Labgrãos Magazine – v.1, n.2, 2017
ISSN 2594-7141

Changes in soybean quality during storage

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In Brazil, the 2016/2017 soybean crop showed an increase of almost 20% in production compared to the previous crop. This means that almost half of the grains produced in Brazil are soybeans.

Even with the high production, losses in the productive chain are high and difficult to quantify. It is well-known that a great quantity of grains is lost in the highways when the crop is transported. However, qualitative losses are quieter and are a danger to the safety of foods made from grains.

The Brazilian Normative Instruction (IN MAPA 37/2007) establishes the technical regulation of the soybean and defines its official standard of classification, with the requirements of identity and quality. By quality, it is understood the set of extrinsic or intrinsic parameters or characteristics of a product or a process, which allow to determine its qualitative-quantitative specifications, through aspects related to defects tolerance, measure or content of essential composition factors, organoleptic characteristics, hygienic-sanitary or technological aspects.

During post-harvest, soybeans undergo through a series of steps until processing. Many of these operations can reduce the quality of the grains and compromise its subsequent conservation. The knowledge of the physical, chemical and biological characteristics of the grains can help to minimize the loss of quality through proper handling.

The main external factors affecting the grain ecosystem are the temperature and relative humidity. The variation of the ambient temperature can be extreme, from values below zero to above 40 °C, and may have positive or negative implications on the extent of losses during storage.

Relative humidity is another factor that can present large variations, from 10 to 20% in deserts or very dry places to about 90% in the tropics. The combined effect of relative humidity and temperature at a particular storage location determines the activity of all the biotic components of the system, which lead to safe storage or grain losses. In grains with high levels of unsaturated fatty acids, such as soybeans, technical decisions must be taken to avoid deterioration and preserve quality.

For storage, there is not a specific moisture content defined but a range of moisture content depending on the physical properties of each species, temperature, storage time, and even the characteristics of the variety and grain quality, which includes the percentage of impurities, damaged grains and other factors.

The chemical reactions involved in the respiratory process are controlled by enzymes. Higher moisture contents favor the biological activity of soybeans because the enzymes and substrates are more easily mobilized for the process. The higher the temperature, the greater will be the metabolic activity of the grains, thus increasing the deterioration of the raw material.

The natural respiration of moist grain and fungi consumes O_2, which drops from about 21% in air to 1 or 2% and produces CO_2, which goes from about 0.035% in air to almost 20%. Under anaerobic environment, the death of insects and mites occurs more easily, besides preventing the growth of aerobic microorganisms.

"The lipid fraction of the soybean grains is the most susceptible to degradation during storage"

Occasionally, if the grains are very moist, yeast and lactic bacteria will multiply. Generally, high levels of CO_2 and reduced O_2 keep th quality of grains stored for long periods. The fundaments underlying controlled and modified atmosphere technologies include reduced respiration rate, microbial growth, and enzymatic deterioration by reducing oxygen levels in the storage environment.

The quality of soybeans commercialized in Brazil is mainly related to the content of damaged grains. Damaged whole or broken grains are those described as burnt, moldy, fermented, germinated, damaged, and immature.

A characteristic of stored soybeans is acidification of its lipid fraction, which occurs more rapidly at higher moisture contents and temperatures. Greater amounts of foreign matter, stones, crushed and peeled grains also favor acidification.

The main post-harvest operations that can cause quality losses and increase the number of defects in the grains are drying and storage. In the case of soybean, inadequate handling in these operations results in rancidity of oil (lipids), degradation of proteins, and changes in the bioactive compounds of soybean.

Changes in lipids

The lipid fraction is the most susceptible to degradation during storage. In a more generalized classification, lipids comprise two groups, the apolar or neutral lipids (glycerides, waxes, and steroids) and the group of polar lipids (phospholipids and other complex lipids). Lipids are esters of fatty acids with alcohol and in foods are mostly fatty acids with linear chain, which may or may not present double bonds. Thus, fatty acids are divided into saturated and unsaturated fatty acids (Figure 1). The higher the degree of unsaturation in the linear chain of fatty acids, the less stable the oil will be, and more susceptible to degradation during drying and storage processes.

The most expressive components of soybean oil are triglycerides and their physical properties depend on the structure and distribution of the fatty acids.

Considering that soybean possess 18-22% of oil, evaluations in this fraction are considered a good quality indicator. Oil rancidity can occur in two forms: hydrolytic and oxidative.

In the hydrolytic rancidity, the action of the lipase enzyme present in the grains is responsible for the breakage of the ester bonds of glycerides, increasing the free fatty acid content, that is, the acidity of the oil. On the other hand, oxidation occurs in the unsaturations of fatty acids, with formation of hydroperoxides (primary oxidation products), and which can decompose into volatile compounds of lower molar mass (secondary oxidation products), such as alcohols, aldehydes and ketones.

Oxidation of lipids not only produces rancidity, odors and flavors, but can also decrease the nutritional quality of soybean. One of the many methods to limit lipid oxidation is the use of modern packaging technology, such as hermetic packaging and oxygen absorptive packaging.

Studies have shown that the increase in primary oxidation products may occur exponentially when grains are improperly stored (Figure 2). However, the use of low temperatures can reduce the rate of oxidation.

It is important to note that the peroxide index may be a good indicator of lipids oxidation. The primary oxidation products may be converted to secondary oxidation products and, thus, masking the oxidation state of the grains. The anisidine index is a parameter that quantitates the secondary oxidation products, being especially important for soybeans stored at hot climates, where the level of oxidation may reach a high stage.

Soybeans have 6 to 8% of linolenic acid in their fatty acid profile. Linolenic acid (C18:3) is a polyunsaturated fatty acid that has three double bonds in its chain. Due to the high instability, linolenic acid is the most susceptible fatty acid to degradation processes. A study conducted at Labgrãos showed a reduction of 10% of linolenic acid in soybeans stored inadequately (moisture content of 16%, w.b.) for six months (Figure 3).

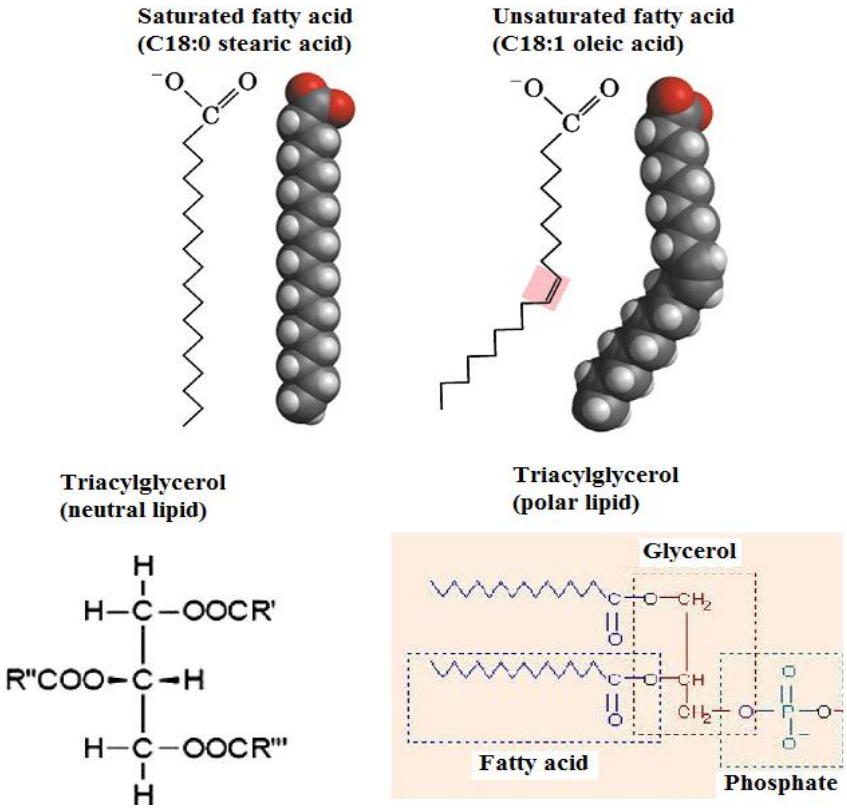

Figure 1. Lipid molecules (neutral and polar) and fatty acids (saturated and unsaturated).
Adapted from Halim et al., Biotechnology Advances, v 30, p. 709-732, 2012.

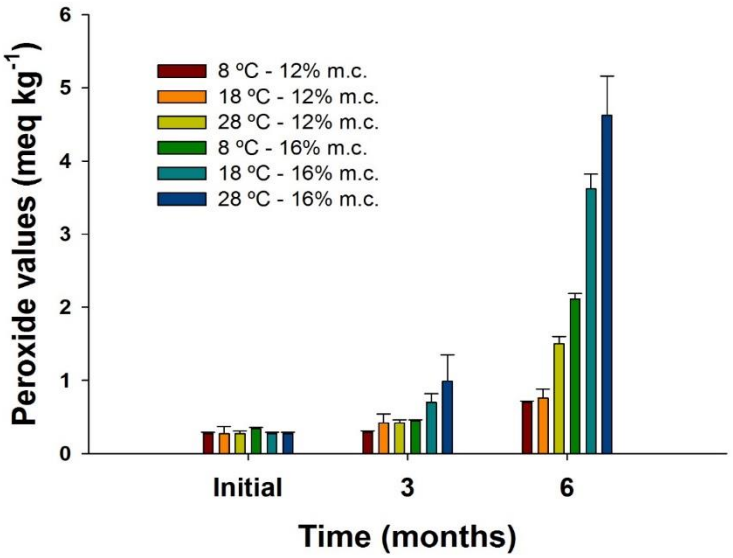

Figure 2. Peroxide values of soybeans stored under different moisture contents and temperatures. Result of research performed at Labgrãos, in 2017.

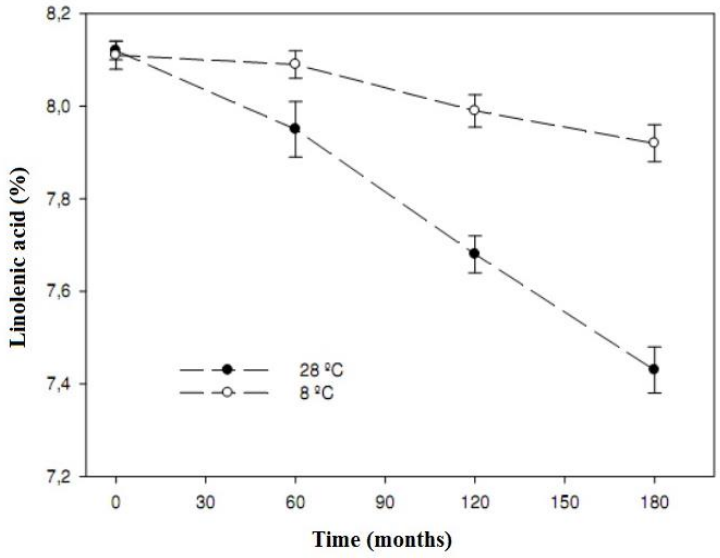

Figure 3. Influence of storage temperature on linolenic acid from soybean grains. Result of research realized at Labgrãos (2017).

Bioactive compounds

Recently, studies have been conducted to verify the changes in soybean bioactive compounds during post-harvest processing.

In soybean, phenolic acids (mainly vanillic, caffeic, ferulic, protocatecuic and cumaric acid) and flavonoids (mainly quercetin and isoflavone glycosylated isoforms) are well known for their antioxidant, anti-inflammatory and anticarcinogenic properties.

Unlike phenolic acids and flavonoids, which are hydrophilic constituents, carotenoids and tocopherols are lipophilic and are found in the lipid fraction. Carotenoids are precursors of vitamin A, and tocopherols (vitamin E) possess antioxidant activity and the ability to prevent carcinogenesis and coronary disease.

The amount of phytochemicals in soybean varies depending on grain genotype (for example, tegument color, grain size), environmental factors (temperature and precipitation), and post harvesting and processing operations (heating, drying temperature, storage period, and hydrothermal treatment). The uninterrupted consumption of soybeans makes its storage a key step in enabling grain supply throughout the year.

A study carried out at Labgrãos in 2016 found that soybeans stored for one year at 15% moisture content and temperature above 18 °C exhibit a decrease in the content of carotenoids and tocopherols.

Soy protein

Soy proteins are applied in various food products, such as dairy products, pasta, and a variety of nutritional supplements due to their excellent functional (protein solubility, absorption capacity of water and oil, emulsifying capacity and foaming), and bioactive properties. These proteins are composed primarily of globulins, which can be extracted with diluted saline solutions.

The quality of soy products, such as tofu and soymilk, which are mainly produced and consumed in the Asian continent, is directly influenced by the quality of soy protein.

Exposure of soybeans to adverse storage conditions is one of the main causes of reduced protein extractability and structural changes in the soy protein, such as denaturation, glycosylation, strengthening of disulfide bonds, and decreased hydrophobic surface area, which ultimately reduce tofu and soymilk yield.

Soy protein concentrate is rich in isoflavones, which have been cited for their health benefits, including protection against uterine cancer, relief of menopause symptoms, treatment of inflammatory diseases of the airways, and prevention of oxidative damage.

Another study conducted at Labgrãos in 2017 revealed that improper storage conditions may reduce the extraction yield and protein solubility of soy protein isolates, with increased emulsifying capacity and foam formation.

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