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VACUUM WETTING OF SOYBEAN SEEDS AND MAIZE GRAINS AT DIFFERENT TEMPERATURE AND TIME CONDITIONS

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Summary. Moistening is a commonly used treatment in the processing of cereal grain. Some significant changes occur during such a treatment in the structure and physical properties of processed raw materials. Water absorption by grainy raw materials depends on a number of factors connected with the grain properties as well as with the environmental conditions where the process proceeds. The aim of the undertaken studies was to determine an effect of ambient pressure on the quantity of water absorbed by grain. The initial evaluation of the raw material included basic physical properties of grain, such as the moisture content, bulk and shaken density as well as the angle of slide. During the experiment the maize grain was moistened by pouring with water under atmospheric pressure and the pressure reduced to 5 kPa. The time of grain moistening ranged from 30 sec to 10 min, at the temperature of water from 15 to 70 deg C. After treatment under such conditions the final moisture content of grain was determined and the changes in the morphological grain structure were recorded on photographs.The results were presented in form of diagrams illustrating the changes in grain moisture content after its moistening under atmospheric and vacuum pressure of 5 kPa, in function of moistening duration. Basic statistical processing of the results included an analysis of regression and significance test of particular factors' effect. It was confirmed that the amount of water absorbed by moistened maize grain depended significantly on the ambient pressure at the treatment. Under the pressure of 5 kPa the maize grain achieved higher final moisture contents than the same grain moistened under atmospheric pressure. Changes in the morphological structure of maize grain after moistening were perceptible, however not to an extent comparable with the earlier-tested cereal grain and legume seeds.

Key words: physical properties, maize grain, moistening

INTRODUCTION

The wetting process is commonly applied in cereal and other crop grains. It is used as a preliminary process (e.g. before hulling) during processing of leguminous plant seeds. Wetting plays an important role at preparing the seeds for milling. Properly performed it has a significant influence on extract index value for white flours and the quality of the obtained milled products. Moreover, it ensures the optimum working conditions for a grinding device resulting in a uniform condition of the seeds by improving such traits as endosperm tenderness as well as ductility and elasticity of cover.

In milling works, wetting consists in an injection of a given water amount, that is distributed by various means over the seed surface (Bühler, Vibronet systems). In such a context, the uniformity of seed wetting is far from perfection. It is a very useful attempt, because it makes it possible to relatively accurately estimate the final moisture content of a product. However, it involves many difficulties, which is proved by the fact that even triple wetting of the same raw material before milling is intended in large processing works. Moreover, that way of the process performance makes it necessary to use long-term seasoning of a raw material. As compared to the above method, the process of cereal wetting by soaking ensures uniform water access and does not require specialized and expensive devices.

A variety of important changes within raw material structure occur during seed wetting. Physical and chemical as well as structural properties are changed then.

During grain soaking, all its geometric parameters get changed due to swelling. Thermal properties (including an increase of grain thermal conductivity) change as well [Wallapapan and Sweat 1982].

The temperature of starch gelatinization at wheat during soaking increases, and at the same time the temperature range, in which the process may occur, narrows down. Maize, whose temperature of gelatinization peak is shifted, along with the moisture content increase, from 73 to 76°C, behaves in similar way [Perez *et al.*2001].

The increase of maize grain moisture content by 1.5% causes the internal injuries formation. Their number grows along with the moisture content increase reaching its maximum after 8 hrs of grain contact with water [Wu *et al.* 1988]. Too fast water imbibition due to low initial moisture content level is the reason for structural injuries [Sivritepe *et al.* 1995].

Among other strength properties affected by wetting, a double decrease of elasticity coefficient is apparent [Singh *et al.* 2001].

The phenomenon of soluble substances elution from grains is observed in technologies requiring long-term soaking. During maize soaking before wet milling, the content of substances dissolved in water reaches 7%, but up to 50% protein is contained in such an „extract". An increase of water temperature applied to shorten the soaking time intensifies that process [Gunasekaran *et al.* 1988]. In general, extraction of soluble components in grain leads to worsening of grain quality [Schoettle *et al.* 1984, Mc Donald *et al.* 1988].

There is a variety of modern technologies requiring the grain soaking to above 30% of moisture content. Among them, wet milling is the most common method for the production of starch, protein or fat isolates [Muthukumarappan *et al.* 1992, Owens 2000]. Maize grains are soaked in water at 50°C for 40–60 hrs to reach about 45% of moisture content. Endosperm loosening and achievement of prepared starch with proper viscosity is the effect of the thermal process [Gunasekaran *et al.* 1988].

Soaking is often applied in useful food production [Abu Ghannam 1998, Prasada Rao 2002].

The wetting process is significantly affected by environmental pressure. Commonly applied at rice processing the soaking process led under 10.5–70 MPa pressure allows for shortening the grain processing time. In addition, it decreases the energy inputs within the whole rice processing stage [Vellupai and Verma 1982]. Also maize under similar pressures and soaked for 1 hr absorbs more water than under ambient pressure [Gunasekaran *et al.* 1988, Gunasekaran 1992].

Vacuum impregnation is one of the newest technologies improving the water penetration into raw material's internal structure. It is applied at processing of animal-origin and fruit materials [Guamis *et al.* 1997, del Valle *et al.* 1998, Gonzalez *et al.* 1999, Fito *et al.* 2001, Betoret *et al.* 2003, Chafer *et al.* 2003].

However, there is a lack of publications on the vacuum grain soaking in available literature.

THE AIM OF THE RESEARCH

The aim of the research was to determine the opportunity and conditions for controlled wetting of maize and soybean grain outer layer under vacuum.

Experiments were targeted to study the variability of:

– pressure in moisturizing chamber from 5 to 100 kPa (atmospheric pressure);
– temperature of wetting agent from 15 to 70°C;
– time of grain contact with water under the studied pressure from 0.5 to 10 min.

METHODS

Experiments were carried out for maize of Janna cv. and soybean of progress cv. grains on measurement stand presented in Fig. 1.

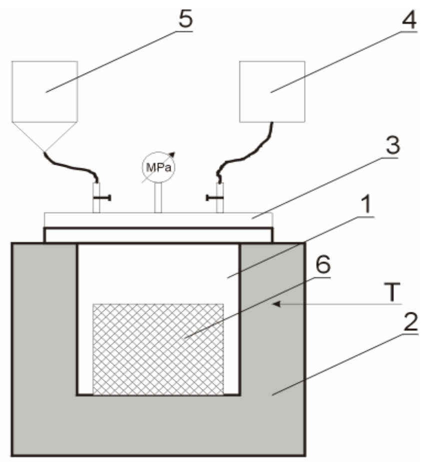

Fig. 1. Scheme of measurement stand for studying the wetting by means of soaking method under vacuum conditions: 1 – vacuum chamber, 2 – ultra-thermostat, 3 – cover, 4 – vacuum pump, 5 – reservoir, 6 – reservoir for raw material.

The wetting temperature in ultra-thermostat was set after placing the vacuum chamber with reservoir filled with raw material (40 g). The following temperatures were applied: 15, 30, 50 and 70°C. Water for wetting had similar temperature as that within the chamber. These temperatures difference was not higher than ±2°C. After heating, hydraulic pipes were filled with water. Then the chamber was closed and, after opening, the valve joined with vacuum pump and the pressure level was set. Two pressures were applied: 5 and 100 kPa (atmospheric pressure). After setting the pressure at 5 kPa, the valve joining the chamber with vacuum pump was closed and the connection with water reservoir was opened. Each time the sample was flooded with water of about 0.2 dm^3 capacity. A slight pressure increase along with an increase of water level in the wetting chamber was observed during flooding of sample with water of 5 kPa pressure. The tested samples were kept in water for 30 seconds as well as 1,5 and 10 minutes. Then, in the case of vacuumed samples, the pressure was suddenly set to atmospheric level.

The excess of not absorbed water was removed by drying the grain surface with filter paper [Gunasekaran *et al.* 1988, Verma *et al.* 1999, Maskan 2001, 2002]: a single layer of grains was placed on double layer of filter paper, covered with double layer of filter paper and thoroughly moved for 30 seconds. The procedure was twice repeated using new filter papers. After water removal, grain moisture content was determined by means of drier method in accordance to PN-86/A-74011.

Study results were subjected to statistical processing including significance analysis of the influence of studied parameters on the grain's final moisture content as well as regression analysis, which resulted in defining the dependences in a form of equations.

RESULTS

An influence of three factors: pressure, temperature and time of grain-water contact on the final product's moisture content, was studied during the wetting process. Fig. 2 presents the dependence of maize grain's final moisture content wetted under atmospheric pressure as a function of temperature and contact time, and Fig. 3 – dependence of maize grain's final moisture content wetted under pressure of 5 kPa on temperature and grain-water contact time.

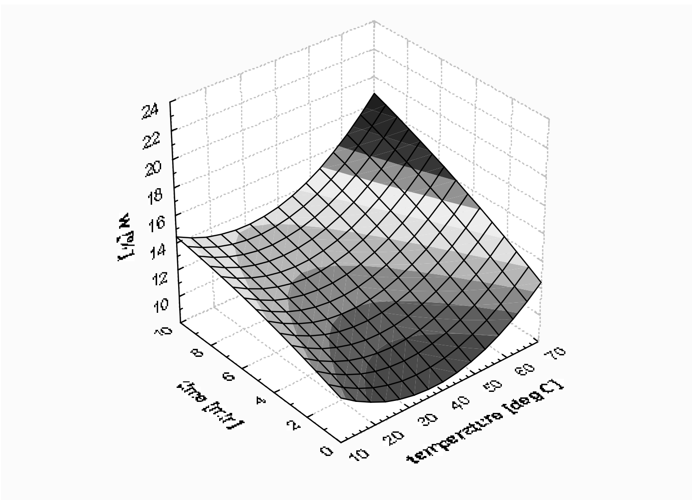

Fig. 2. Dependence of final moisture content of maize wetted at 100 kPa on process duration and temperature of wetting agent

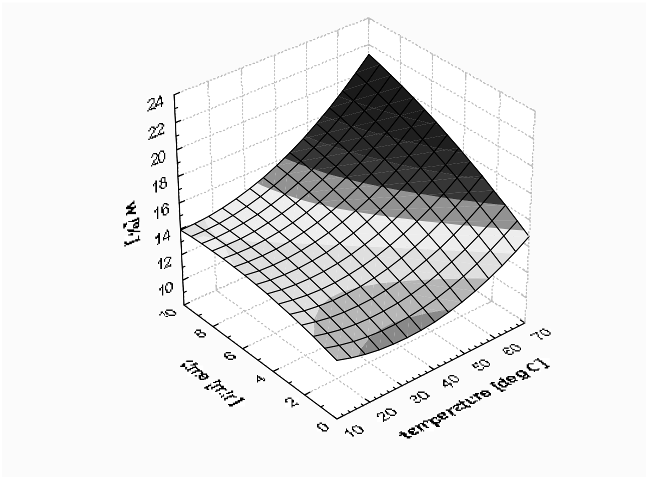

Fig. 3. Dependence of final moisture content of maize wetted at 5 kPa on process duration and temperature of wetting agent

An increase of grain moisture content occurred along with an increase of wetting time and temperature. Grain wetted at 15°C and atmospheric pressure achieved 9.61% of final moisture content after 30 seconds (an increase in relation to initial moisture content by 11.7%) and after 10 minutes – 14.1% (an increase by 63.4%).The increase was by 40.1% and 86.3%, respectively at the pressure of 5 kPa. At temperature 70°C and atmospheric pressure, the grain final moisture content was 13% (after 30 s) and 19% (after 10 min.). Therefore, it increased by 50.7% and by 120.9%, respectively. The achieved gains of grain moisture content were 86.6% (after 30 s) and 144.7% (after 10 min.) at the same temperature, but the pressure of 5 kPa.

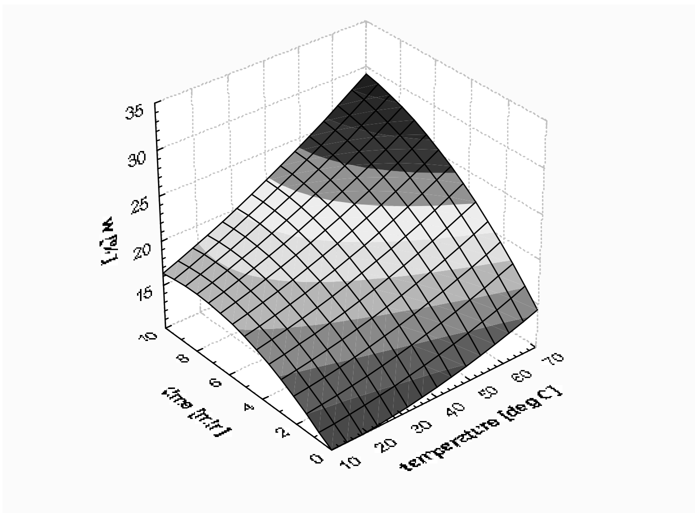

Fig. 4. Dependence of final moisture content of soybean wetted at 100 kPa on process duration and temperature of wetting agent

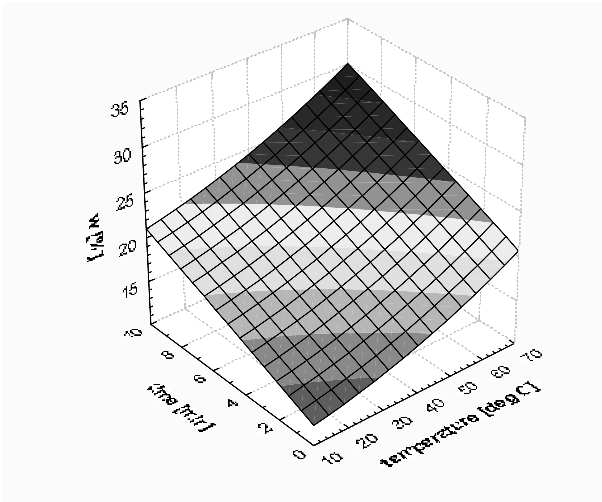

Fig. 5. Dependence of final moisture content of soybean wetted at 100 kPa on process duration and temperature of wetting agent

Soybean seeds wetted at 15°C and atmospheric pressure achieved 10% of moisture content after 30 s (an increase by 21.9%) and at 5 kPa – 12.8% (an increase by 56.6%). At that temperature, moisture content of tested seeds increased by 128.2% (atmospheric pressure) and by 168.4% (pressure of 5 kPa).

The following values of final moisture content were achieved at atmospheric pressure and 70°C: 14.1% after 30 s (increase by 71.9%) and 27.5% after 10 min. (increase by 235.2%). At that temperature, an increase of final moisture content by 19.9% (after 30 s) and by 29.2% (after 10 min.) was recorded.

Results from studies upon the wetting of maize grain and soybean seeds were subjected to analysis of the influence significance of factors (pressure, temperature, time) on final moisture content of the tested materials. An analysis was made using multiple Tukey's confidence intervals at the significance level of $\alpha<0.05$ (Table 1).

Table 1. An analysis of the significance of selected factors influence on wheat final moisture content (the same letters indicate no significant differences)

Factor	Value	Maize	Soybean
Temperature °C	15	a	a
	30	ab	b
	50	b	c
	70	b	c
Pressure kPa	5	a	a
	100	b	b
Wetting time min	0.5	a	a
	1	b	a
	5	c	b
	10	d	c

Tukey's test revealed that the studied factors (time, pressure and temperature) within accepted variability range significantly affected the final moisture content values of tested raw materials.

Dependencies achieved in studies on the influence of pressure (p), temperature (t) and time (τ) on grain moisture content of tested materials were subjected to multiple regression analysis as well as described using equations with defining the determination coefficients R^2. These equations along with the factors variability ranges within which they are obligatory and values of R^2 coefficients are presented in Table 2.

The multiple regression equations obligatory within the whole tested ranges of time, pressure and temperature variability are characterized by determination coefficients from 0.83 in the case of maize grain to 0.87 for soybean seeds.

Table 2. Regression equations and determination coefficients describing the dependence of grain moisture content (w) after wetting on water-grain contact time (τ), for various pressures (p), at the tested wetting temperatures (t)

Material	Variability range	Equation	A	B	C	D	R^2
Maize	$p \in (5–100)$ kPa $t \in (15–70)$ °C $\tau \in (0{,}5–10)$ min	$w = Ap+Bt+C\tau+D$	-0.032	0.072	0.143	14.136	0.83
Soybean	$p \in (5–100)$ kPa $t \in (15–70)$ °C $\tau \in (0.5–10)$ min	$w = Ap+Bt+C\tau+D$	-0.038	0.065	0.161	14.282	0.87

CONCLUSION

1. Maize grains and soybean seeds wetted under vacuumed conditions contain more water than at atmospheric pressure.
2. No significant influence of wetting agent temperature on the amount of absorbed water was observed after short time of the water-grain contact (30 s). That influence significantly appeared after longer time of wetting amounting to 5 and 10 min.

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