RESEARCH ON THE PHYSICAL CHANGES OF CEREAL SEEDS DRIED IN THE INNOVATIVE EQUIPMENT HYBRID DRYING

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Abstract

Hybrid drying of cereal seeds is a modern drying method. Over time, more research has been carried out in the field of grain drying, moving from convective drying as the commonly used method, to hybrid drying that combines the convective phenomenon with that of thermal conduction or radiation. Current technology offers the possibility of using hybrid methods of drying cereal seeds, which have the advantage of lower energy consumption and shorter drying time compared to the convective drying method. The paper proposes the analysis of the physical changes that occur after the hybrid drying of cereal seeds. The research was carried out by drying cereal seeds on an innovative hybrid drying facility that uses both convection and microwaves. In this sense, the physical changes that occur in corn seeds were studied, through determinations of humidity, changes in color, dimension, as well as changes related to the mechanical resistance of the seeds. The maximum drying temperatures inside the dryer were between 48 and 50 °C, obtained at a maximum microwave power of 2400 W, and a drying time of 3 seconds.

Key words: (seed, hybrid drying, physical parameters)

The quality of cereal seeds depends on their moisture content. Moisture content is an important parameter affecting the quality of stored seeds. It is taken into account in grain quality standards (Tomkiewicz, D., 2009). Too much moisture content causes physical, biochemical and microbiological changes in the seeds. The movement of water in cereal seeds leads to dimensional, mass and color changes. Variation in the rate or path of water movement is affected by seed species (Gegas V.C. *et al*., 2010). Seeds have different shapes, so differences in shape can be substantial depending on type, variety, quality, etc. (Dornez E. *et al.* 2011; Mebatsion H.K. *et al.,* 2012). Seed volume and mass increase during increasing seed moisture and their shape changes (Robert C. *et al*., 2008). The process of moisture growth is an inhomogeneous process (Rathjen J.R. *et al*., 2009). During the drying of cereal seeds, the moisture content decreases and hence the physical changes. Physical changes in cereal seeds during increasing or decreasing moisture content are usually described by changes in mass; volume, density, color and porosity (Blahovec J. *et al.,* 2015). Numerous studies have shown that the physical properties of cereal seeds and seeds of other crops mainly depend on their water content (Horabik J., 2001) and change significantly with it (Kaliniewicz Z. *et al*., 2021). As it follows from scientific publications, the moisture content of seeds affects not only their dimensions, but also the values of the coefficient of external friction, angle of repose and cohesion (Rusinek R. *et al.,* 2006). On the other hand, too low humidity can increase the susceptibility of seeds to mechanical damage, which will lead to a loss (Borkowska B. *et al*., 2018). For this reason, it is necessary to know the physical properties of agricultural seeds in order to predict their quality. In order to obtain a humidity of preservation, the drying operation is used, which can be done by convection, conduction, fluidized bed, microwave or hybrid. All these drying methods lead to physical changes in the cereal seeds, which can have positive aspects, if the operation is properly conducted, or negative if the parameters of the drying process are not properly controlled depending on the type of dried seeds. In this paper, the changes in the physical parameters of corn seeds were investigated, applying hybrid drying.

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MATERIAL AND METHOD

In this study, the physical changes occurring during the drying process were analyzed in corn seeds of the hybrid DKC 5068. The drying was carried out in the innovative equipment hybrid drying with a drying capacity of 500 kg/h and an installed power of microwaves of 2400 W at a frequency of 2.45 Ghz, (*figure 1*).

Figure 1 **The innovative equipment hybrid drying**

The hybrid drying method combines the phenomenon of convection, which drives the moisture from the seeds from the outside to the inside as their temperature increases in the same direction, with microwaves that heat the seeds volumetrically throughout the mass, removing the moisture from the inside to the outside of the seeds. The drying time varies depending on the variety of seeds and their initial moisture. In order to ensure the preservation of corn seeds, the humidity of the seeds must be lower than 14%, so after drying the seeds must not exceed this value. The diagram of the movement of cereal seeds in the innovative equipment hybrid drying, (*figure 2)*.

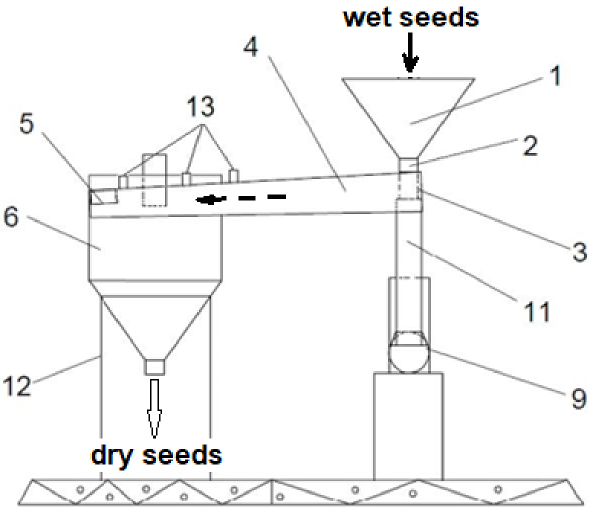

Figure 2 **Scheme of the hybrid dryer and the movement of the seeds in the dryer**

(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 hot air pipe; 12 support brackets; 13 antennas)

Hybrid drying and the determination of the physical changes that occur during drying in the corn seeds, follow moisture, color, size and hardness as a texture parameter.

Moisture varies with the amount of water in the seed, the distribution of water in the grain structure, and the type of seed.

Color change is another parameter that shows changes during the drying process, this is due to the pigments in the upper layers of the seeds, which by removing moisture change their color.

Changing the size of cereal seeds. This is due to the shrinkage that occurs in the seeds with the loss of moisture in the drying process. When the drying process is conducted properly, low drying temperatures and lower humidity of the seeds, the contraction phenomenon does not affect the quality of the seeds. If the amount of moisture lost by the seeds during drying is too high in a short time, and the drying is carried out at high temperatures (85-100ºC), there is a risk of the appearance of micro-cracks on the surface of the seeds, which can propagate inside them.

By losing moisture, the texture of the seeds also changes. A texture parameter analyzed in the paper is seed hardness, which increases with decreasing moisture in the drying process.

The experimental method was the following: the preparation of a quantity of 500 kg of clean corn seeds, which was previously subjected to cleaning and sorting processes; random sampling of 10 samples of 300 grams each from the wet seed mass, and the same number of samples from the dry seed mass, for determination of initial physical characteristics (moisture, color, size, hardness); drying the seeds in the hybrid drying equipment with an average temperature of the pneumatic seed conveying hot air of 42.1ºC and a microwave power of 2400 W which was given to the seeds in pulses of 4 seconds and pause of 1.5 seconds; taking an equal number of samples from the dried seeds, resulting at the end of the process.

To determine the physical changes obtained in the drying process, the following laboratory equipment was used: the Agreto GFM+ electronic moisture meter (humidity range 5-40%, accuracy +/-0.5%, humidity resolution 0.1%), the thermobalance AGS200 (accuracy +/-0.3%, humidity resolution 0.01%), color analyzer RGB-2000 (10 bits), texturometer (0-1000N, resolution 0.2N). Also, to determine the dimensional changes (surface), a photometric system using a camera and a specific software was used.

The moisture content of the corn seeds both before drying and after the drying process was determined both with the help of the electronic moisture meter and with the help of the thermobalance to increase the accuracy of the determinations.

The color changes of the seeds during the drying process are carried out with the help of the 10-bit RGB-2000 color analyzer, where for each color space (R red color; G green color; B blue color) 1024 different shades can be highlighted.

The changes in the hardness of the seeds in the drying process are measured with the help of the texturometer, determining the force resulting from the compression tests of the corn seeds, before and after the drying process.

RESULTS AND DISCUSSIONS

The results of the physical changes of the corn seeds obtained after drying with the innovative equipment hybrid drying for the 10 samples before and after drying, (*table 1)*. The experimental determinations of the 10 randomly selected corn seed samples from the mass of 50 kg, before drying, were subjected to the determination of the physical characteristics of moisture, size, color and hardness. Seed moisture was determined with both the hygrometer and the electronic thermobalance for the 10 samples, and the resulting average differences were 0.2%. Taking into account that the precision of the thermobalance is higher, and the humidity indication is with two decimal places, the experimentally processed values, (*table 1*). After drying, 10 samples of corn seeds were randomly selected, from the resulting mass after drying, to determine the characteristics physical properties of moisture, size, color and hardness. The dimensional determinations of wet and dry corn seeds were made by photographing 20 seeds from each sample, for which the area was determined, using the ImageJ software. The average value of the area obtained for the 20 seeds represents the size for a sample.

Table 1

Physical changes in maize seeds subjected to drying

No. sample	wb_i (%)	wb_f (%)	A_i (mm^2)	A_f (mm^2)	F_i (N)	F_f (N)	ΔE
1	16.07	13.69	56.95	51.54	314.73	536.35	0.57
2	16.18	13.42	58.53	53.97	341,38	556.81	0.68
3	16.31	13.78	55.37	49.55	309.16	523.13	0.43
4	16.56	13.45	56.16	50.88	384.22	561.01	0.26
5	15.98	13.81	58.19	54.19	352.29	523.34	0.32
6	16.28	12.88	57.23	53.12	332.41	529.96	0.16
7	16.72	13.01	55.71	51.22	343.31	546.16	0.44
8	16.42	13.29	56.31	51.01	327.98	539.12	0.38
9	16.25	13.47	55.82	50.55	312.12	519.32	0.29
10	16.48	12.96	57.35	51.78	326.11	544.02	0.19
x_{med}	**16.32**	**13.37**	**57.76**	**51.78**	**334.37**	**537.92**	**0.37**
s	**0.22**	**0.33**	**1.06**	**1.51**	**22.52**	**14.29**	**0.16**
CV (%)	**1.38**	**2.52**	**1.88**	**2.92**	**6.73**	**2.65**	**44.09**

Color determinations for wet and dry seeds were made by selecting a number of 10 seeds from each sample for which the color parameters were determined, later making an average for each individual sample. The color change was achieved by the difference obtained in wet and dry seeds.

Hardness determinations for both wet and dry corn kernels consisted of selecting 10 kernels from each sample, which were subjected to compressive stresses using the texturometer. The maximum force at which the seeds crack is their hardness. The experimental value for a sample represents the average compression force obtained from the 10 seeds tested with the texturometer.

From the analysis of the data obtained for the initial moisture of the corn seeds subjected to hybrid drying, of the 10 samples subjected to the study, the calculation of the deviation *s* and the coefficient of variation *CV* was made. The standard deviation of the mean, or deviation *s*, shows the degree of error loading of the mean, indicating the limits between which the true mean lies, which in the case of wet seed moisture is +/-0.22%. The coefficient of variation which represents the measure of the variability of the initial moisture of the corn seed samples is 1.38 %. It is estimated that the variability of the initial moisture data of corn seeds is small, since the percentage is less than 10%.

The data obtained for the moisture of corn seed after drying show a deviation of +/-0.33% from the mean, which shows that the standard deviation of the mean is slightly higher than for wet seed. The coefficient of variation obtained for the dry seed sample data has a value of 2.52%, this shows a small variability. By comparison, the initial and final moisture data obtained after drying show a greater inhomogeneity of the dried seeds in terms of moisture. But nevertheless, it can be said that, all values are lower than 14%, which is the upper limit of storage moisture.

The data obtained for size represent the average value of the area in mm^2, which in the case of wet corn seed samples have a deviation of +/-1.06 mm^2 from the average, and the coefficient of variation is 1.88%. The resulting coefficient of variation shows a small variability that falls below 10%. The data obtained for the size of the dry seed samples have a deviation of +/-1.51 mm^2 from the mean, and the coefficient of variation is 2.92%. From the analysis, a greater dimensional variability is observed in dry seeds compared to wet seeds.

From the analysis of the hardness data of the wet corn seed samples, it is observed that the values of the maximum compression forces from which the first cracks in the seeds appear have a deviation of +/-22.52N from the average, and the coefficient of variation is 6.73%, indicating low variability. For dry seeds, the deviation value is +/-14.29N from the mean, and the coefficient of variation is 2.65%, indicating little variability. By comparing the values obtained for hardness between wet and dry seeds, a greater deviation and coefficient of variability is observed for wet seeds compared to dry ones, explained by the fact that wet seeds are softer and the dispersion of values is greater, and for dry seeds these parameters decrease a lot with decreasing humidity, the values of the samples becoming more homogeneous.

Color variations between wet and dry corn seeds are shown as averages for the 10 samples, thus the deviation is +/-0.16 and the coefficient of variation 44.09%. This indicates high data variability, as the coefficient of variation is greater than 20%. The high variability in color differences between wet and dry corn seeds obtained in the 10 samples may have several causes, and research should be continued to establish the factors that determine this variation.

Analyzing the data of the physical characteristics, obtained before and after drying the corn seeds, it can be said that from the point of view of moisture, the wet seeds are more homogeneous than the dry ones, while from the point of view of hardness, the wet seeds are less homogeneous than dry ones. Dimensionally, wet seeds are more homogeneous than dry ones, a fact also explained by the different contractions of the seeds during drying, average contractions reaching 10% of the initial size. Color variation of maize seeds before and after drying did not give conclusive results.

CONCLUSIONS

Physical changes occurring in corn seeds by drying in an innovative equipment hybrid drying are evaluated from the point of view of variation in moisture, size, hardness and color.

The initial moisture of the corn seeds has an average of 16.32%, indicating a homogeneity of determinations throughout the mass of corn to be dried. The average humidity after drying the seeds is 13.37%, humidity that falls below the conservation limit of 14%, and the homogeneity of the data is reduced due to structural changes in the drying process.

Dimensionally, the wet seeds have an average surface of $57.76 mm^2$, and the experimental determinations indicate a greater homogeneity of the wet seeds, compared to the dry ones, where the homogeneity of the determinations is lower, due to the contractions that occur through drying, contractions that on average reach 10%.

The hardness of the wet seeds, expressed in the maximum compression force up to which cracks appear in the seeds, has an average value of 334.37 N, and a lower homogeneity of the data of the 10 samples, compared to the values obtained for the dry seeds. This fact is explained by the fact that the wet seeds are softer and the maximum forces vary over a larger range, because the seeds also go through an elastoplastic phase before they end up cracking.

The color variation of the corn seeds before and after drying for the samples taken in the analysis did not give conclusive results.

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