EXPERIMENTAL STUDY OF VACUUM DRYING SEEDS OF GRAIN CROPS

Prof. Doc. Eng. Adamchuk V., PhD., Doc. Eng. Shvidia V.

National Scientific Centre, “Institute for Agricultural Engineering and Electrification”,
11, Vokzalna Str., Glevaкha – 1, Vasylkiv District, Kiev Region, 08631, Ukraine

Abstract: *The article is devoted to the problem of drying seeds without their thermal injury by applying vacuum technology. In this paper work presents experimental studies of vacuum drying of seeds of grain crops on the example of maize seeds, during which the safe drying regimes were studied, in which the most intense water separation occurs. It has been found that by heating the batch of seeds to 30° C and subsequent evacuation to a pressure of 4 kPa with bubbling under atmospheric pressure is most intense dehumidification at a rate of 0.259%/min.*

KEYWORDS: *VACUUM DRYING, RESIDUAL PRESSURE, SEEDS,* HEAT, *TEMPERATURE OF HEATING SEEDS,* DEHUMIDIFICATION, *DRYING MODE.*

1. Introduction

Modern technologies for drying seeds use heating, as the process of moisture transfer from the inner layers of the seed to the external layers is intensified, as is the evaporation of moisture from the surface. As a rule, the heating of seeds occurs through the action of a temperature field with an amplitude value of about 80 ° C, which results in individual seeds before the biochemical processes that cause a change in their structure and chemical composition. But in the same time, due to the difference in the properties of individual seeds, the thermal diffusivity of the seed layer has a nonlinear character, which contributes to the uneven drying and, as a consequence, to the under-drying of individual layers of the seed mass.

To reduce the thermal injury and increase the germination of seeds it is necessary to limit the influence of temperature or even prevent it, and to ensure uniform drying of all seeds. These conditions are satisfied by the technology of drying seeds using vacuum. With this technology, the moisture from the seeds is removed by reducing the partial pressure of water vapor in the external environment. This technology has proven itself in the food industry [1-5].

Nevertheless, researches of the effect of vacuum drying of seed grains and industrial crops were insignificant, making it impossible to assess the availability of this technology. Therefore, these researches are relevant and necessary for improving the quality of post-harvest seed treatment.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

Researches [6-7] found that for drying without traumatizing seeds, the heating temperature of most seeds of crops should not exceed 40 ° C to 45 ° C.At the same time, the moisture content in one technological cycle of drying does not exceed 5%-6%, since with a larger value of the moisture content, cracks in the seeds are formed [8].It was found that with the increase in the initial moisture content of the seeds, the maximum permissible temperature of seed heating falls [8].To prevent injury to seeds when drying has been proposed to use mild temperature conditions convection drying [9].However, when using soft temperature regimes of presence with undried seeds.At the same time, existing heat generators do not always provide the necessary stable temperature regime.

In [10] it was proposed to reduce the energy consumption for heating and drying the periodic evacuating rapeseed. To smooth the moisture content of the rape seed, a vibrating surface was applied, which adversely affects the quality of the seeds.

Researches [11] found that to increase the intensity of moisture separation, it is necessary, under vacuuming, to apply constant heating of seeds to a temperature close to the permissible temperature.Other researchers propose to use the vacuum-pulse method to increase drying speed [12-13]. However, using these methods could be a risk of thermal injury to the seed.

Existing researches have established critical temperatures for heating and the rate of moisture separation during drying of seeds, but it is not known what regimes of vacuum drying of seeds provide a rapid moisture release at parameters (heating temperature) that are less than permissible.

2.2. Purpose of the research

Search for options of intensive vacuum drying of seeds of grain crops with parameters, it is unacceptable to heat traumatize the seeds.

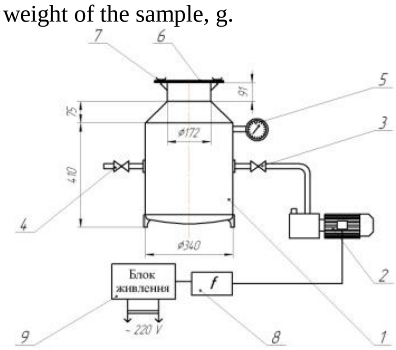
3. Results and discussion

To research the vacuum drying regimes, a simple experimental setup was developed and manufactured, which makes it possible to vacuum the seeds of grain crops to a pressure of 2 kPa (Fig. 1).The seeds were heated by an external heater to a temperature of 30 ° C. Electronic weights and a moisture meter were used to calculate the moisture release and the drying rate.

The drying speed υ_W was calculated using the formula:

$$\upsilon_W = \frac{\Delta m}{m_0 \cdot \tau_E} \cdot 100\%, \qquad (1)$$

where Δm is the change in weight of the sample during drying during exposure time τ_E, g;
m_0 — initial weight of the sample, g.



a

Fig. 1. *– The construction scheme (a) and general view (b) of the experimental plant for the study of vacuum drying of seeds of crops: 1 – vacuum chamber; 2 – rotary vane vacuum pump subzero to the vacuum; 3 – faucet of a vacuum pump; 4 – faucet for throwing down of vacuum; 5 – vacuum-gauge; 6 – cover with gasket; 7 – locking mechanism; 8 – frequency converter; 12 – power supply.*

The object of drying was a sample of maize seeds weighing 490 g and an initial humidity of 20%, which was placed in a vacuum chamber, in which various modes of changing the air pressure were used. The minimum air pressure in the vacuum chamber, which was used in the studies, was 4 kPa.

In direct evacuation weighed corn seeds at a temperature 19 ° C were placed in a vacuum chamber at a pressure of 4 kPa for 75 minutes, after which the pressure was restored to atmospheric pressure (fig. 2).

As a result, the moisture separation and drying rate were calculated, which for corn were approximately equal to 2.6 g and 0.006% / min, respectively.

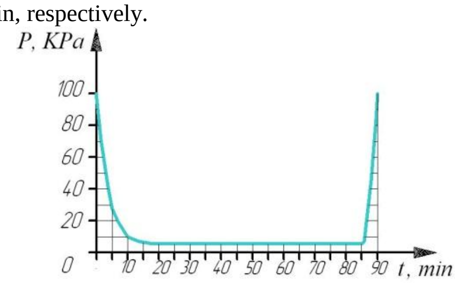
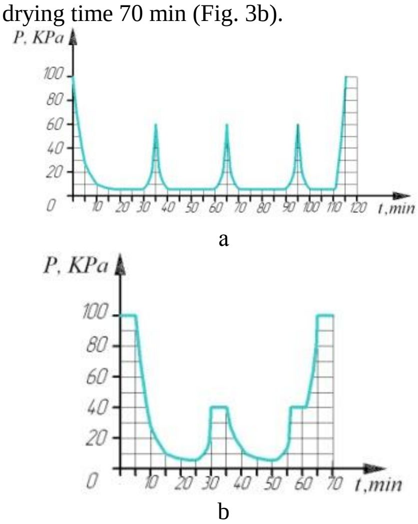


***Fig. 2.** – Change in pressure in the environment during the direct evacuation of grain seeds*

The rate of vacuum drying was significantly lower than convective drying. Since the samples of the seeds were dried in containers, water vapor, which was released during drying, filled the intergranular space in the absence of air movement, which worsened the conditions of moisture separation.Therefore, the sample of corn seeds was filled up in a flat vessel in one layer, while its weight was 190 g. The rate of drying of maize seeds in one layer increased, respectively, to 0.025% / min. The moisture release was 4 g.

For the purpose of determining effect of air movement (blowing) on the drying speed, the regime was used with partial blowing of the seeds and increasing the pressure to 60 KPa — drying time 115 min (Fig. 3a) and a blowdown mode for 10 min at 40 KPa — drying time 70 min (Fig. 3b).



a

b

***Fig. 3.** — The pressure change in the surrounding space by direct evacuation seeds of crops: a — partial blowing mode of seeds and increased pressure to 60 kPa; b — blowdown mode for 10 min at 40 KPa*

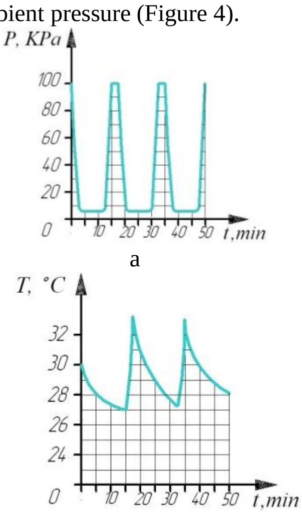
As in the previous regime, we used a sample of maize seeds weighing 490 g, an initial humidity of 20%, and a temperature of 19 ° C.

The following results were obtained: for the regime (Fig.3a) — moisture extraction: 3 g, drying rate: 0.005% / min; for the mode (Fig.3b) — moisture extraction: 6 g, drying speed: 0.017%/min.

The drying speed of the regime (Fig.3a) turned out to be at the direct vacuum level, since during the blowing time, which is a pressure pulse with an amplitude of 60 kPa and a duration of 10 min, the decrease in the concentration of water vapor in the near-grain space is insufficient.When the blowing mode is at a fixed pressure (Fig.3b), the drying speed is half the amount of the direct evacuation mode in one layer, in spite of blowing at constant pressure (40 kPa).

For all the above process modes seed drying in vacuo there was them cooled to 10 ° C. The decrease in temperature during drying is due to the consumption of thermal energy of the seed for the evaporation of water. That is, drying in a vacuum is an adiabatic process.As the pressure in the near-grain space decreases, intense evaporation of moisture from the surface of the seed takes place, and as a consequence, its cooling, which leads to a slowing down of the diffusion of internal moisture outwards.This explains the low drying rate compared to convection. To increase drying speed, periodic heating of the seeds during the drying process is necessary.

To verify these claims, the regime was tested with periodic heating of the seeds to a temperature of 33 ° C, evacuation to a pressure of 4 kPa and blowing for 5 minutes at atmospheric pressure.For this linkage used also maize seeds weighing 490 gr of preliminary heated to a temperature of 30 ° C. The graphs of temperature and ambient pressure (Figure 4).



a

b

***Fig. 4.** – The change in the ambient pressure (a) and the heating temperature of the seeds (b) during the periodic heating and evacuation of seeds of cereals*

In carrying out this mode, dehumidification drying maize seeds was observed in vacuo at 51 g and the drying speed was 0.259%/min, which is significantly higher than in previous modes. This confirmed the allegations put forward earlier. By varying the depth of the vacuum and the temperature of the seed heating, the rate of drying can be adjusted. Since the heating of seeds is carried out below the critical temperature, then the risk of thermal injury is minimal.Therefore, the application of this mode of drying grain seeds is promising. Further studies of this regimen with regard to the influence on the ability to germinate and the growth force of seeds of agricultural crops will improve the quality of seed material and reduce the thermal costs of drying.

4. Conclusions

As a result of experimental researches by vacuum drying of cereal seeds by the example of maize seeds it was found that the most intense dehumidification (drying rate 0.259% / min) without thermal injury observed during batch mode by heating, evacuation and purging at atmospheric pressure. Intensive dehumidification occurs due to compensation of heat losses in evaporation in a vacuum, which maintains a stable diffusion rate.

5. References

1. Gaifullina, R.R. Experimental setup for studying the kinetics of drying capillary-porous materials by vacuum-pulse technology / R.R. Gaifullina, M.S. Kurbangaleev, Z.I. Zaripov, D.A. Anashkin // Bulletin of Kazan. technol. University. - 2011. - T.14, №2. - P.132-137.

2. Dykii N.P. Some features of thermovacuum drying / N.P. Dykii, A.M. Egorov, V.A. Kutovoi, E.P. Medvedev and others //

Questions of atomic science and technology. 2007. № 4. Series: Vacuum, pure materials, superconductors (16) - P. 53-57.

3. Vacuum drying of agricultural products, the effect of different types and drying regimes on energy costs, biological and nutritional value [Text] / V.A. Kutovoi [and other]. - H.: NSC KIPT, 2003. - 23 p.

4. Drouzas A.E. Microwave application in vacuum drying of fruits/A.E. Drouzas, H. Schubert // Journal of Food Engineering.– 1996.– № 28.–P. 203–209.

5. Hu Q.G. Performance evaluation of vacuum microwave drying ofedamame in deep-bed drying / Q.G. Hu, M. Zhang, A.S. Mujumdar, G.N. Xiao,J.C. Sun // Drying Technology.– 2007.– № 25 (4) .– P.731–736.

6. Lichko N.M. The technology of processing of plant products / N.M .Lichko. - Moscow: Kolos, 2008. - 583 p.

7. Musyvov K.M. Technology of storage and processing of plant growing products / K.M. Musyvov, E.A. Gordeeva. - Astana: KazGUU, 2007. - 367 p.

8. Kirpa M. Ya. Heat resistance of seeds of maize hybrids and features of their post-harvest treatment / M. Ya. Kirpa, M.O. Styurko, Yu.S. Basileva // Bulletin of Dnepropetrovsk Agrarian and Economic University - № 3 (37), 2015 - P. 58-63.

9. Kirpa M. Ya. Injury of seeds: how to prevent / M. Ya. Kirpa // Proposition - № 1, 2017 - P. 152-155.

10. Nasikovskiy A. B. Installation for vacuum drying of rape seeds / AB Nasikovskiy // Bulletin of Vinnytsia Polytechnic University - № 4, 2007 - P. 136-139.

11. Kutovoy V.A. Development of the scientific foundations of energy-efficient thermovacuum drying equipment: the author's abstract. dis. ... Doct. tech. Sciences: 05.14.06 "Technical Thermophysics and Industrial Heat Power Engineering" / Kutovoy Vladimir Aleksandrovich - Lvov, 2015. - 42 p.

12. Burtsev S.A. Experimental stand for drying of plant raw materials by vacuum-pulse method / S.A. Burtsev, T.F. Fatykhov // The Bulletin of Kazan. technol. University. - 2017. - T. 20, № 21. - P. 126-128.

13. Gaifullina, R.R. Experimental setup for studying the kinetics of drying capillary-porous materials by vacuum-pulse technology / R.R. Gaifullina, M.S. Kurbangaleev, Z.I. Zaripov, D.A. Anashkin // Bulletin of Kazan. technol. University. - 2011. - T.14, № 2 — P.132-137.