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The influence of changes in the water content of ground soybean grain on its quality during transport processes

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Abstract

Many factors that determine the quality and the vulnerability of transportation have changed. During the handling, storage and transport phases of different modes of transport, qualitative changes occur in ground soybean grain. These properties are the subject of changes that determine the quality of cargo and transportability. They constitute the group of quality features. Water content is an important characteristic affecting the quality of soybean meal from its production until after the storage process. In this article, we present the results of research on the hygroscopic characteristics of ground soybean grain and its different fractions, including the effect of temperature, relative humidity, ambient air and grain composition.

Introduction

Maintaining the quality of ground soybean grain during transport processes depends on conditions of storage, handling and transportation. An important aspect of the transport process is knowledge of the transportation-technological quality features of soybean seed cake.

Those properties important in transport can be selected from the characteristics of this cargo. With regards to previously presented results of the author (Drzewieniecka, 2004), these include: size distribution, particle shape, water content, equivalent humidity, density, bulk density, porosity, kinetic (natural) angle of repose and static angle of repose.

These features have a significant impact on the technology of the various stages of the transport chain and determine their progress and performance.

It is not without significance that there is a correlation between these features, their variability over time and the dependence on the parameters of the ambient air.

Water content is an important characteristic affecting the quality of ground soybean grain and other fodder materials from its production until after the storage process. The water content of ground soybean grain is formed in the processes of production and transportation.

The distinguishing feature of this transport process mainly depends on the ambient microclimate conditions: temperature and relative air humidity, and is closely related to equivalent humidity content. Equivalent humidity (as the physicochemical property) and water content are shown in the group of transportation-technological quality features due to their high impact on other features.

According to previous research of the author (Leśmian-Kordas & Drzewieniecka, 2003) and from the literature (Prusiński, 1993), the settling rate of constant water content in soybean grain depends primarily on the size of particles. A reduction in the size of particles is found to reduce the time required after a change in the ambient microclimatic conditions for the water content to adjust, seeking to achieve thermodynamic equilibrium with the surrounding atmosphere.

Hygroscopic features of ground soybean grain

Changes in moisture content of fodders caused by hygroscopy cause changes in their structure and properties, and lead to changes in the characteristics of technology, storage, transport and usage. Previous research of the author in storage, transport and usage shows that hygroscopy is an undesirable feature that can cause acceptable moisture limits to be exceeded in fodders, leading to such negative processes as: fermentation, rot, molding, caking and hanging in the outlet hatches of silos and tanks and paths of transport, as well as heating up of the fodders in the process (Drzewieniecka, 2013).

The occurrence of the above-mentioned processes limits safe storage time. The limit of moisture content for raw materials such as grain is 14.5%, and for ground soybean grain 12–12.5% (Walczyński, 1997). Similarly, according to the American Soybean Association, ground soybean grain used for fodder should have a moisture content of not more than 12%, while 12.5% is considered to be an absolute maximum (Britzman, 1994).

The problem of hygroscopy in soybean seed cake is treated marginally in the literature. Moisture equilibrium is determined by the effect of competing absorption phenomenon: adsorption of water vapor from the ambient air into the body – having a porous structure, unrolled surface area and a high degree of fragmentation; and casting this vapor to the environment (desorption). This is defined as hygroscopy. There is constant exchange of water vapor between hygroscopic goods and ambient air, until thermodynamic equilibrium is reached – known as hygroscopic balance.

Research methodology

This article presents the impact of changes in the water content in ground soybean grain and its various fractions taking into account the effects of temperature, relative humidity, ambient air and fineness grade on its quality. The results were obtained from tests carried out and research.

The research material was soybean seed cake. From natural soybean seed cake, fractions were isolated having a particle size of less than 0.075 mm (G); with range: 0.075–0.1 mm (F), 0.1–0.25 mm (E), 0.25–0.4 mm (D), 0.4–1.2 mm (C), 1.2–3 mm (B) and the fraction having a particle size greater than 3 mm (A).

The samples of each fraction were stored in a climatic cabinet at temperatures of 20°C and 40°C, at relative humidity of air (φ): 30%, 40%, 60%, 75% and 95%.

Research results

The relationship between the equivalent water content in ground soybean grain and the relative humidity was set for the various factions in temperatures of 20°C and 40°C. The results obtained are shown in the form of adsorption isotherms (Figures 1 and 2).

The equivalent humidity of natural ground soybean grain at 20°C varied from 3.30 to 22.70%. Depending on the size of particles of soybean grain, the equivalent humidity at 20°C varied from 2.80 to 23.40%.

For natural ground soybean grain, the critical value of relative humidity at 20°C was found to be equal to 60%. At this point, the equivalent humidity

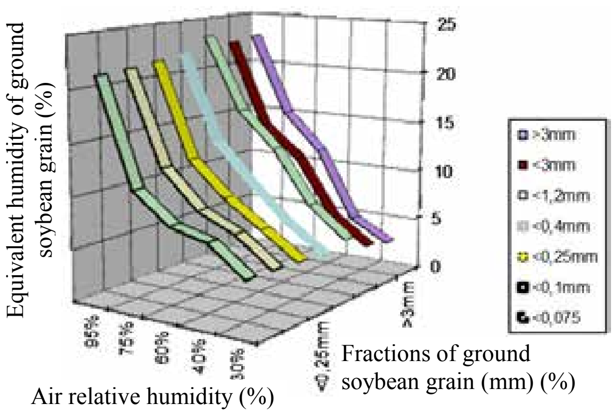

Figure 1. Sorption isotherms of different fractions of ground soybean grain at a temperature of 20°C

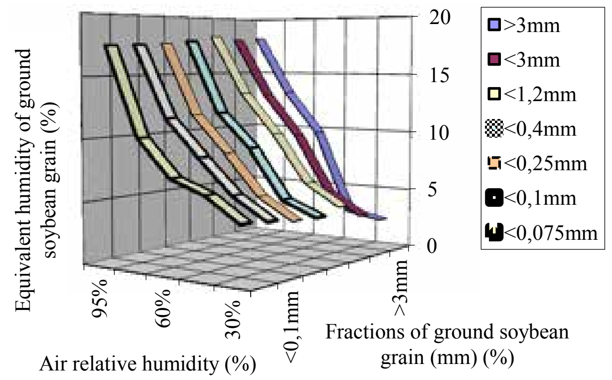

Figure 2. Water sorption isotherms of different fractions of ground soybean grain at a temperature of 40°C

of soybean grain was 11.42%, which in accordance with PN-80/R-64773 was almost at the maximum limit value. At a temperature of 40°C and at the same relative humidity, the equivalent humidity of soybean grain was 9.10%, while at air relative humidity of 75% it was 13.20%, thereby exceeding the maximum limit of water content.

In conditions corresponding to the extreme environment that may occur on a ship during carriage by sea, which is a temperature of up to 40°C and air relative humidity of 95%, equivalent humidity of natural ground soybean grain was 18.20%.

The equivalent humidity of soybean fractions at 40°C varied between 2.42% and 18.30%, depending on the size of particles and relative air humidity.

The lowest equivalent humidity at a temperature of 20°C and 40°C and relative humidity of 30% was found in a fraction containing particles larger than 3 mm. At temperature of 20°C and 40°C and relative humidity of 95%, the least hygroscopic was the fraction of particle size less than 0.075 mm.

In both crypto-climatic conditions, the maximum equivalent humidity was found in the fraction containing particles in the range of 0.4 to 1.2 mm (Figure 3).

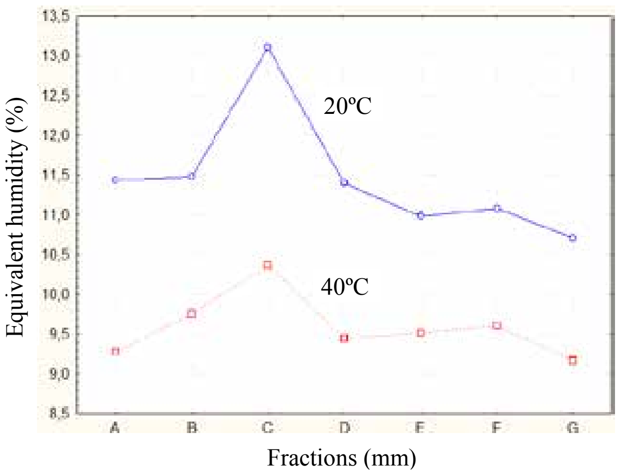

Figure 3. Equivalent humidity of individual fractions of ground soybean grain at different air temperatures and at average relative humidity

The sorption isotherms of natural ground soybean grain and their individual fractions at a temperature of 20°C are shown in Figure 1, and at the temperature of 40°C in Figure 2.

In terms of numerical values, at a temperature of 20°C the fraction having a particle size in the range 0.4–1.2 mm can be regarded as the most hygroscopic, and the fraction with particles smaller than 0.075 mm as the least hygroscopic. The maximum equivalent humidity fixed at ϕ = 95% was 23.55% and 21.35% respectively for those fractions.

The graph of water content changes with increasing equivalent humidity at a temperature of 40°C (Figure 2) shows that the most hygroscopic fraction at this temperature is the one having particle size in the range of 0.4–1.2 mm, and the least hygroscopic the fraction with particle size less than 0.075 mm. The maximum equivalent humidity at ϕ = 95% was 18.30% and 17.40% respectively for these fractions.

Considering the various values of relative air humidity at 20°C, a relationship was observed between the equivalent humidity and the size of the extracted particles. At relative air humidity of 30 and 40%, the equivalent humidity of ground soybean grain increased with a decrease in the size of soybean particles. In contrast, at relative air humidity of 60, 75 and 95%, the equivalent humidity of ground soybean grain increased with an *increase* in the size of soybean particles.

A similar situation occurred at the temperature of 40°C, namely at air relative humidity of 30 and 40%, equivalent humidity decreased with an increase in the size of particles of soybean. In contrast, at 60, 75 and 95% humidity, equivalent humidity increased with an increase in the size of soybean particles. The research has shown a significant relationship between equivalent humidity of ground soybean grain and air relative humidity, and between equivalent humidity and ambient temperature (Figure 4).

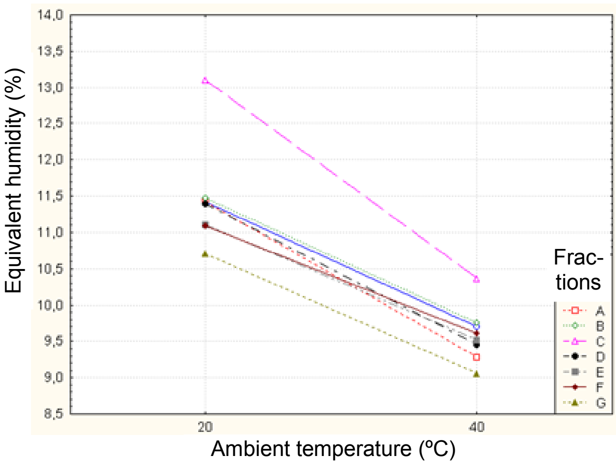

Figure 4. Equivalent humidity of natural ground soybean grain and its fractions at various ambient temperatures

At the significance level α = 0.05, equivalent moisture values for each air relative humidity and for the particular temperatures were statistically differed. Equivalent humidity increased with an increase of air relative humidity and with a decrease of temperature. The correlation coefficients in these two cases were high and were respectively equal to 0.97 and 0.94.

The water content, its changes, the value of equivalent humidity and the time to reach equilibrium humidity have a great importance in maintaining good quality ground soybean grain during transportation processes.

According to different sources (Lewicki et al., 1977; Walczyński, 1997; Polska Norma, 1980; Drzewieniecka, 2004), the time taken for ground soybean grain to reach equivalent humidity varied between several days up to three months, depending on chemical composition, grain composition and microclimate conditions.

The time to establish equivalent humidity found during the research varied depending on the programmed crypto-climatic conditions. At temperatures of 20 and 40°C and air relative humidity of 30, 40, 60, 75 and 95% it was between 3 and 5 days, depending on grain composition of the soybean.

For the fine particle fractions (< 0.4 mm), the period of water content changes was shorter and equivalent humidity stabilized faster. The unfractioned soybean behaved as fractions containing a particle size greater than 0.4 mm.

The literature review (Leśmian-Kordas & Drzewieniecka, 2003) indicates that finer fractions of ground soybean grain are more hygroscopic than larger fractions. However, the results achieved by these researchers suggest a more complex relationship: namely that, at temperatures of 20°C and 40°C and air relative humidity of 30 and 40%, equivalent humidity of ground soybean grain increased with a decrease in the size of particles of soybean, whereas at air relative humidity of 60, 75 and 95%, equivalent humidity of soybean increased with an increase in the size of particles of soybean. In both the programmed temperature conditions, the highest values of equivalent humidity belong to the fraction C. The values of equivalent humidity that were determined for this fraction at $\varphi = 95\%$, and $t = 20°C$, $t = 40°C$, are respectively 23.51% and 18.28%. The finest fraction G was the least hygroscopic, also as compared to the natural soybean.

In previously presented results, the author (Leśmian-Kordas & Drzewieniecka, 2003), found that the equilibration time depends on the size of particles in tested fractions. For the fraction greater than 3 mm that time was longer (5 days), whereas for the fraction of smaller size particles (from 0.4 mm) the time was shorter (3 days).

The statistical calculations carried out have proved that, in the studied crypto-climatic conditions, equivalent humidity for air relative humidity of 30% and 40% is inversely proportional to the size of particles. In other cases (i.e. at a temperature of 20°C and 40°C with air humidity of 60%, 75% and 95%), equivalent humidity is directly proportional to the size of particles.

The results indicate a significant direct relationship between equivalent humidity of ground soybean grain and relative air humidity.

Conclusions

1. The equilibration time of equivalent humidity between the tested ground soybean grain and environment is directly proportional to the size of particles.
2. For each fraction of ground soybean grain at temperature of 20°C the equivalent water content is higher than at temperature of 40°C.
3. The individual fractions of ground soybean grain absorb different quantities of water vapor from the environment at different rates, hence it is required to take this into account in determining the optimal microclimatic conditions during storage and transport.
4. The research into the relationship between the size of particles and equivalent humidity during changing of ambient conditions showed that at air relative humidity of 30 and 40%, it assumes a linear relationship. At humidity of 60%, 75%, 95% the functions deviate from linearity, which means that particles increase their equivalent humidity with increasing size.
5. The adsorption isotherms plotted for the different fractions of ground soybean grain do not clearly confirm an inversely proportional relationship between the size of particles and their properties of water vapor absorption. This relationship has been confirmed only at temperatures of 20°C and 40°C, at relative air humidity of 30 and 40%.
6. Changes in the water content of ground soybean grain have a great importance in maintaining its good quality during transport processes.

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