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THE EFFECT OF INFRARED HEATING TREATMENT ON THE CHANGES OF PRESSURE TAKING PLACE IN THE COURSE OF HUMIDIFICATION OF SOYBEAN SEEDS

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ABSTRACT

The paper presents the results of studies on the changes of tensions taking place in the process of humidification of soybean seeds, Poland cv. Before humidification, which was performed at different temperatures, the material was heated with infrared heating. It was stated on the basis of the studies that treating the seeds with infrared heating was the cause of considerable decrease of the values of recorded pressures. The pressures appearing in the course of humidification of the thermally treated seeds were approximately 10 times as low in comparison with the pressures recorded while humidifying the seeds that were not subjected to any treatment.

Key words: micronization, pressure, humidification, soybean

INTRODUCTION

One of the factors determining the proper course of technological processes and the quality of the products is related to physico-chemical properties of the raw materials. One of the most important physical properties is an ability of dry plant material to absorb water. In this process, the seeds increase their volume, which causes an increase of the pressure to the walls of storage containers, which can undergo damage in extreme conditions.

It is commonly known that imbibition is accompanied by considerable forces which can affect the behaviour of the seeds in the mass [7, 9, 10]. Such behaviour of the seeds has an influence on a number of phenomena taking place in silos, where the material is stored in thick layers, frequently of different moisture.

The problem of the effect of the imbibing grain on the construction of containers has been dealt with by many authors. Muthukumarappan et al. [12] and Deshpande et al. [6] stated that grain imbibes during humidification and the increase of the grain volume is proportional to the amount of the absorbed water. The mathematical relation worked out by them anticipates the increase of the volume proper by $1.0 \cdot 10^{-5} m^3 \cdot kg^{-1}$ per each percent of the increase of the water content. Zhang and Britton [15] worked out a model of calculating the loads for the construction of a container which were caused by hygroscopic phenomena, and they tested it on maize grain. They showed that the index of an increase of pressures was 5.0 to 8.6 with an increase of the water content in maize grain by 10%.

Although a lot of studies have been conducted concerning this subject, no universal solution has been found, which would comprise all the plant materials. Therefore, while designing various containers the kind of the stored material and above all the values of forces appearing in the course of imbibition should be taken into consideration.

One of the thermal processes which dry plant materials are subjected to and which has gained new applications in agricultural food processing over the years is micronization. The term 'micronization' refers to the process of thermal treatment of dry raw materials or plant products which is the result of heating them with infrared radiation in a short period of time up to the temperature usually exceeding 100°C. At present, the process of micronization is qualified within a group of processes defined with a generally accepted abbreviation HTST (high temperature – short time) [2, 3, 13, 14].

The method of micronization makes it possible to get high quality flakes of wheat, barley, rice and rye. It can be widely used in food industry. In feed processing, especially interesting results were achieved during mieronization of the whole soybean seeds. While the level of inhibitor trypsin decreases, the nutritive value of protein improves considerably, and the level of metabolic energy increases reaching the value of 3750 kcal kg^{-1}. This method of treatment also increases the energetic value of other seeds such as pea, faba bean or lupine seeds, while reducing the content of anti-nutritive elements [2, 8].

It can be generally stated that micronization makes it possible to reduce anti-nutritive thermo-labile factors completely, without any clear denaturation of proteins. Besides, the content of bacteria and mycotoxins decreases by 70-90% [1].

Nowadays, the application of micronization in agricultural-food processing has more and more advocates. In Great Britain this process is widely used for example in the production of additives to brewer's cereals, special additives to baker's products, breakfast cereals, instant (cooking) seeds of pea, bean, lentil, feeds for young farm animals and domestic animals and many other products. Such a great variety of applications as far as miconization process is concerned means the necessity of conducting additional studies both on the very course of the process and the physico-chemical properties of the achieved products. Therefore, the purpose of the paper is to mark the changes between the pressures appearing in the course of humidification of thermally untreated soybean seeds and the seeds after infrared heating treatment.

MATERIAL AND METHODS

Choosing the material. The studies were conducted on soybean seeds, 'Polan' cv. The material was uniform as far the cultivar was concerned. The water content in the seeds was 0.149 kg kg^{-1} dry matter. The physical properties of the research material are presented in table 1.

Table 1. The basic physical properties of the research material [11]

Properties	Value
Water content (kg kg^{-1} d.m.)	0.149
Weight of 1000 seeds (g)	170.6
Volume of 100 seeds (cm^3)	12.1
Mean diameter of seeds (mm)	4.69
Heaping density (kg m^{-3})	713.2
Shaking density (kg m^{-3})	756.3
Angle of pouring (deg)	9.4
Angle of dump (deg)	33.02

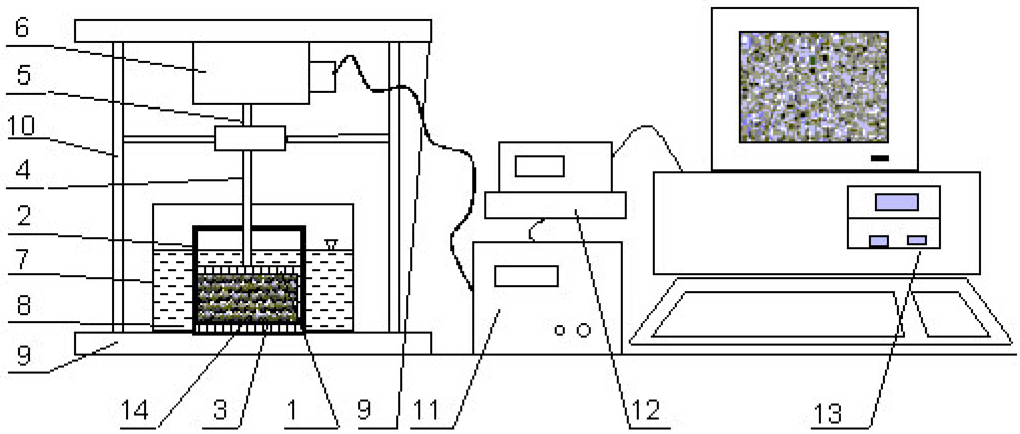
Course of studies

Micronization. The process of micronization of seeds was realized on a research stand equipped with an infrared radiator of Helios Company with a symbol IR1 (the power of the lamp was 250 W). The radiator used in the studies was characterized by: a simple manner of service, very short time of heating, simultaneous illumination of the heated material, a possibility of using the sockets of the lighting network. Seed samples with the weight of 100 g were heated with infrared heating at the temperature of 180°C for 120 s. Before and after the process of micronization the changes of pressures caused by hygroscopic imbibition of the seeds were studied.

Measurement of pressures. The studies were conducted on a measurement stand, whose scheme is presented in figure 1.

Before the measurement, the water content was established in the material according to the norm AACC Method 44-15 A.

Fig. 1. A scheme of the stand for measuring the pressures in the mass of the material:
1 – perforated piston, 2 – cylinder, 3 – perforated bottom, 4 – regulating pivot of the piston, 5 – regulating pivot of the force sensor, 6 – force sensor, 7 – container with water, 8 – water with constant temperature, 9 – resistance plate, 10 – fastening bars, 11 – bridge amplifier, 12 – digital recorder, 13 – computer with software, 14 – examined seeds



A cylinder was filled with a 100 gram sample of seeds and next placed in container 7. A perforated sliding piston was lowered on the content of the cylinder, regulating the position of pivots 5 and 4 in such a way that indication of the force sensor 6 was 0. Then the measurement was started.

The water with constant temperature, while moving through the perforated piston 1 and perforated bottom 3 was absorbed by the mass of seeds which increased their volume exerting influence on piston 1 fitted through sliding with cylinder 2. By means of regulating pivots 4 and 5 the pressure of imbibition was transferred to force sensor 6 fixed to the resistance plate 9. Next, the electric signal moved from sensor 6 to the bridge amplifier 11 and further on to recorder 12, from where it was periodically transferred to PC computer with software. The process was performed at two temperatures: 20°C and 40°C. The studies were begun after establishing the thermal conditions of the instrument. The measurement lasted 24 hours with the sampling frequency of 1 minute (except for the measurements performed at 40°C, which lasted 6 hours because of the maximum measurement range of the force sensor).

After the process was finished, the water content was determined in the material according to the norm AACC Method 44-15 A.

The obtained values of forces were converted to pressures.

In order to maintain constant temperature of the process, the instrument was placed in a water-electric thermostat CWE 2a and the temperature was maintained with the precision of 0.5°C.

The measurements were performed in three repetitions.

RESULTS

The process of changes in the pressures appearing in the mass of soybean seeds in the course of humidification is presented in a graphic form in figures 2-5.

Fig. 2. The course of pressures appearing during humidification of thermally untreated soybean seeds at temperature 20°C (max. standard deviation: 0.125)

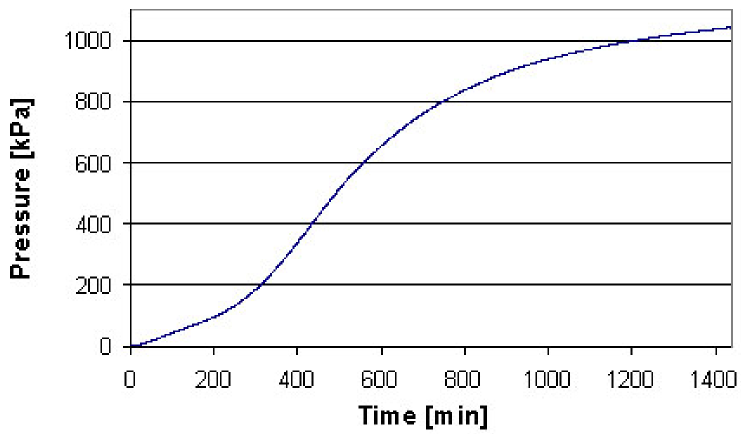


Fig. 3. The course of pressures appearing during humidification of thermally untreated soybean seedsat temperature 40°C (max. standard deviation: 0.027)

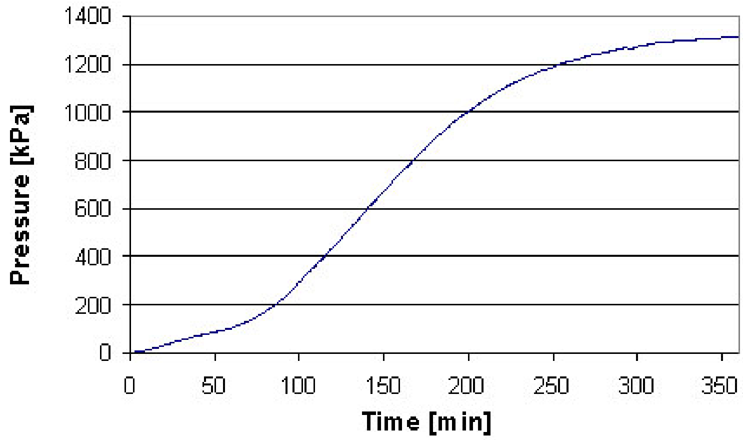


Fig. 4. The course of pressures appearing during humidification of soybean seeds at temperature 20°C. Before the process the seeds were subjected to micronization (max. standard deviation: 0.013)

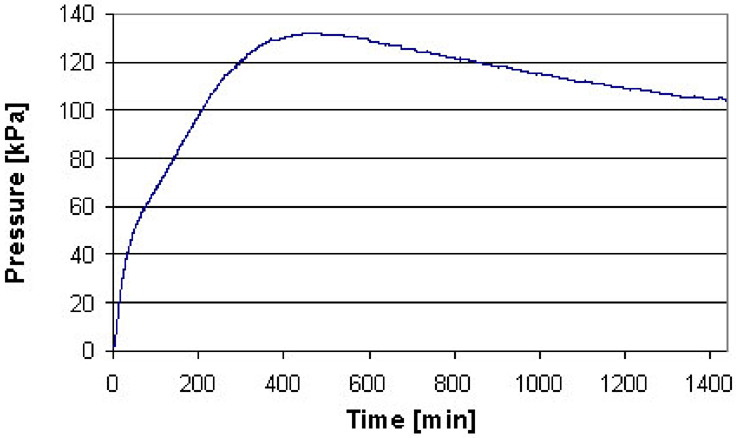
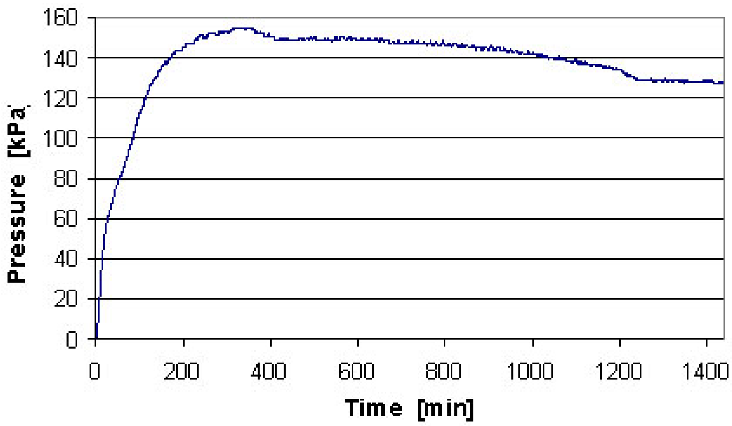


Fig. 5. The course of pressures appearing during humidification of soybean seeds at temperature 40°C. Before the process the seeds were subjected to micronization (max. standard deviation: 0.005)



Comparing the curves of changes of the pressures in the time function of the process it has to be stated that their shape and the obtained values of pressures were related to the kind of the examined material (thermally treated and untreated) and the temperature of the process.

The course of the curves of changes in pressures in the function of time of humidification of thermally untreated soybean seeds at temperatures 20 and 40°C are characterized by similar shapes (figs. 2-3). After an initial slight increase of the value of pressures, which was 350 min for the seeds humidified at 20°C, and about 75 minutes for the humidified seeds at 40°C, a rapid increase of the values of pressures was observed. After approximately 750 minutes in the case of seeds humidified at 20°C, and about 225 minutes of the process going on at 40°C, the studies observed stabilization of the pressures exerted on the piston. After those times, the values of pressure increase were low. Besides, it should be stated that the temperature of the process was the factor determining the values of pressures appearing during humidification of soybean seeds. During the experiment conducted at 20°C the maximum pressures were read after 1440 minutes and they were 1040 kPa on average, while the highest pressures of about 1314 kPa were recorded already after 350-minute-long humidification of soybean seeds at 40°C. Therefore, raising the temperature from 20 to 40°C caused a four times shorter time after which the recorded values of pressures appearing in humidification of soybean seeds reached the maximum values.

Identical measurements were performed for soybean seeds that were thermally treated with infrared heating. The results of these studies are presented in figures 4-5. Analyzing the course of changes presented in the curves it should be stated that maximum values of pressures in the mass of seeds were recorded already after about 400 minutes independently of the temperature. The studies observed only a small influence of temperature at which seeds humidification was performed on the values of maximum pressures. They were about 132 kPa at 20°C, and about 155 kPa at 40°C.

Comparing the values of maximum pressures obtained in the course of humidification of soybean seeds that were thermally untreated and heated with infrared heating, significant differences were found out. Those values were about ten times lower in the case of soybean seeds subjected to micronization before humidification.

Strain reduction (comparison to the raw material) forming during heat treatment (micronization) and expanding at constant volume is probably caused of the decrease seed cover permeability and changed chemical composition of the seed in effect of high temperature. Miocronization creates starch gelatinization and protein denaturation [4, 5].

Table 2. Multiple regression equations and the values of determination coefficient R^2 describing changes of pressures in the process of imbibition in the constant volume of soybean seeds in the time function (for the interval from 0 to 1440 min) for the level of significance 0.05

Name	Regression coefficient	R^2
Untreated soybean – 20°C	$y = -5E\text{-}07x^3 + 0.0006x^2 + 0.9688x – 77.386$	0.989
Untreated soybean – 40°C*	$y = -8E\text{-}05x^3 + 0.0379x^2 + 0.6713x – 25.391$	0.994
Micronization treated soybean – 20°C	$y = 2E\text{-}07x^3 – 0.0006x^2 + 0.4325x + 28.924$	0.958
Micronization treated soybean – 40°C	$y = -4E\text{-}10x^4 + 1E\text{-}06x^3 – 0.0015x^2 + 0.6963x + 47.655$	0.900

***for an interval from 0 to 360 min**

Table 3. The content of water in soybean seeds before and after the process of imbibition

Name	Water content [kg kg^{-1} d.m.]
Thermally untreated soybean	0.149
Soybean seeds after micronization	0.124
Thermally untreated soybean seeds after humidification at 20°C	0.988
Thermally treated soybean seeds after humidification at 20°C	0.961
Thermally untreated soybean seeds after humidification at 40°C	1.028
Thermally treated soybean seeds after humidification at 40°C	0.920

All the curves presented in the diagrams were described by means of regression of the 3rd or 4th order (tab. 2). Proper adjustment of the experimental data to the theoretical description is proved by the high values of coefficients R^2, which are within the range from 0.900 to 0.994.

Table 3 presents numerical values of the water content before and after the process of soybean seeds humidification. No statistically significant differences were observed between the water content after humidifying the micronized and thermally untreated seeds.

CONCLUSIONS

The following conclusions were formulated on the results of studies:

1. Humidification of soybean seeds is accompanied by very big pressures working on the elements of the cylinder and the piston (exceeding the value of 1000 kPa) growing in the function of the time of humidification.
2. The rate of increase of the values of pressure appearing in the course of soybean seeds humidification is related to the temperature of the process. The temperature increase from 20°C to 40°C causes a more than four times shorter time after which the pressures reach the maximum values.
3. Exposition of soybean seeds to thermal treatment with infrared heating is the cause of a considerable decrease of the pressures appearing during humidification of soybean seeds. In the course of humidification the seeds that were thermally treated exerted about 10 times lower pressures as compared to the pressures exerted by the material that was not subjected to the process of micronization.

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