RESEARCH ON THE OPERATION OF AN INNOVATIVE EQUIPMENT HYBRID DRYING

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Abstract

The study of the operating parameters of an innovative equipment hybrid drying for cereal seeds is important for drying technology. An optimal operation of the hybrid dryer model requires the monitoring of essential technological parameters such as the velocity, temperature and humidity of the drying agent at the entrance to the dryer, as well as the temperature plus humidity of the drying agent at its exit. The energy consumption of the hybrid drying equipment is also monitored. Equipping the hybrid dryer with sensors to track these technological parameters is important, and knowing the accuracy of their measurement both in stationary and non-stationary regimes, leads to the evaluation of the degree of variability of the acquired numerical data. An important role in the evaluation of the technological parameters of the installation is also given by the mounting position of the sensors in the hybrid drying installation. The innovative equipment hybrid drying has both a convective pre-drying component and a final drying component through high frequency currents (microwaves). In the convective drying component, the cold air is heated in a heating battery with electrical resistances to a maximum of 44.9°C at an average dryer air inlet velocity of 16.54 m/s. In the final part of the drying plant, after passing through the microwave component, the maximum temperature reaches 39.3°C. The average energy consumed in idle operation of the hybrid dryer is 1.52 kWh.

Key words: (hybrid drying, innovative equipment, cereal seed)

Cereal seeds are "of great economic importance worldwide not only as human food, but also as animal feed and as raw material for a large number of industrial products and biofuels" (*García-Lara S. et al., 2019*). To be stored safely, avoiding respiration processes, germination, mold damage or insect infestation, cereal seeds must be dried immediately after harvest (Chulze S.N., 2010). Concerns towards the production of dehydrated products on an industrial scale have appeared since 1900, when the main objectives were the development of drying equipment that would accelerate the drying process and its independence from atmospheric conditions (Miraco Industry Research and Design Center). The first drying facilities built were those with natural convection, where the drying agent was a mixture of air with combustion gases or only heated air. Starting from this type of dryer, a new equipment was invented in which the drying chamber was equipped with a liquid fuel burner, fan and air regulating flaps, the model after which the vast majority of drying installations in that period (Baker C., 1997). All existing seed dryers generally have common subassemblies with precise and well-defined functions. Due to the diversity of cereal seeds, which behave differently depending on their structure and composition, some of them do not withstand aggressive drying conditions, characterized by high temperatures and low moisture content of the drying agent (Rudobashta C. P. *et al.,* 1996). Taking into account all this, with the development of the technique, in the process of designing tower dryers for cereal seeds, the attention was directed towards obtaining a superior quality of the dried product. However, energy consumption and drying time were not greatly reduced with these equipments (Gageu L. *et.al*., 1999). The first industrial drying equipment for the food industry was a hybrid tunnel dryer with continuous operation, combining convective and high-frequency current (microwave) drying using microGas™ technology in an integrated drying system powered by natural gas (http://www.microwavedrying.net). The paper presents the operating parameters of an innovative hybrid drying equipment for cereal seeds.

MATERIAL AND METHOD

The innovative equipment for hybrid drying of cereal seeds was designed and realized within a

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research project (*figure 1*). The innovative equipment hybrid dryer was tested in the first stage without product, monitoring the technological parameters (velocity, temperature, humidity, energy consumption). Tests prior to introduction of cereal seeds for drying offer the advantage of some equipment adjustments.

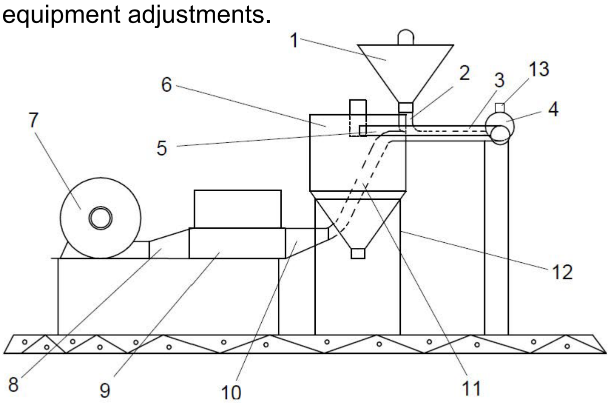

Figure 1 **Schematic of the innovative equipment hybrid dryer for drying agricultural seeds**

(1 wet seed hopper; 2 lock; 3,5 pipelines; 4 hybrid truncated cone dryer; 6 cyclone; 7 fan; 8,10 link pieces; 9 air heating battery; 11 warm air pipe; 12 support brackets; 13 antennas)

The location of the sensors and their position within the drying installation, for monitoring the technological parameters, is important in the control of the drying process, (*figure 2*).

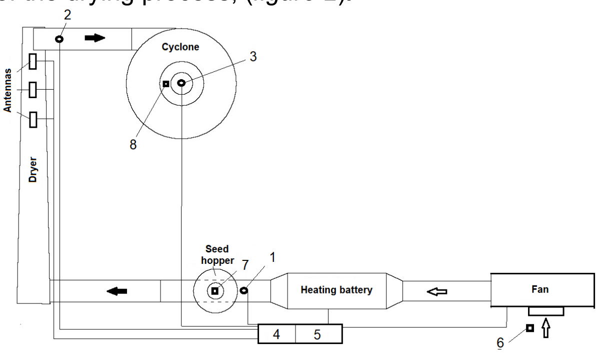

Figure 2 **The position of the parameters monitoring sensors at the hybrid drying equipment**

(1 temperature sensor and anemometer; 2, 3 temperature sensors; 4 temperature display; 5 energy consumption display, 6, 7, 8 humidity sensors)

The temperature in the hybrid drying equipment was continuously monitored with K-type thermocouples (0-1000ºC, resolution 0.25ºC), in three points respectively, the temperature of the heating agent at the entrance to the dryer, the temperature of the heating agent at the exit from the dryer, the temperature of the used drying agent at the exit of the cyclone.

The air velocity at the dryer inlet was monitored with a Testo 405i anemometer (0 - 30 m/s, resolution 0.01 m/s, -20 and 60ºC), over the entire section of the hot air inlet pipe. The velocity was determined at different air inlet flow rates, obtaining various pneumatic transport velocities of the cereal seeds.

Air humidity and temperature was determined using Pro tag wireless sensors (0-95% RH, resolution 0.12% RH, measurement error ±2% RH, -40 and 85ºC). The determination of humidity and temperature is carried out at the entrance of the air into the fan, after the heating battery for the thermal agent, at the exit of the spent agent from the cyclone.

The energy consumption of the drying equipment was monitored with a three-phase digital meter type 6M 02-552/DIG (IP51, 100A, P_{min} < 2W), at idle operation for the fan and the heating battery, and at load operation with subjected seeds the three antennas for the generation of high frequency currents are also added to the drying.

K-type thermocouple temperature sensors were calibrated by three consecutive determinations at three different temperatures (10°C, 25°C and 50°C) in the working range of the dryer, and the temperature values were compared with the temperature indicated by a thermometer precision calibrated and with a response time below 0.3 s. The humidity sensors have a calibration certificate in the range 0 - 95% RH with a deviation of ±2% RH and the indication not to exceed 95% to avoid the formation condensation on the sensor.

RESULTS AND DISCUSSIONS

The first test of the innovative hybrid dryer equipment was carried out to observe the separate operation of the fan, heating coil and antennas. By seedless testing of the hybrid drying equipment, the air flow of the fan is adjusted by changing the frequency with the frequency converter. Changing the frequency of the electric current and, respectively, the velocity of the fan, more air velocities are obtained at the entrance to the dryer, *(figure 3)*.

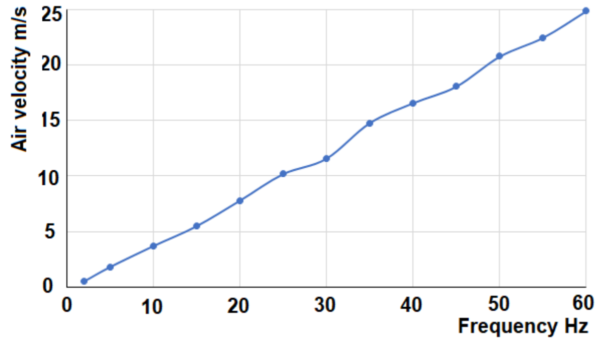

Figure 3 The variation of the velocity of air input

The second series of tests of the equipment aimed at obtaining the temperature and humidity parameters in the equipment, at air velocity that would ensure the pneumatic transport of grain seeds. The results obtained at a frequency of the electric current of 30 Hz, an average velocity of air input in the dryer of 11.55 m/s, with an external air temperature of 4.2 ºC and humidity of 67.2%, (*table 1*). The heating time in this case was 15 min, and the energy consumed was 2.46 kWh. It is observed that with the increase in temperature, the humidity of the air decreases, being properly correlated with the thermodynamic diagrams of the air. For drying cereal seeds, it is necessary that the temperature during drying does not exceed 50ºC in order to preserve the quality of the seeds in the drying process. At the end of the test with the air inlet speed of 11.55 m/s, a difference of 4.5 ºC is observed between the inlet and outlet of the drying equipment, a phenomenon due to thermal losses in the installation. It is expected that at a lower outside air temperature, these losses will increase by 1-2ºC, stabilizing due to the external thermal insulation existing on the heated areas of the equipment. Also, when introducing the seeds into the installation, depending on their nature, humidity and their initial temperature, the differences in air temperature between the inlet and outlet of the drying equipment is expected to increase. From the laboratory experiments, it is expected that the air temperature at the exit from the equipment will not fall below 40ºC, due to the input of energy brought by the microwaves.

Increasing the frequency of the electric current in the converter to 40 Hz, the average velocity of the air inlet in the dryer also increases to 16.54 m/s, when the outside air temperature is 4.4 ºC and humidity 69.3%, (*table 2*). The heating time in this case decreased to 8 min, and the energy consumed decreased to 1.52 kWh, compared to the previous test. It is also observed in this case that as the temperature increases, the air humidity decreases. At the end of the 8 minutes of testing the drying equipment, the air temperature at the inlet stabilizes at 44.9ºC, and at the exit from the drying equipment does not exceed 39.3 ºC.

By increasing the frequency to 50 Hz, the average velocity of the air entering the dryer reaches 18.07 m/s, at a humidity of 77.2% and an inlet air temperature of 5ºC, and the energy consumed to 2.58 kWh, after 9 minutes of operation. At this velocity, the inlet temperature in the dryer stabilizes at 38.2 ºC, and at the outlet from the dryer it reaches 34.7 ºC.

Table 1

Technological parameters for seedless operation of the drying equipment at velocity of 11.55 m/s

Inlet in the drying equipment		Outlet from the drying equipment	
Air temperature ºC	Air humidity %RH	Air temperature ºC	Air humidity %RH
8.5	58.8	9.2	54.3
15.4	41.9	14.3	39.2
20.6	30.5	19.6	27.3
24.9	23.0	23.5	20.5
27.4	19.6	26.4	16.1
31.8	14.2	30.1	13.4
35.6	9.9	33.4	9.3
39.4	7.9	38.3	7.7
45.3	5.8	44.8	5.7
50.4	4.5	45.9	4.1

Table 2

Technological parameters for seedless operation of the drying equipment at velocity of 16.54 m/s

Inlet in the drying equipment		Outlet from the drying equipment	
Air temperature ºC	Air humidity %RH	Air temperature ºC	Air humidity %RH
9.1	60	9.2	54
18.5	32.9	11.3	45.7
23.1	24.2	13.6	40.2
27.9	17.3	17.4	31.3
30.3	13.8	22.1	22.7
34.8	9.7	23.5	21.2
40.1	8.1	28.3	17.2
44.9	5.7	39.3	6.8

During the tests of the innovative equipment hybrid drying, of cereal seeds, it was found that when the external humidity of the external air entering the dryer increases, the electricity consumption also increases. Of course, this energy consumption in operation is determined by several factors, which determine a synergistic effect in the energy balance.

By comparing the three test variants, it can be found that the optimal variant is at the velocity of air inlet in the dryer of 16.54 m/s, a velocity that offers the possibility of pneumatic transportation of cereal seeds in the installation without destroying them, with a minimum electricity consumption in seedless operation of the drying equipment of 1.52 kWh. Also, at this velocity the temperature in the dryer is sufficient to maintain the seeds at a temperature not exceeding 50ºC, taking into account that these seeds will receive an energy supply for final drying from the antennas that generate high frequency currents.

CONCLUSIONS

The testing of the innovative hybrid drying equipment of cereal seeds, is an important stage, because it precisely establishes the technological parameters to be adjusted in the cereal drying process, so that the energy consumption is as low as possible.

Research carried out in seedless testing of the equipment for three different frequencies to provide average pneumatic seed transport velocities (11.55 m/s, 16.54 m/s, 18.07 m/s) led to an air velocity of 16.54 m/s, at which the energy consumption is minimal, of 1.52 kWh.

As the average pneumatic transport velocity of the seeds increases, the final temperatures in the equipment stabilize faster, but at lower temperatures below 35ºC, while there is also the risk of mechanically damaging the seeds during transport.

According to the research, it turns out that at the average pneumatic transport velocity of 16.54 m/s, after a period of 8 minutes the air temperature at the inlet stabilizes at 44.9ºC and a humidity of 5.7%, and at the outlet from the equipment drying temperature does not exceed 39.3ºC with a humidity of 6.8%.

ACKNOWLEGMENTS

This work was supported by a grant of the Romanian Ministry of Education and Research, project number CNCS/CCCDI-UEFISCDI, project number PN-III-P2-2.1-PED-2019-3001, within PNCDI III, contract no. 378PED/2020. Thanks for all your support.

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