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Susceptibility to oxidation in relation to safety of soybean seed cake sea transport

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Abstract

Safety of carrying bulk cargoes is an important problem in all stages of the supply chain. At the moment, soybean seed cake is one of the many bulk cargoes, which is the best substitute of protein in the composition of fodder. During the transport, soybean seed cake is mostly under the form of loose cargo and is carried by various and specialized means of sea and overland transport. There are occurred the quality changes of soybean seed cake during the transport processes that are understood as the followed cyclical operations of warehousing, handling and transportation by various means of transport. A lot of characteristics are subject to changes. They are decisive in the nutritional value and in the susceptibility of transport, and they are determining the basic quality-creative factors in the scope of usable quality called functional quality. Maintaining of initial quality of soybean seed in transport process depends on providing the optimal condition of storage, handling and transportation. The influence of functional quality factor that means susceptibility to oxidation in relation to safety of soybean seed cake sea transport is presented. The results of researches are provided on diagrams and evaluated by statistic methods.

Introduction

Characteristic feature of soybean seed cake is instability of its physical properties and chemical composition. Regardless of means of transport, handling methods and construction of warehouses, the transported, handled and stored soybean seed cake is exposed to influence of exo-genetic factors. Atmospheric factors such as oxygen content in air and humidity are counted to it. These factors are affecting the transmutation courses reducing the quality of soybean seed and are dangerous in transportation processes.

Under the commonly used loose form of transport and storage of bulk soybean seed and pneumatic handling, there are favourable condition for oxidation of unsaturated fatty acids that lead to local accumulation of significant amount of thermal energy, increase of temperature and creation of chemically self-heating spots. These phenomena are not in favour of safety of transportation and storage.

Susceptibility to oxidation is one of the usage quality factors of soybean seed cake, named as functional quality. Literature observation [1, 2, 3, 4, 5, 6, 7, 8], research and experiments provided the basis for water content, balanced humidity and fat content that can be included to them.

There are mainly the important chemical properties. These features have significant influence on cargo transmutations during successive stages of the supply chain, determining their courses and quality of cargo. The mutual dependence of factors and their changeability in time can be with no significance.

The mentioned parameters have huge meaning in successive stages of transport cycle of solid loose bulk cargoes.

Susceptibility to oxidation

Susceptibility to self-heating of soybean seed cake during transportation and storage depends on its chemical composition, quality of initial

resources, means of production, technological pollution, ambient condition and remaining time of these stages in transport cycles. In comparison to expellers, soybean seed cake due to small amount of fat up to 2% is less susceptible to self-heating. Pollution in soy bean cake by any organic substances (leaves, paper and the like) increase possibility of self-heating that stimulates unfavourable quality changes and creates self-ignition hazard.

Besides self-heating that stimulates unfavourable quality transmutation and restricts time of safe storage and transportation, oxidation process of soybean seed cake can be the reason of decreasing of oxygen content in surrounding environment. The reducing of oxygen content in the atmosphere of the enclosed spaces creates hazard to personnel handling holds with soybean seed cake. The intensification of these processes is increased along with increase of temperature, quantity of lipids containing unsaturated fatty acids and water contamination.

Among many of ingredients included in soybean seed composition, fats are the most susceptible to unfavourable changes that occurring during storage. Under the influence of oxygen in air, light and temperature there are changes that occurring in a way of auto-oxidation and photo-oxidation.

Hydroxides, created in lipids' oxidation process are very impermanent and can undergo a different transformation. As a result of broken carbon chain there are created short chain products such as: hydrocarbon, aldehydes, khetons, esthers, lactatons, alcohols and ethers [4] that can exist as unsaturated and saturated compounds. Short chain aldehydes and resulting from them due to oxidation acids are in a considerable degree responsible for characteristic smell of rancid fat or food products consisting of lipids.

As it resulted from available literature sources, susceptibility to oxidation of soybean seed cake by atmospheric oxygen determined as percentage decline of oxygen in time function, in enclosed reaction spaces that contains sample of soybean seed, has not been the subject of research yet.

The marked in this way loss of oxygen is measure of oxidation processes proceeding in compound system consisting of characteristic ingredients, undergoing a transformation under the influence of oxygen that results in reducing of their content. Characteristic components (substrates) of soybean seed cake susceptible to oxidation are first and foremost lipids containing the unsaturated fatty acids and moreover protein and vitamins.

Progress in oxidation of lipids is increased with rise of content of unsaturated fatty acids and their saturation degree. Oxidation processes proceed the quicker when the bigger surface is affected by contact with oxygen in air, the quicker is diffusion of oxygen in mass the higher is temperature and the longer is time to the light exposition [4, 9, 10].

Research methodology

The main purpose of research was to establish susceptibility to oxidation one of the functional quality factors of soybean seed cake.

During these research the natural soybean seed cake and the extracted fractions were considered. The composition of grains that is fragmentation of soybean seed cake was marked according to PN-89/R-64798 by mechanical passing through the sieve of soybean seed cake samples with water content 10% through the set of grids: 3 mm, 1.2 mm, 0.4 mm, 0.25 mm, 0.1 mm and 0.075 mm with use of mechanical shake machine.

Before the research were commenced, the composition of soybean seed cake grains was determined.

Susceptibility to oxidation of soybean seed cake by oxygen in air with temperature 20°C and relative humidity 60% was determined by oxygen analyzer BA4000 and instrument TGAK-3 that prepares gas atmosphere. Research of susceptibility to oxidation process of soybean seed cake consisted in cycle measuring of oxygen depletion in reaction system (Fig. 1).

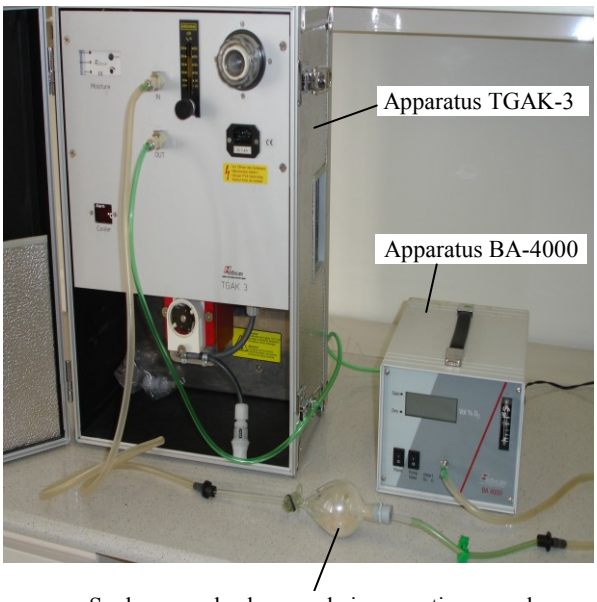

Fig. 1. Set of instruments TGAK-3 and BA 4000 for research of soybean seed cake susceptibility to oxidation [own study]

The soybean seed cake samples with 10 g by mass were placed in reaction vessel that is element

of researching instrument working in enclosed system. In the air flowing above sample surface with steady speed (that is assured by instrument TGAK-3) the oxygen concentration was continuously measured by oxygen analyzer BA4000.

Research results

Research results on susceptibility of soybean seed cake and its fractions to oxidation are presented both, in tables 1 and 2 and in figures 2 to 4.

Table 1. Susceptibility of soybean seed cake and its fractions to oxidation [own study]

Natural soybean / Fractions	Oxygen content in reaction vessel (%) during the successive days of measuring										
	Initial test	3	6	9	12	15	18	21	24	27	30
Natural soybean seed cake (O)	20.9	20.1	19.6	19.2	18.5	18.0	17.7	17.0	16.8	16.8	16.8
A	20.9	20.0	19.6	19.3	18.7	18.5	17.9	17.2	17.0	17.0	17.0
B	20.9	19.6	19.0	18.7	18.5	17.7	17.1	16.8	16.5	16.5	16.5
C	20.9	18.9	18.4	18.0	17.4	16.5	16.1	16.0	16.0	16.0	16.0
D	20.9	19.0	18.6	18.1	17.1	16.2	16.0	16.0	16.0	16.0	16.0
E	20.9	18.8	18.4	17.9	17.0	16.2	16.0	16.0	16.0	16.0	16.0
F	20.9	18.8	18.3	18.0	16.9	16.2	16.0	15.9	15.9	15.8	15.8
G	20.9	18.8	18.2	18.0	16.9	16.0	15.8	15.8	15.8	15.8	15.8

Table 2. Depletion of oxygen in reaction vessel with natural soybean seed cake and its fraction during successive days of measuring [own study]

Natural soybean / Fractions	Depletion of oxygen (%) in successive days of measuring									
	3	6	9	12	15	18	21	24	27	30
Natural soybean seed cake (O)	0.8	1.3	1.7	2.4	2.9	3.2	3.9	4.1	4.1	4.1
A	0.9	1.3	1.6	2.2	2.4	3.0	3.7	3.9	3.9	3.9
B	1.3	1.9	2.2	2.2	3.2	3.8	4.1	4.4	4.4	4.4
C	2.0	2.5	2.8	3.5	4.4	4.8	4.9	4.9	4.9	4.9
D	1.9	2.5	2.8	3.8	4.7	4.9	4.9	4.9	4.9	4.9
E	2.1	2.5	2.9	3.9	4.7	4.9	4.9	4.9	4.9	4.9
F	2.1	2.6	2.9	4.0	4.7	4.9	5.0	5.0	5.1	5.1
G	2.1	2.7	3.0	4.0	4.9	5.0	5.1	5.1	5.1	5.1

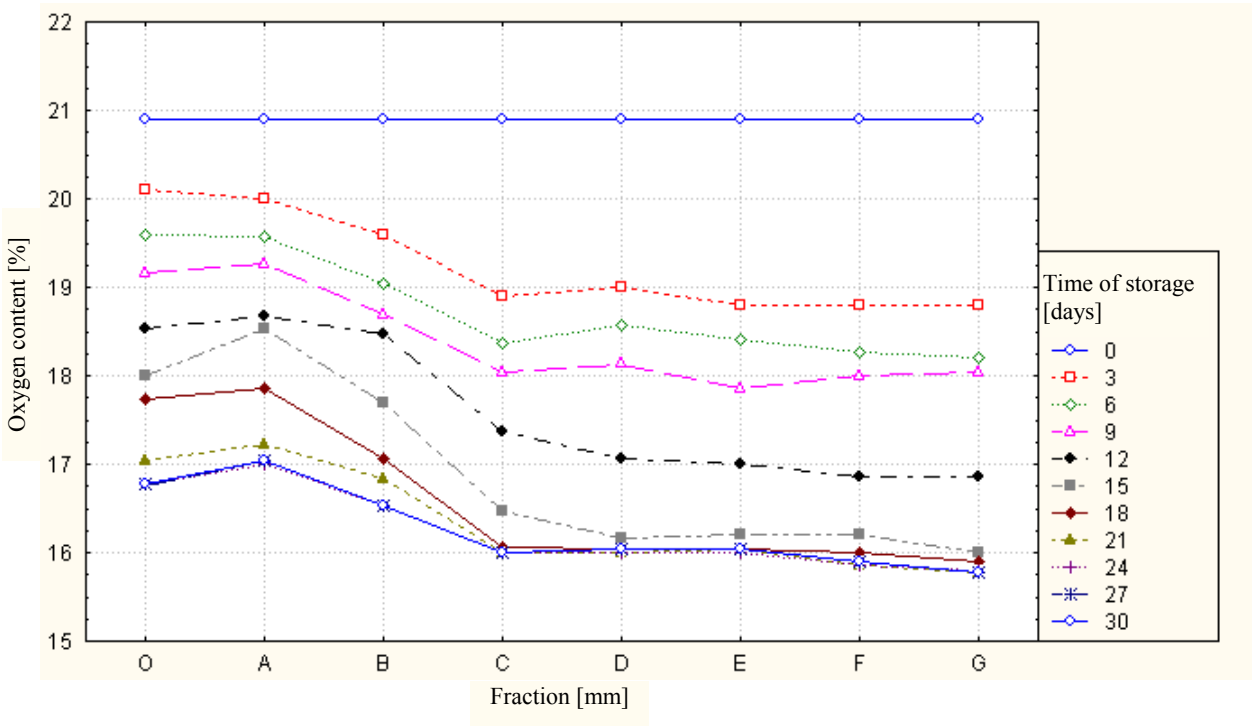

Fig. 2. Changes in oxygen content during storage of natural soybean seed cake and its fractions [own study]

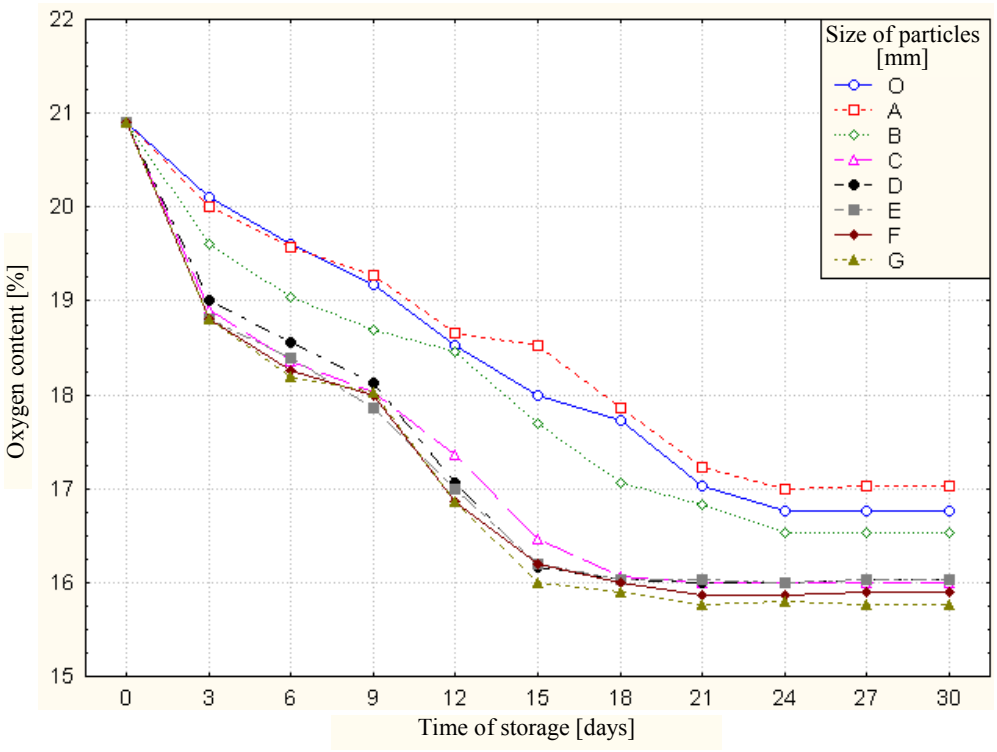

Fig. 3. Relations of changes in oxygen content in reaction vessel of soybean seed cake and its fractions since time of storage [own study]

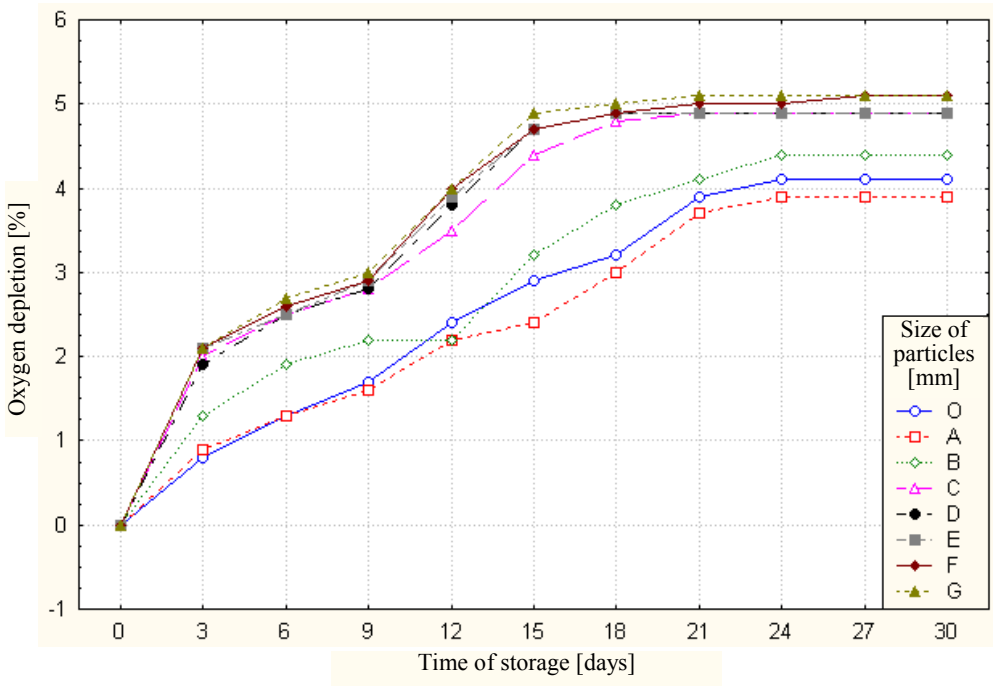

Fig. 4. Oxygen depletion in reaction vessel of soybean seed cake and its fractions since time of storage [own study]

During 30 days of storage oxygen depletion in reaction vessel with natural soybean seed cake was 4.1%. The biggest oxygen depletion that was 5.1% appeared during storage of fractions: containing particles with size of 0.075–0.1 mm (F) and in smaller particles than 0.075 mm (G).

Along with reducing of particle size of soybean seed fraction, susceptibility to oxidation was increasing. Correlation factor of dependability between susceptibility of soybean seed to oxidation and the particles size of tested soybean seed was 0.53.

Along with storage time passing, oxygen content was significantly depleted in reaction vessel of soybean seed (Fig. 3) and the same oxygen depletion was going up (Fig. 4).

The value of correlation factor between oxygen content in reaction vessel and storage time was 0.86.

Time of determining of constant oxygen content in reaction vessel was directly proportional to particles size and was appropriately for:

- Natural soybean seed cake and its fraction with particles size bigger than 3mm and fractions in range of 1.2 ÷ 3 mm – 24 days;
- Fractions 0.4 ÷ 1.2 mm – 21 days;
- Soybean seed with particles size smaller than 0.4 mm – 18 days.

Discussion of results and conclusion

There have been made the research in the trend changes of functional quality factor, which was susceptibility of soybean seed cake to oxidation by oxygen in the air in temperature of 20°C and relative humidity 60%.

The adopted research model was corresponding to the condition close to the very often existing during storage, handling and transportation by various means of transport.

The flaked soybean seed cake from import and seven distinguished its fractions were used as the research material.

The initial fat content in tested soybean seed cake was equal to 2%.

It is known from literature survey [4, 10, 11, 12] that along with passage of storage time and increase of temperature, oxidation speed was increasing too. Data obtained during the research and showed in this paper have demonstrated that during storage of natural soybean seed cake and its fractions in period of 30 days, speed of oxidation processes was initially growing up to the moment when the balance condition was determined (Tab. 1).

Time of settling the constant oxygen content in reaction vessel was directly proportional to particles size and was equal for the case of natural soybean seed cake and its fractions to 24 days for particles size bigger than 3 mm and for range 1.2÷ 3 mm. In case of fractions 0.4÷1.2 mm, it results 21 days and for fractions smaller than 0.4 mm 18 days.

During storage of natural soybean seed cake the oxygen depletion in reaction vessel was equal to 4.1% of oxygen. Along with reducing the size of particles oxygen depletion was increasing and for the finest fractions with particles size smaller than 0.075 mm was equal to 5.1% of oxygen (Tab. 2).

Conclusions

On the basis of results of research and statistical analysis, the following conclusions have been formulated:

1. Long time of carrying soybean seed cake by sea transport and specific micro climatic condition existing in ships' cargo holds create favourable condition for adverse transformation in fats.
2. Size of soybean seed cake particles significantly affected oxygen depletion during storage of soybean seed cake.
3. Oxygen depletion during storage of soybean seed cake in enclosed space, being the synthetic measure of course of oxidation process, was bigger in case of fine soybean seed fractions in comparison to natural soybean seed cake. Oxidation processes in fine fraction were proceeding quicker.
4. During storage of natural soybean seed cake and its fractions in period of 30 days, speed of oxidation processes was initially growing up to the moment when the balance condition was determined.

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