ABSTRACT

The cereal and technical plant seeds are basic elements in nutrition, due to their content rich in proteins, lipids, carbohydrates, minerals, their consumption being beneficial to health.

Because of the humidity that the agricultural seeds have after the harvest, their perishability is very big or medium, so, they may be used only after the dehydration, an advantageous method of conservation of agricultural seeds for longer periods of time.

The drying objective is the humidity decrease of the seed mass, up to a balanced or critical one, at which the storage may be possible for long time, without losses.

The phenomena that take place due to the physiological processes running during the storage, with different intensities, mostly unwanted and with particularly serious consequences, are caused by the too high humidity of the stored seeds.

There are many systems of seed storing, but the storage in dried state is actually the most largely used one, regardless the destination, because in these conditions the physiological processes are running at an extremely little intensity and the microorganisms do not find growing conditions, the system thus being efficient and economical.

The working process for the controlled drying of the agricultural seeds proved to be benefical for the possibility of storing and using them for long periods of time, as long as there are solutions for technical installations for seed drying, with superior output and which can preserve the nutritive and sensory properties.

One can prove that by using relatively simple equipments, the drying process may be managed so that the finite products should be of best quality and the costs as low as possible.

Many authors of different researches have stated that the drying agent temperature, its velocity and humidity have the greatest influence on the drying process.

In the same direction are presented the researches carried out in this doctoral thesis, entitled **”Researches regarding the optimization of the working process for cereal and technical plant seed drying”**, in which the author plans to analyse the present level of knowledge and technical achievement in the domain of agricultural seed conservation, by drying, and to study more variants for the working process optimization, that could be applied for getting finite products of superior quality.

The doctoral thesis content has 319 pages and is structured in 9 chapters, including 109 figures, 111 tables, 67 mathematical equations and 172 bibliographic titles.

In **chapter I**, entitled "*General aspects regarding cereal and technical plant cultivation*", there are some considerations concerning the importance of cereal and technical plant seeds in human nutrition and the presentation of the physical and chemical characteristics of some types of agricultural seeds, such as wheat, barley, corn, sunflower seeds, which were the subject of the experimental researches.

Cereals are grass plants cultivated on the largest agricultural areas in the world. They are particularly important in both human and domestic animal nutrition.

The cereal grains represent the basic food for almost the whole population of the world, these being used under different forms, grinded and prepared as bread, semolina, pasta, polenta etc, or boiled and consumed as such.

Under the form of whole grains or grinded, as green plants, dried or silage, as secondary products (straw, chaff or corn stalks) and sub products (bran), the cereals are used in feeding all species of animals raised by man.

The cereal grains are used as raw material for some industries such as those of spirits, alcohol, starch, beer, dextrose, glucose etc, and straw is used as raw material in the cellulose and paper industry.

There are also remarks referring to the volumetric mass, the specific heat, the water content, elements necessary to the qualitative appreciation of their conservation by drying for some categories of seeds.

Chapter II, entitled "*The present knowledge stage in the domain of technologies and machines for agricultural plant seed drying*", includes several important parts. In the first subchapter are discussed the importance of the cereal and technical plant seed drying, the physiological processes in the seed mass and the physico - mechanical properties of the seeds in the drying process.

The quality evaluation clues for the artificial drying are: drying in short time and with no grain degradation, reduced energy consumption, unchanged chemical composition of the seeds, well-preserved seed purity and germination power. For having all these, one must take into account the thermal agent temperature and that of the grain heating, the exposure time, the drying method and the choice of the adequate type of installation.

The humidity extraction from the seeds during their passing inside the dryer cannot exceed a certain limit without affecting their quality, and between two exposures of the seeds through the dryer it is required to take a break for a redistribution of the humidity inside the seed.

The artificial drying is the safest means of seed drying, but it supposes a big energy consumption and greater injury of seeds by cracking or breaking, because of the big internal tensions occurring during the drying process. To avoid these inconvenients it is required a gradual drying by means of some complexe installations, in which the thermal regime is automatically controlled according to the type of the seeds, to their humidity and to the drying agent parameters.

The chapter continues with some remarks on the present technologies and on the tendencies regarding new machines and equipments for agricultural seed drying.

Chapter III, "*Studies and researches regarding the working process for agricultural plant seed drying*", presents some aspects related to the modalities of heat and mass transfer, which is done by thermal conduction, thermal convection and thermal radiation.

The heat transfer respects two principles of the thermodynamics: the first one expresses the law of the thermal energy conservation in the transfer processes and the second expresses the fact that the heat transfer is always carried out from a higher temperature to a lower one.

The mechanism of heat transfer by conduction consists of the energy transfer from areas with high temperature to those with low temperatures. This energy transfer is produced mainly through contact (little by little) with the adjacent material and there is no physical movement from one place to another. The thermal conductivity is a property of bodies which depends on their nature, temperature, humidity and pressure.

The thermal convection refers to the heat transmission between a fluid moving and a solid body, under the action of a temperature difference between the fluid and the solid body. The process is carried out by the simultaneous action of the conduction in the fluid layer from the close proximity of the limit (the limit layer) and the proper convection, which implies the mixing of the fluid particles.

The thermal radiation represents the process of heat transmission between bodies at distance, without direct contact. The thermal radiation is the result of the transformation of the internal energy of the bodies into electromagnetic wave energy, that spreads in space with wavelengths between λ = 0,7 μm and λ = 400 μm, corresponding to the domain of visible infrared and ultraviolet rays.

In **Chapter IV,** entitled ”*The aim and the objectives of the doctoral thesis*”, there is a short synthesis of the previous chapters, from which results the idea that the subject of the doctoral thesis is of great actuality.

The subject of the thesis was chosen analysing the fact that after the harvest, the cereal and technical plant seeds have a moisture content that causes a reduced stability of these products, favoring the microbiological and enzymatic activity and the hydrolysis reactions in the interior of the products.

The agricultural seeds are thermosensitive products, and during the drying process suffer some modifications: the protein content decrease, the germination alteration, color changes, volume modifications, the appearance of some nonspecific flavors, the reduction of some nutritive components etc. The drying process is based on knowing the chemical composition of the products and of the specific particularities concerning their transformations during the processing.

It is specified that the main objective of the doctoral thesis refers to the optimization of the working process for cereal and technical plant seed drying.

In order to reach this objective, other secondary objectives were carried out, such as:

- the analysis of the present stage in the domain of theoretical researches and practical achievements regarding the cereal and technical plant seed drying;
- the analysis of the present stage regarding the construction of driers for agricultural seeds;
- the analysis of the technical and functional parameters of the driers and of their influence on the energy parameters of the process;
- the project and the construction of the installation for laboratory drying, provided with two boxes, a parallelepipedal one according to the conventional technology and a cylindrical one with an interior conical deflector for getting a uniform flow of the drying agent;
- the determination of the maximum level of the temperature and its

influence on the conservation of the nutritive qualities of the seeds at a constant drying regime;

- the determination of the drying regime influence on the germination power of seeds after the drying, pointing out the effects;
- the selection of the equipments for the experimental investigation;
- the selection of the biological material;
- the mathematical simulation of the drying process.

For the mathematical modeling of the conservation process through agricultural seed drying and the simulation of the drying process were used the real values obtained by measuring the parameters specific to the drying process by means of the drying installation used during the experimental researches. The analysis of the kinetics of the seed drying process and of the qualitative indexes of the samples obtained made possible the determination of the optimal drying regime.

Chapter V, "Material *and method*", largely presents the biological material and the working methods used, as well as the steps in the construction of the installation for agricultural seed dehydration in laboratory conditions. The biological material used in the experiments consisted in wheat, barley, corn and sunflower seeds.

The experimental researches were done in a period of two years. They took place in the laboratory with machines for food industry inside the group of disciplines with profile of agriculture mechanization in USAMV Iași.

The raw material used, respectively wheat, barley, corn and sunflower seeds were collected each of them at four stages of ripeness, having different humidity levels, from the fields cultivated by an agricultural company in Neamț county, specialized in vegetal production.

The experiments regarding the product drying were done by means of the laboratory installation for drying agricultural products. The installation permits the control and the monitoring of the drying process parameters, that can be chosen by the user before or during the drying program.

At present, throughout the world, for drying the agricultural plants, are used vertical and horizontal dryers with a continuous and discontinuous functioning, based on dehydration through convection, the heat being transmitted from the drying agent to the product, by convection.

As drying agents are used the warm air, flue gases, the superheated steam etc.

All these dryers do not solve the problem of the uniform flow of the drying agent. For example at the vertical dryers existing in the whole world, the type with concentric perforated cylinders (the seeds submitted to drying move through the space generated by the two concentric bodies), the drying is more intense towards the end of the mixing chamber of the drying agent.

In order to eliminate this inconvenient, a device was designed for equalizing the parameters of the drying agent, the type with tapered plates based on Coandă effect and which permits a uniform spreading of the warm air in the product mass to be dried.

The device with tapered plates for directing the drying agent, was conceived by simulation, calculations of fluid dynamics (CFD), after which adjustments for optimal layout have been done in order to obtain an equal profile of velocity and temperature all over the interior surface of the perforated cylinder in which it is included, regardless the porosity of the seed layer.

The aim of the invention is to solve the problem of uniform drying of the product layer in the drier by conceiving a method and a device that should permit the uniform flow of the fluid.

According to the invention, the procedure consists of a uniform distribution of the drying agent in the whole mass of the product, by creating a profile of constant and equal velocity in each circular section of the seed layer to be dried.

For the evaluation of the cereal and technical plant seeds to be dried, the following methods were used:

- the oven - drying method, according to the methodology in Annex 4 of the Agriculture Ministry Order 70/2006;
- the method of the cereal humidity determination with the analytical thermo balance MAC, by means of which one can do the humidity analyses, getting results directly in percentage;
- the Kjeldahl method for the determination of the protein content;
- the method of moist gluten determination for wheat (SR EN ISO 21415-2, 2008);
- the method of the deformation index determination for wheat (STAS 90, 1988);
- the statistical interpretation of the results.

In this chapter there is also a graphical presentation including the general experimental plan according to which the researches were done, the steps of the drying process, the equipment used for the experimental research, as well as the laboratory equipment necessary for the experiments.

At the same time there are remarks referring to the mathematical modeling process of the drying as well as to the CFD (Computational Fluid Dynamics) simulation of this one.

Chapter VI, ”*The working process modeling and simulation for the cereal and technical plant seed drying*”, deals with the mathematical modeling and the simulation CFD (Computational Fluid Dynamics) of the drying process for the agricultural seeds in the two boxes proposed.

The optimization of the drying agent flow in the cylindrical box had as object the equalization of the drying agent temperature gradient and velocity. The complex process of optimization required the simulation of the drying agent flow through CFD, modifying the constructive parameters of the drying agent distributor of the box and the functional velocity and temperature parameters of this agent when entering the box.

The CFD simulation uses the mathematical model proposed by: the crossing of the stages of numerical meshing of the field computing with the method of finite volumes in the preprocessing stage; condition imposing at limit for getting a system determined by equations, that are functioning in the preprocessing stage for geometry and in the processing stage for the velocity parameters of the drying agent, temperature, humidity; the equation system solving in each node of the field through the iterative approach up to the point of getting the convergence, in the processing stage; the graphical representations obtained in each node of the studied field, for the parameters velocity, temperature, humidity, and current lines, in the postprocessing stage.

By means of the CFD simulation, an optimal model was built for the drying agent distributor inside the cylindrical box (initially the interior of the cylindrical box was empty, and finally the distributor is made up of a conical deflector with three truncated cones and an end cone), which gives the possibility of getting uniformly dried seeds, and after the drying, superior technological and qualitative parameters.

Chapter VII, entitled "*Experimental researches regarding the working process optimization for cereal seed drying*", presents the results obtained at the end of the cereal seed drying process (wheat, barley, corn), the influence of each parameter of the drying agent on the drying process, their statistic interpretation, as well as the comparison with the theoretical ones.

The temperatures at which the drying has been done were 40ºC, 50ºC, 60ºC, 70ºC, 80ºC, and the velocity values were 1 m/s, 1.5 m/s, 2 m/s and 2.5 m/s. Each sample of material, regardless the seed type and the initial humidity, had the same volume. By varying the velocity and temperature values of the thermal agent, and of the seed initial humidity, and by testing the two drying boxes, there were 160 experimental variants studied for each category of seed.

Throughout the researches there was a continuous monitoring of the influence that the constructive and functional parameters of the dehydration installation have on the humidity and temperature variation, in the three seed layers, up to the point of reaching the conservation humidity. The research also contains the determination of the protein content, the germination power, the energy consumption per mass unit, the gluten content (for the wheat seeds) and the deformation index (for the wheat seeds). In the end, one concludes upon the optimal variant for each type of seed drying process.

High values for the drying time have been recorded for 1 m/s and 1.5 m/s velocity. It is also evident that there is a decrease tendency of drying times at the same time with the increase of the thermal agent velocity values and of the working temperatures.

When getting in, the humidity of the drying agent varies inversely proportional to its temperature. When getting out, the humidity initially has an increase tendency, followed by a decrease, due to the water removal from the product. Up to the half drying period, the humidity keeps staying constant, then it starts decreasing as the temperature increases.

For each velocity of the drying agent the final humidities decrease at the same time with the increase of the temperatures.

One can state that the values of the germination power of seeds vary inversely proportional to the air temperature and directly proportional to the air speed.

Generally, both the protein content and the germination power of the seeds were the most severely affected at the temperature of 80ºC.

The use of the cylindrical box optimized all the parameters taken into account during and after the drying process.

Chapter VIII, "*Experimental researches regarding the working process optimization for technical plant seed drying*", presents the results obtained at the end of the drying process of sunflower seeds, their comparison with the theoretical ones as well as the statistical interpretation of the results. Finally the optimal variant for the sunflower seed drying process is stated.

In the case of the sunflower seeds the drying time gradually increased at the same time with the air velocity and temperature decrease. Generally, the drying time for sunflower seeds was much longer than the time values obtained for cereal seeds drying, regardless the initial humidity of the seeds. This is due to the low conservation humidity for the sunflower seeds, that is to the STAS.

The variations of the final humidity values in the seed layers I and II followed mostly the same patterns as in the case of the the other studied seeds. Unlike the cereal seeds, the variant with uniform drying, in which the humidity values of seed layers I and II didn't drop very much in comparison to the third one, was obtained for the air velocity of 1 m/s, at a temperature of 40ºC.

The energy consumption varied according to a very well defined pattern, in the following way: its values decreased as the air temperature increased and they increased as the velocity of the thermal agent got higher. For the both boxes the minimum energy consumption was recorded at the thermal agent velocity of 2.5 m/s and the temperature of 80ºC.

It is evident the fact that unlike the studied cereal seeds, the maximum of energy consumption for sunflower seed drying, especially for those with an initial humidity of 19%, was also obtained for the same thermal agent temperature of 40ºC, but at a velocity of 2 m/s.

The protein content of the sunflower seeds varied mostly in the same way as in the case of the corn seeds. It was drastically affected during the drying process at the air velocity of 1 m/s and at temperatures of 60ºC, 70ºC and 80ºC. For temperatures of 40ºC and 50ºC there were not changes recorded.

The protein content recorded lower values starting with temperatures of 55ºC...60ºC. Once the drying agent velocity increases, the protein content is no more so much affected. The drastical decrease of the protein content was recorded at the drying agent velocity of 1 m/s, at the temperature of 80ºC.

After the statistical analysis, significant differences for the protein content and the germination capacity of dried sunflower seeds, in both drying boxes, were obtained for the air temperature variation. For the air velocity variation there were no significant differences obtained neither for the protein content nor for the germination capacity of dried sunflower seeds.

In **Chapter IX**, entitled ”*Conclusions and recommendations*”, there is a synthesis of the conclusions expressed in the end of each chapter, grouped as general conclusions and conclusions regarding the theoretical and experimental researches, finally followed by recommendations.

The construction of the cylindrical box provided with an interior conical deflector, opens new ways to the research related to the aim of getting dried seeds of superior quality, reduced energy consumptions for the drying process, a shorter drying time, low costs for dryer constructions, shorter drying columns, respectively a shorter dryer, as the drying may be done uniformly**.** At the existing dryers, in which the interior of the perforated cylinder is empty, the drying takes place only at the end of it.