Agronomy Research Biosystem Engineering Special Issue 1, 91-97, 2011

Corn drying experiments by pilot dryer

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Abstract: The drying of agricultural products is one of the most important possibilities in the whole processing line. To ensure the safe storage of the end product, drying of agricultural products is the most important. Corn drying experiments were carried out with different settings of pilot dryer to investigate the impact of drying parameters during drying. The drying process depends on several factors, such as drying temperature, air speed, and additional drying conditions. The aim of the research was to determine the behaviour of corn, the mass loss, the environmental parameters, which characterize the moisture content and temperature distribution changes during different drying conditions. The results of the experiments could help the users of an industrial dryer and manufacturers to optimize the drying process.

Key words: Corn drying, modular dryer; energy analysis.

INTRODUCTION

Many experimental researches show that agricultural products can be satisfactorily dehydrated using auxiliary energy sources at present (Ivanova et al., 2001). During the drying process a certain number of quality features can significantly change. There is no doubt that from the point of view of safety storage the most important parameter is the material moisture content (Esper et al., 1998). During drying, shrinkage takes place simultaneously with moisture diffusion and may thus affect moisture removal rate (Kocsis et. al., 2009). Volume changes depend on several factors, such as type of the sample, dehydration method, and drying conditions (Moreira et al., 2000).

The aim of the recent study was to determine moisture changes during corn drying using a modular dryer which had been designed for appropriate measurement of different materials. The importance of this type of investigations was to determine the different layers during the drying process because in the industrial cross-flow dryer a similar segregation is observable. It is caused by the different residence time of the different layers and is also caused by the place of the vertical layers. Close to the walls and airducts of the industrial cross-flow dryer the residence time is much higher than in the middle of the dryer so here the corn layers are over dried which causes food value losses.

MATERIALS AND METHODS

In this section the description of the drying unit will be introduced along with a method for the preparation of materials to be dried.

Modular dryer unit

The laboratory dryer device (Fig. 1) was designed to simulate the drying process of different products, especially corn. The drying unit was manufactured to carry out different drying experiments. Different cereals and fibrous materials can be dried with this system by adjusting drying parameters and dryer systems applied in practice.

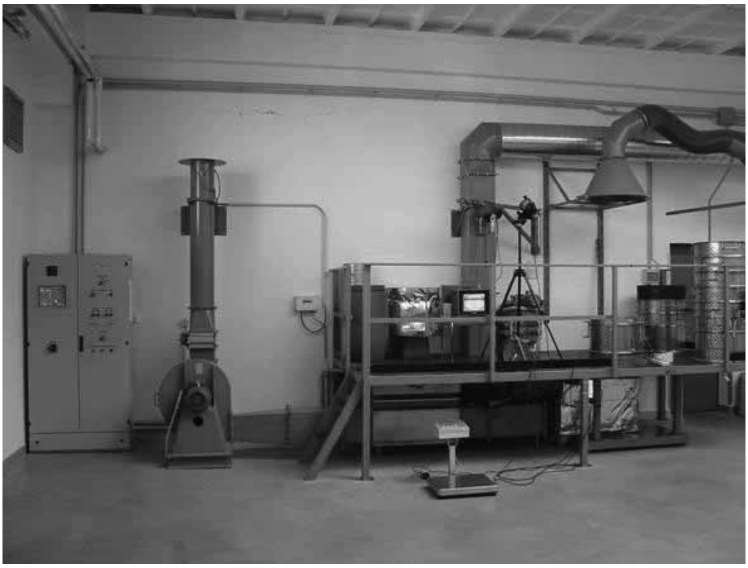

Figure 1. The laboratory dryer device.

Main drying technology parameters are as follows:
- drying layer thickness;
- drying agent speed;
- drying agent temperature;
- drying agent's relative humidity.

According to the requirements of the research tasks, these parameters could be varied in a wide range. The set speed of the air-flow is measured by an orifice pressure gauge and regulated by a frequency changer. The drying device carries out an item-by-item drying as the required drying temperature can be set. During the drying process the degree of water loss is determined by gravimetric method with the help of a built-in scale with 4 measuring points. An AHLBORN type of measuring and data collecting system ensures the measurement of heat and air engineering parameters. The device is suitable for drying layers with dimensions of maximum 4x20cm and 10x10cm and is capable of simulating drying processes by these conditions.

Preparation of Materials

Several laboratory layer drying measurements were carried out with different types of crops. Maize, sunflower, and soya bean were dried under different circumstances and the behaviour of these crops was determined. The physical characteristics (content of humidity, volume mass and density, 1,000 seed mass, crumbling force before and after the drying) of wet products harvested by combine were measured. The characteristics of the drying process, the change of humidity content in time, (dw/dt) the continuous change in the initial and final state characteristics (°C, %) of the drying agent were determined in the laboratory dryer.

RESULTS AND DISCUSSION

During the measurement series the drying parameters were changed to compare different variations of drying. The drying temperature and the velocity of the drying air have been varied. With different settings of the dryer 3 corn measurement series were carried out. In all cases the 80°C, 110°C and 130°C drying temperature and $v=0{,}129 m\ s^{-1}$, $Q=115 m^3\ h^{-1}$, $v=0{,}225 m\ s^{-1}$, $Q=200 m^3\ h^{-1}$ and $v=0{,}409 m\ s^{-1}$, $Q=360 m^3\ h^{-1}$ dry air velocity (v), volume of the drying air (Q) were combined.

Mass loss of the crops

During the drying period mass loss of the crops was continuously weighted. The average initial mass of the crops for each experiment was 35kg and in the case of sunflower it was 20kg along with 13–19% dried base (d.b.) moisture content. The initial weight of the samples always depends on the thickness of the layers. In all cases the thickness of the crop layers was 20cm. The initial drying parameters were the drying temperature and the air speed of the drying air next to the initial weight and the moisture content of the crops.

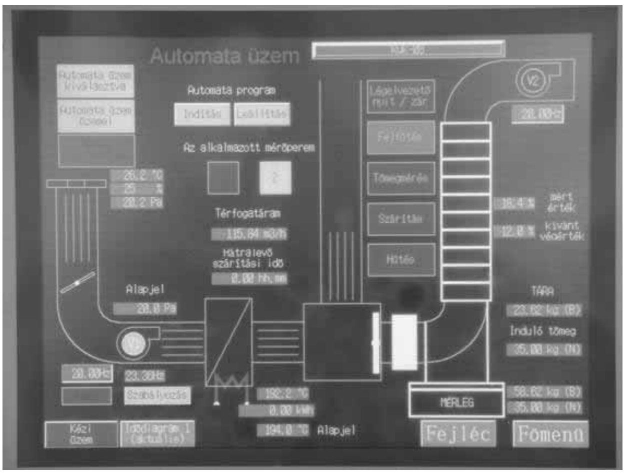

Figure 2. Control system of the dryer.

These parameters were controlled by the dryer controlling system (OMRON controller and special designed software). Before starting the drying the initial parameters were set into the program and during drying the dryer program kept the values in adequate range.

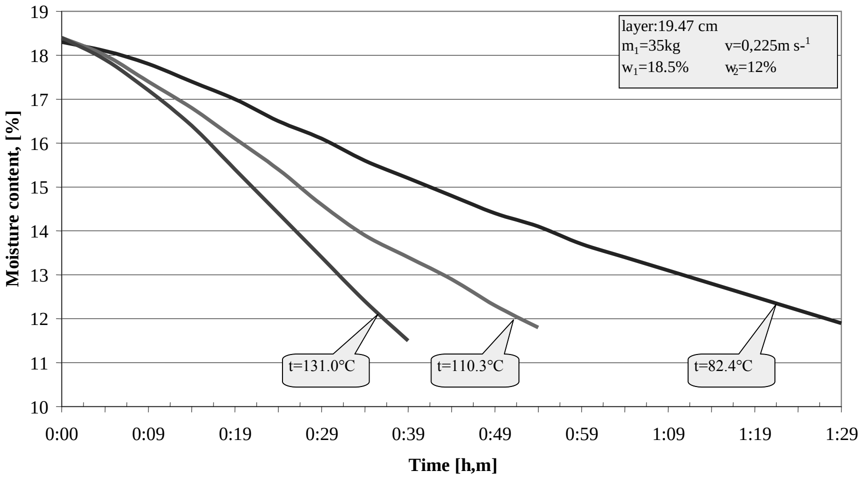

Figure 3. Mass loss during the drying period of corn at different temperatures.

From the depicted diagram in Fig. 3 it can be easily observed that by increasing the temperature from 80°C to 130°C it is possible to reduce the drying time significantly. In case of 80°C drying temperature the drying time was almost 90 minutes, at 110°C a bit less than one hour and with 130°C drying temperature to reach the same final moisture content the drying time was 40 minutes. Based on these results we can say that by increasing the temperature from 80°C to 130°C the drying time drops to less than a half.

After finishing the drying process it has also been observed that using higher drying temperature caused colour changes of the samples. Because of the drying method it was a static drying and when the layers were separated, the colour of the samples was different. After the measurements also some pictures were taken of the segregations of the samples by thermo graphic camera (Fig 4.). The importance of thermo graphic investigations was to determine the different layers by thermo pictures during the drying process to analyse the developed segregations which are observable in the industrial cross-flow dryer too. It is caused by the different residence time of the different layers and also caused by the place of the vertical layers. Close to the walls and airducts of the industrial cross-flow dryer, the residence time is much higher than in the middle of the dryer; consequently, it is here that the corn layers are over dried.

In the taken thermo images it can be observed how the segregation of the temperature distribution in different layers of the dried corn developed. It can be seen that the temperature of the top layer is around 20°C less than that of the bottom layer where the drying air enters the drying chamber. It is also very well observable how big the differences of the corn temperature are because of the layout of the dryer. These effects disturbing the drying process will be reduced by the reconstruction of the air tubes of the drier to achieve more accurate results.

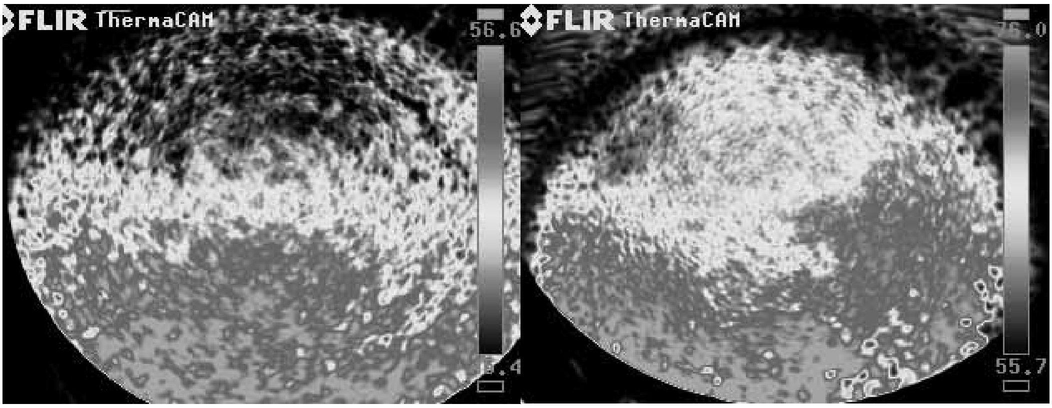

Figure 4. Thermo images of corn after drying at 80°C.

The same experiments were repeated by changing the velocity and volume of the drying air from v=0,129m s^{-1}, Q=115m^3 h^{-1}, v=0,225m s^{-1}, Q=200m^3 h^{-1} to v=0,409m s^{-1} Q=360m^3 h^{-1} at same drying temperature. In Fig. 5 the results of these measurements can be seen where the drying air temperature was 110°C.

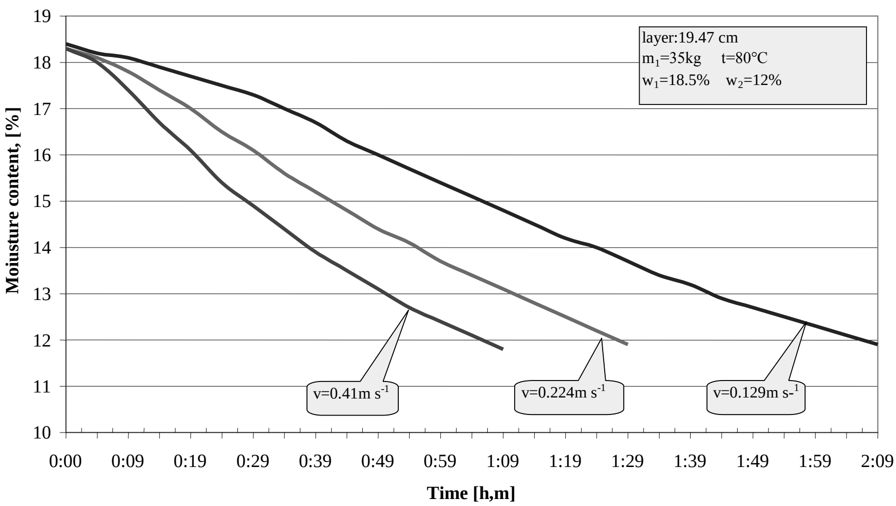

Figure 5. Mass loss during the drying period of corn at different air flow rate.

From the diagram in Fig. 5 it is can be observed that by increasing the velocity of the drying air from 0.129m s^{-1} (115m^3 h^{-1}) to 0.409m s^{-1} (360m^3 h^{-1}), it is possible to reduce the drying time more significantly than by increasing the drying air temperature. In case of the 0.129 m s^{-1} drying temperature the drying time was almost 80 minutes, at 0.225m s^{-1} a bit less than one hour and at 0.409m s^{-1} with drying air velocity reaching the same final moisture content the drying time was 40 minutes. Based on these results we can state that by increasing the velocity of the drying air from 0.129m s^{-1} to 0.409m s^{-1} the drying time is reduced to half the time.

Energy analysis

In the previous section the presented results of the experiments showed that by increasing the drying air temperature or the velocity of the drying air it is possible to reduce significantly the drying time. During the measurement series the energy consumption was also measured besides the additional parameters of the drying process.

From both types of measurement series the results of the 'middle case' were presented when the drying air temperature was constantly 110°C and the drying air velocity changed and when the drying air velocity (volume of the drying air) was constantly 0.225m s^{-1} (200m^3h^{-1}) and the drying air temperature was changed because of the border conditions. The measured energy consumption values were the following (Fig. 6.):

Used energy was 6.24kWh (80°C) 6.58kWh (110°C) and 8.03kWh (130°C) at 0.225m s^{-1} constant drying air velocity. Used energy was 7.24kWh (0.129m s^{-1}) 6.58kWh (0.225m s^{-1}) and 6.09kWh (0.409m s^{-1}) at 110°C constant drying air temperature.

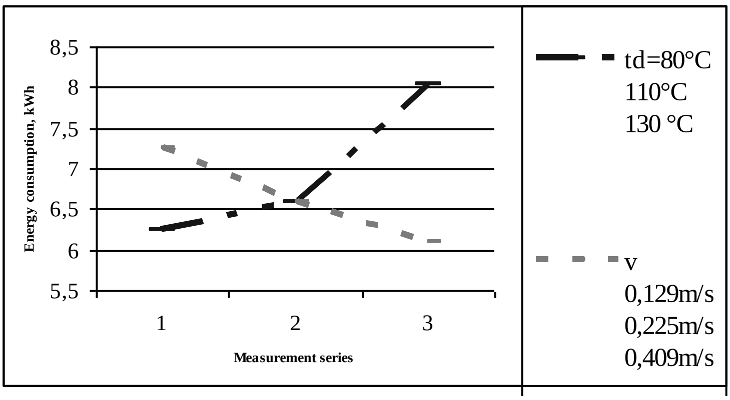

Figure 6. Energy consumption of corn drying.

CONCLUSIONS

During the measurement series the drying parameters were changed to compare different variations of drying. The drying temperature and the velocity of the drying air were changed. With different settings of the dryer 3 corn drying series were carried out.

In all cases 80°C, 110°C and 130°C drying temperature and v=0,129m s^{-1}, Q=115m^3 h^{-1}, v=0,225m s^{-1}, Q=200m^3 h^{-1} and v=0,409m s^{-1} Q=360m^3 h^{-1} dry air velocity (v), volume of the drying air (Q) were combined.

The measurement results show that by increasing the temperature or the velocity of the drying air it is possible to reduce the drying time significantly. From the energy analysis of the measurement series it appeared that increasing the temperature requires 28.7% higher amount of energy but the increased velocity of the drying air reduces the energy consumption by 18.9%.

So based on the results of the experiments it would be necessary to state that the best drying method neglects one more very important factor. This factor is food value. During the measurements also some thermo pictures were taken of the samples. The importance of this type of investigations was to determine the different layers during the drying process because in the industrial cross-flow dryer a similar segregation could be observed. It was caused by different residence time of the different layers and also by the place of the vertical layers. Close to the walls and airducts of the industrial cross-flow dryer the residence time is much higher than in the middle of the dryer, so here are the corn layers over dried which causes food value losses. It became evident how big temperature segregation develops during drying causing uneven drying. Another important result of the measurement is the determination of the irregularity of the dryer which causes inhomogeneous drying. The irregularity of the dryer is caused by the layout of the dryer. Based on these results the air tubes of the drying air will be reconstructed to reach more accurate drying.

After finishing the drying process it has also been observed that the use of higher drying temperature causes colour changes of the samples. Because of the drying method it was a static drying (because the samples did not move) and when the layers were separated the colour of the samples was different. The seeds in the samples which were closer to the walls of the dryer or contacted them were the most coloured. These parts of the samples coloured and burned because of the higher temperature when the drying air temperature was changed.

In the future the effect of the drying parameters on the food value and also the value of the colour changes by hyper spectral analyses will be analysed and published.

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