RESEARCH ON THE EFFICIENCY OF AERATION PROCESS AND ENERGY CONSUMPTION IN A VERTICAL SILO

Petru Marian CÂRLESCU[1], Marius Mihai BĂETU [1,2], Alexandru Sorin TUDORAN[1], Nelu STAMATE[2]

e-mail: pcarlescu@uaiasi.ro

Abstract

The objective of this study was to examine the efficiency of the grain aeration process in a vertical silo and the energy consumption required for aeration. Aeration of cereal seed for long-term storage is a widely used method in agriculture. By understanding the aeration process and the physical problems that arise from it, the results indicate that by eliminating factors that lead to inadequate aeration and introducing an automation system, significant savings in aeration energy consumption can be achieved. In addition to this energy advantage, the cereal seeds are maintained in quality parameters for a longer time, avoiding weight loss. Comparing the experimental results of energy consumption in a vertical silo and the time needed for aeration with other energy consumption in the world, a reduction can be observed by introducing automation and preconditioning of the grain before it is placed in the silo. Also, by automating the aeration of silos, excess aeration is avoided due to the need to remove excess moisture from the seeds and high temperature kernels formed in the silo.
Key words: (aeration, cereal, silo, energy consumption)

According to the latest data from the World Food and Agriculture Organization (FAO) in 2022, cereal production increased by 0.7% from last year to 2.796 million tons. The annual global analysis shows that cereal production is on an upward trend (https://www.fao.org/worldfoodsituation/csdb/en/). Consumption and storage data also track production data in a similar way, and the latest FAO data shows that about one third of cereals produced are stored. As production and consumption follow each other in similar quantities, it becomes very important that stored cereals are kept in appropriate conditions, without loss of quantity, quality with minimum energy consumption required for storage. On the other hand, the development of agricultural technologies has reduced the time between harvesting and storage of cereals from a few weeks to a few hours. In this case, seeds may need to be dried and cooled depending on climatic conditions. Another problem is when grain is transported and stored again for long and even intercontinental transport under varying temperature and humidity conditions. In this case, because the cereals are exposed to conditions very different from ideal storage conditions, the nutrient and moisture balance may be disturbed. Although moisture content of 12-14% (wet basis) for cereal grains has been considered the optimal condition for long-term storage, it has been found that harvesting at this desired value has been difficult due to the sudden change in climatic conditions in temperate zones, leading to the development of aeration and cooling drying strategies for subsequent management of stored grains (Navarro S., 2022). Each abiotic (temperature, humidity and airflow) and biotic (grain, insects, fungi and bacteria) component interacts continuously in grain storage silos. Also, the external impact of changing climatic conditions, storage structure design, aeration system design, proper evaluation of seed mass in long-term storage and energy consumption have become important research topics in grain storage (Tefera 2011; Magan 2007; Jayas 2003). Increasing silo storage capacities of cereal grains have required the introduction of computerized platforms to collect energy consumption data and temperature, humidity parameters in and outside silos to manage storage by maintaining temperature, moisture content, airflow and keeping insect populations and pest development in silos under control (Singh 2017; Maier 1999).

This paper aims to study the aeration process of corn seed, the major factors influencing it and to determine the energy consumption of silo aeration by monitoring temperature, humidity and power parameters over a month.

[1] Iasi University of Life Sciences, Romania
[2] TOPZONE SRL, Ovidiu, Romania

MATERIAL AND METHOD

The research studied aeration and energy consumption with aeration in a silo filled with about 211 tons of corn. The silo is vertical with a conical bottom having a ventilation system positioned at the bottom of the silo, and three outlets positioned at an angle of 120º on the silo roof. The fan for the aeration system has a motor with an installed power of 70 kW, and the air distribution required for aeration is evenly distributed at the bottom under the perforated truncated conical bottom. Monitoring of temperature parameters inside the corn silo, humidity and temperature of the air outside the silo, as well as the active motor power of the aeration fan was carried out during March 2023. All sensors were previously calibrated so that measurement error of the parameters was excluded. The automation system of the aeration system at the vertical silo consists of the frequency converter connected to the fan motor, to the electrical network and to a PLC controller. The controller is connected to the temperature transducer system inside the silo as well as to the temperature and humidity transducers at the weather station near the silo. With the software, all the components of the automation system work in such a way that the aeration fan starts and stops automatically. The start and stop time is set in the program when the temperature difference between the corn and the environment is at least 8 ºC and the outside air humidity does not exceed 75%.

RESULTS AND DISCUSSIONS

The temperature evolution inside the corn silo was monitored using 18 temperature sensors placed on the height of the silo (Fig. 1). Analysis of corn temperature variation shows at least three periods of rise and fall. The increase in temperature is explained as a result of corn seed metabolism and partly as a result of an increase in temperature in the environment outside the silo. In the first period the corn temperature increased on average between 7 and 9.5 ºC, then decreased on average between 5.5 and 6.5 ºC. In the second period the temperature increased from 5.5 and 6.5 ºC to an average value between 8 and 9.3 ºC, and in the last period the average temperature reached values between 8 and 9.8 ºC, and then decreased to average values between 5 and 6.6 ºC.

The evolution of temperature and air humidity recorded by the weather station near the corn silo shows a variation between -2.8 and 25.8 ºC, with a monthly average of 8.2 ºC, and air humidity varies between 17.3 and 96.3%, with a monthly average of 74.1% (Fig. 2). The correlation between humidity and air temperature is in agreement with theoretical models showing that humidity decreases with increasing temperature and vice versa. Therefore, following the average variation of air temperature shows that it increases twice over 11.2 ºC, thus insufficient to correlate with the increase of the temperature inside the corn seed. Taking this into account it follows that the increase in corn temperature is partly influenced by the increase in environmental temperature. The determination of the outside air temperature is useful to the automation system, and the implemented program makes the temperature difference with the corn in the silo, so that when a difference of more than 8ºC is reached between the corn and the outside air, the silo aeration starts. Humidity determination is the second condition that determines whether the aeration system starts or stops, so when the humidity of the outside air exceeds 75%, the aeration system stops automatically by switching off the power supply to the fan motor.

Monitoring of the active power drawn from the electrical grid by the fan motor was performed for the corn silo aeration system in March 2023 (Fig. 3).

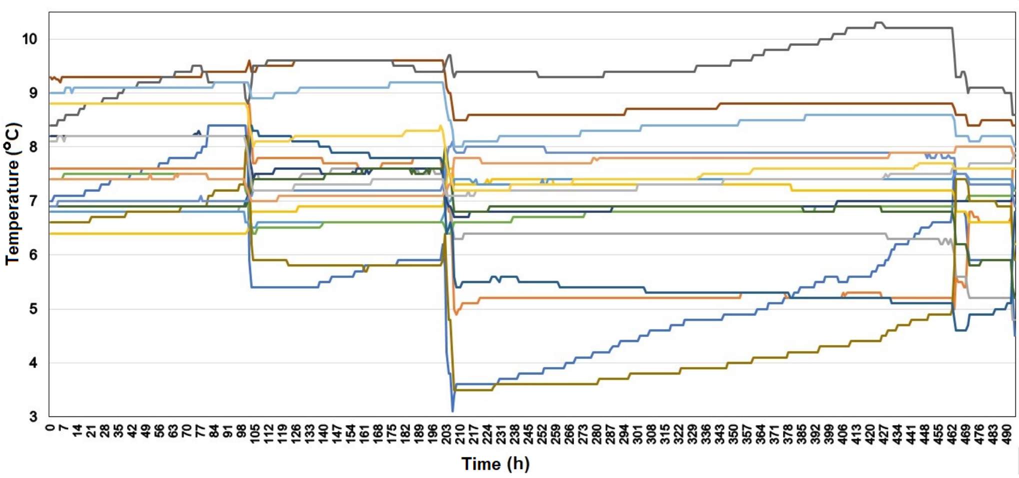

Figure 1 **Temperature variation of grain in the silo**

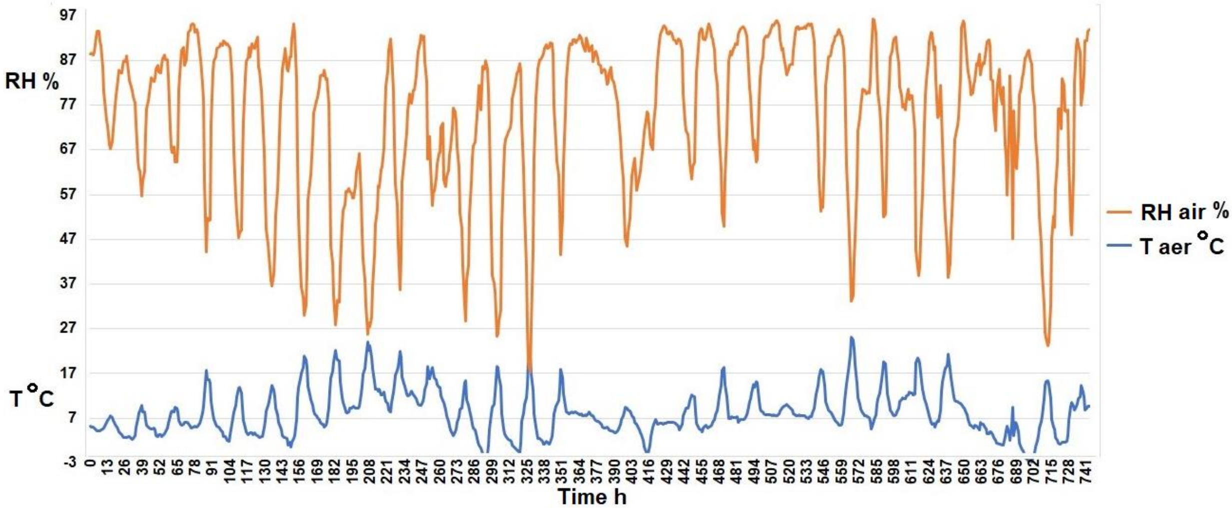

Figure 2 **Variation of humidity and air temperature outside the silo** (March 2023)

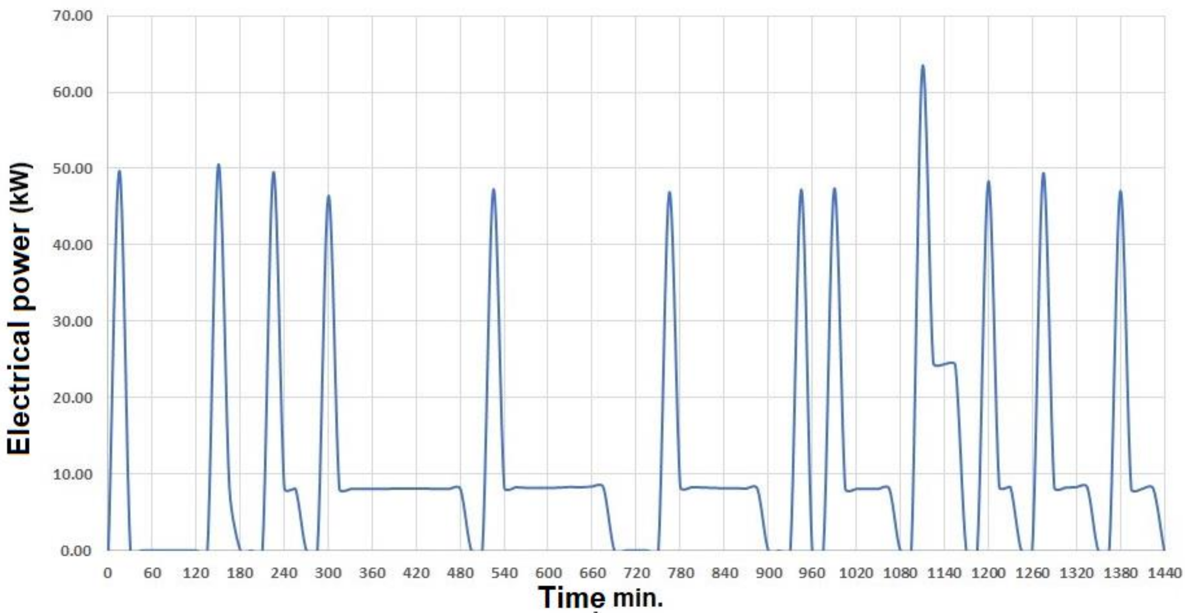

Figure 3 **Electrical power recorded at silo aeration process**

From the graph, the on and off periods of the ventilation system can be seen, identifying three longer periods of ventilation, six medium periods and three short periods of fan motor operation. During the longer periods of operation of the aeration system, a higher active power absorbed from the grid at fan start-up is observed. These starts and stops are controlled by the automation system, depending on the temperature parameter of the corn, so if it increases by more than 8 ⁰C the fan starts aeration, and if in the meantime the outside humidity exceeds 75% it stops aeration in order not to introduce moisture from the air into the stored corn mass. In the three short periods of operation of the ventilation system, the ambient humidity was above 75% therefore aeration was stopped even if the temperature difference was more than 8 ⁰C, it was resumed as soon as the ambient humidity decreased to reduce the temperature difference between the corn and the medium below 8 ⁰C.

The energy consumption when aerating the corn silo is calculated by integrating the evolution of active power with time in Figure 3. Thus, the energy consumption when operating the power system is 263.5 kWh for one month, and if the stand-by operation of the system is also considered it increases to 283.6 kWh per month. Knowing the quantity of corn stored in the silo in March, which was 210.74 tons, this gives a specific consumption of 1.346 kWh/t of corn.

The specific consumption for the aeration system, which keeps the corn within normal storage parameters, is lower than the values obtained for other aeration systems, which give values between 2 and 4 kWh/t. This specific consumption also depends very much on the type of seed stored, its degree of impurity, the temperature and humidity at which it is introduced into the silo, the conditions outside the silo, the process automation system, the way air is distributed to the lower part of the silo, etc.

CONCLUSIONS

Management of the aeration system and monitoring of temperature and humidity parameters are essential components for successful long-term grain storage. The benefits of grain aeration allow harvesting to start earlier to prevent field losses and bring grain to safe temperature and moisture levels. Aeration is used to manage grain in the silo, maintain quality and minimize damage from storage pests. The advantages of the vertical silo aeration automation process is that it keeps the stored corn grain within technological parameters, and the specific energy consumption has been reduced to 1.346 kWh/t of corn, lower than the average obtained with other silo aeration systems.

ACKNOWLEGMENTS

This research is co-financed by the European Fund for Regional Development through the Competitiveness Operational Program 2014 – 2020, project "Establishment and implementation of partnerships for the transfer of knowledge between the Iasi Research Institute for Agriculture and Environment and the agricultural business environment", acronym "AGRIECOTEC", SMIS code 119611.

REFERENCES

htps://www.fao.org/worldfoodsituation/csdb/en/.

Jayas, DS; WNDG. 2003 - *Storage and Drying of Grain in Canada: Low Cost Approaches. Food Control. 14:255–261*.

Magan, N; AD. 2007. - *Post-Harvest Control Strategies: Minimizing Mycotoxins i. Food Chain. Int. J. Food Microbiol. 119:131–139.*

Maier, DE; MMD. 1999. - *Modeling Aeration and Storage Management Strategies Previous Approaches to Modeling the Stored Grain Ecosystem. Proceedings of the 7th Internatonal Working Conference on Stored-product Protection. 2:1279–1300.*

Navarro S., NR. 2022- *The mechanics and physics of modern grain aeration management. RC Press*.

Singh, CB; FJM. 2017. - *Recent Developments in Stored Grain Sensors, Monitoring and Management Technology. IEEE Instrum. Meas. Mag. 20:32–5.*

Tefera, T; KF; DGH; HJ; MS; KS; BY; BPM; SB; BM. 2011. - *The Metal Silo: An Effective Grain Storage Technology for Reducing Post-Harvest Insect and Pathogen Losses in Maize While Improving Smallholder Farmers'Food Security in Developing Countries. Crop Prot. 30:240–245.*