperatura, em média 41,7ºC. A máxima temperatura do produto no ato de secagem efetiva foi de 42,0ºC. O tempo total de secagem de mais de 100 horas é excessivamente alto para secagem comercial. A secagem com ar de exaustão precisa de mais de 85% do tempo total de secagem e só é eficaz para niveis de umidade superiores a 18%. O consumo de combustível em secagem efetiva ficou entre 295 e 365 kg de sabugo por ponto de umidade removida, o que se traduz em eficiência de secagem superior a 16.000 kJ/kg.

Palavras-chave: secagem, semente, eficiência.

Introduction

The presence of microorganisms and insects as well as mechanical damages are among several factors which may compromise general seed quality. These factors may be attenuated or even avoided by proper moisture control. Drying is one of the most important post-harvesting techniques before storage: if adequately conducted, it creates conditions to maintain the product quality for long periods, thus avoiding insect damage and fungi development (Carvalho and Nakagawa, 2000).

Drying is used to remove part of the moisture from a product. It may be defined as a simultaneous process of heat and mass transfer between the product and the air. According to Silva (1985), drying depends on the vapor pressure difference between the product surface and the air used in the process. Moisture removal may be accomplished up to the ideal value to keep the equilibrium with ambient conditions in storage, maintaining nutritive and apparent quality, as well as seed viability.

Several kinds of dryers and drying techniques are available, but the most suitable for ear corn seed is the fixed-bed dryer. It is flexible, and may be used for other seeds, like coffee, beans and other agricultural products (Silva *et al.*, 1995). The product does not move during the drying process in a fixed-bed drying. Product is placed over a perforated floor through which the drying air passes (Carvalho, 1994). The system operates at different high temperatures, depending on the end use of the product: as seeds or food and feed industry, for human or animal purposes. Avoidance of drying temperatures above 40ºC is universally accepted, although the seeds drying time is seldom indicated.

Corn seed is usually harvested in the ear to minimize mechanical damage when trashing the wet product (Eldeen *et al.*, 1978). Harvesting by ear allows product removal from the field at high moisture contents, which brings the advantage of harvesting much closer to the physiological maturity of the product, the best recommended stage for harvesting (Dias, 2001).

It is recommended to dry corn seed at the ear. In this way, the seed embryo is much more protected of high drying air temperatures, as well as of mechanical injuries, because it is still attached to the cobs (Silva, 1985). Thus, ear corn seed drying can be performed at 45º to 50ºC (Amaral, 1999), although drying may still take long time if an incorrect dryer design or inappropriate drying techniques are used. Information about these factors is still in short supply, because most of the material published about corn seed drying relates to corn already thrashed (Rosa *et al.*, 2002).

In order to amplify the information about ear corn seed drying, this work evaluated technically a commercial fixed-bed dryer.

Material and methods

The experiment was carried out at Cooperativa Central de Desenvolvimento Tecnológico e Econômico Ltda. – Coodetec, in the municipality of Palotina, State of Paraná, Southern Brazil, located at 24º 12' S latitude, 53º 52' W longitude and 370 m. altitude.

The aim of the study was a horizontal fixed-bed dryer consisting of 12 cells, each dumped at 23º, with 4.4 x 5.5 m at the sides, and layer thickness up to 2.0 m, with 580.8 m^3 maximum drying space, because the dryer may operate at different layer thicknesses. The cells are built in two series of six cells, with a two-floor tunnel between them, where the air moves in and throughout the dryer, as shown in Figure 1.

The drying air is heated in two furnaces, using corncobs as energy source. Air is forced into the dryer at the upper-floor tunnel by a centrifugal fan equipped with a 91.9 KWh electric motor. The air passes through only two cells, where it goes downward through the ear corn seeds, leaving the cells to the bottom-floor tunnel. These two cells receive what is named *effective drying*.

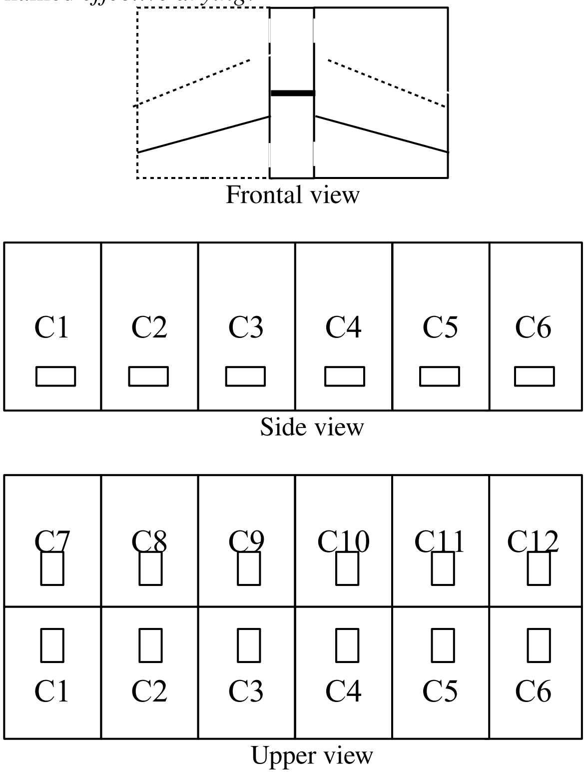

Figure 1. Different views of the cells in a fixed-bed dryer for ear corn seeds.

All other ten cells, or less if the dryer is not filled up, receive this already used air from the bottom-floor tunnel with drying capacity lower than the other two cells. The air passes through them upwardly, and leaves the dryer through a window at the middle top of each cell. These other ten cells receive what is called *exhausting drying*. In this test, cells 1 and 7 or 6 and 12 dried together as *effective drying* cells, although Coodetec performs drying with any cell pair.

Just-harvested corncob seeds are first dried in the *exhausting mode,* until their average moisture content reaches around 18%. After that, the seeds receive *effective drying* in only two cells, with the drying air coming from the furnaces at 46ºC–47ºC, until the final moisture content is reached. In the tested dryer, around 85% of the drying time is spent in the first mode, and only 15% in the *effective drying*.

Seed moisture content was evaluated using a moisture meter available at Coodetec, in order to minimize interference in the drying way. The moisture meter is based on the electrical resistance offered by the product. Moisture and all the other properties evaluated in this test were obtained from samples collected at every four to six hours at the top of the ears layer, in the middle of it, and at its bottom.

Coodetec dries ear corn seeds until their moisture contents are below 13% in all layers.

The product temperature was acquired only when the cell was receiving air directly from the furnaces. A sample from each layer was placed in an isolated container, where a thermometer was placed inside the mass. The results were read after 10 minutes of tempering.

The ambient temperature and relative humidity were obtained using a hot-wire thermometer, by reading dry bulb and wet bulb temperatures.

The drying air temperature was read by a digital thermometer at each cell entrance, when receiving air directly from the furnaces. In order to know its volume, the air speed was determined at that same place through a digital anemometer (Kestrel, model K2000).

The amount of energy consumed in the drying process was obtained by weighing the quantity of burned corncobs.

The drying test lasted for almost a week, working 24 hours a day. The drying procedure of Coodectec was followed, which consists of using only two cells for *effective drying*. Part of the time cells 1 and 7 did that and, at other times, cells 6 and 12. Also, due to differences in the ambient conditions during a day and in different days, no regular statistical analysis is suitable. Drying lasted until all layers of the ear corn seed in *effective drying* had their moisture content below 13%. Some flexibility in time was needed to minimize interference in the normal drying procedures of the dryer's owner.

Results and discussion

The drying results are presented in Table 1. Ear corn seeds were dried at temperatures as high as 46ºC – 47ºC without significantly affecting seed quality, for the two cells receiving *effective drying*. This is based on the results which indicated that ear corn seeds can be dried at 50ºC (Amaral, 1999). For all other cells, the air temperature for drying was much lower, around 40ºC, because the air already did some drying in *effective mode*, which reduced its ability for further moisture evaporation. This is the main reason why drying in the *exhausting mode* took about 85% of the total drying time.

Total airflow was difficult to evaluate, because of the way the dryer is used by its owner. The amount of air passing through cells 1 and 7 should be the same for the other ten cells. When adding the values which went through these two cells and dividing by the airflow average through the cells in *exhausting drying* mode, the result showed that cells in this mode should be eight instead of ten. This indicates that the air distribution at the bottom-floor tunnel is not appropriate. In fact, for better distribution, the air from a cell at the right side, for example, should go only to the one at the left side, or vice-versa. This would guarantee the same amount of air for both cells, as well as to allow air reversal, which results in more homogeneous moisture of the ear corn seeds in both cells.

Table 1. Drying results of one test with the fixed-bed dryer for ear corn seeds

Variables	Cell.1	Cell.7	Cel.6	Cel.12
About the seeds				
Initial moisture content (%)	23.2	23.2	23.6	22.8
Final moisture content (%)	12.2	12.2	12.7	12.5
Average temperature at effective drying	40.7	40.0	39.0	42.1
Total drying time (hr)	111.0	102.3	102.5	110.5
During Exhausting Drying				
Ambient temperature (ºC)	29.8	30.9	30.8	29.8
Amb. relative humidity (%)	88.5	89.9	89.9	88.5
Drying air temperature (ºC)	42.0	41.6	41.2	41.2
Airflow rate (m^3/min)	11.7	10.6	10.3	11.6
Exit moisture content (%)	18.8	18.2	17.8	19.4
During Effective Drying				
Initial moisture content (%)	18.8	18.2	17.8	19.4
Ambient temperature (ºC)	27.7	29.0	29.8	27.7
Amb. relative humidity (%)	94.6	87.0	83.5	94.6
Drying air temperature (ºC)	45.9	46.0	47.7	45.8
Airflow rate (m^3/min)	41.9	46.2	47.7	38.7
Amount of corncobs (kg)	2,065.8	1,810.2	1,850.3	2,060.8
Heating power (kJ/kg)			17,600	
Drying efficiency				
kJ/kg	16,678.4	16,076.2	19,329.2	15,797.0
kcal/kg	3,984.3	3,840.5	4,617.6	3,773.8
Overall dryer efficiency				
kJ/kg			16,970.2	
kcal/kg			(4,054.2)	

A drying time of about 100 hours is too long for a good drying system. Amaral (1999) already indicated the solution for the same dryer tested in this work. The air amount is too low and the fan used is not appropriate for this kind of dryer.

The amount of corncobs spent for drying is an indication of these problems, namely: not enough air used and its inadequate distribution throughout the dryer. The values shown in table 1 refer only to the energy spent during *effective drying*. It varied between 295 and 365 kg of corncobs per point of moisture removed. This is better illustrated by the drying efficiencies summarized by the overall dryer efficiency. The value of 16,970.2 kJ/kg of water evaporated is excessively high, non-economical, even when the source of energy is a byproduct of the ear corn seed production. The corncobs left could be sold in the neighborhood, where wood is still used to warm up the air for drying agricultural crops.

Conclusion

Drying techniques should be appropriated to each condition. As an energy high-consuming operation, all drying procedures should be optimized. The ear corn seed dryer of Coodetec, in Palotina, State of Paraná, BR. is spending more than 4,000 kcal of energy per kilogram of moisture removed, when it could do it with less than 1,500 kcak/kg, for the moistures tested, if each pair of cells placed side by side were treated as one drying unit.

Even more economic would be to use the right airflow rate. As a result, the drying time at the tested dryer can be reduced to about 65 hours, as already shown by Amaral (1999), which is almost the same as to build a new dryer of equal capacity and different drying characteristics of the one currently in use.

References

AMARAL, D. *Avaliação técnica e econômica de secagem de sementes de milho (Zea mays, L.) em espigas, usando simulação matemática.* 1999. Dissertação (Mestrado)-Departamento de Agronomia, Universidade Estadual de Maringá, Maringá, 1999.

CARVALHO, N.M. *A secagem de sementes.* Jaboticabal: Fundetec, 1994.

CARVALHO, N.M.; NAKAGAWA, J. *Sementes:* ciência, tecnologia e produção. 4. ed. Campinas: Funep, 2000.

DIAS, D.C.F. *Maturação de sementes*. Revista Internacional de Sementes. SEED News. v. 5, n. 6, 2001. Disponível em:<*http:// www.seednews.inf.br*>. Acesso em: 15 maio 2005.

ELDEEN, Y.I.S. *et al. Factors influencing drying of ear corn*. St. Joseph: American Society of Agricultural Engineering, 1978. p. 1-26. (ASAE Technical Paper no. 78-6005).

ROSA, S.D.V.F. *et al. Efeito do tamanho da amostra sobre alguns parâmetros físicos de espiga de milho e da qualidade fisiológica das sementes. Cienc. Agrotecnol.*, Lavras, v. 26, n.1, p. 57-65, 2002.

SILVA, F.A.P. *Simulação de secagem de milho (Zea mays, L.) em espigas para sementes.* Viçosa: UFV, 1985.

SILVA, S.F.R. *et al.* Custos de secagem. *In:* SILVA, J.S. (Ed.). *Pré-processamento de produtos agrícolas.* Juiz de Fora: Instituto Maria, 1995, cap. 7, p. 199-229.

Received on July 21, 2005.
Accepted on December 12, 2005.