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Storage stability of three genotypes of sunflower seeds

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ABSTRACT

Sunflower seeds (*Helianthus annuus L.*), due to their high oil content, are among the raw materials cited by the National Program of Biodiesel Production and Use (NPBP) with potential for the production of biodiesel. On the other side, seeds with high lipid content could be more sensitive to degradation that non-oil seeds. The objective of this project was to evaluate the stability of three genotypes of sunflower seeds, kept in two different raffia packages under two storage conditions: a constant temperature and humidity reference condition set at 25 °C/75% RH (Ref) and a cyclic, accelerated aging test (CW), built to reproduce the variation of temperature and humidity of a Center West production region, which was in average of 24 °C/71% RH, but with extreme temperatures of 17–32 °C and humidity of 24–96% RH. As all samples evaluated had almost the same fatty acid composition up to the end of ten monthsístorage, it was concluded that seed can be kept without significant loss of quality in the packaging materials and storage conditions evaluated. Cyclic accelerated aging generated different evolution profiles of the peroxide values and moisture levels when compared to the reference condition, with constant temperature and humidity. All seeds showed dehydration when undergoing the (CW) condition during the winter simulation period, the driest season among the evaluated. During fall, winter and spring simulation, the (Ref) condition generated higher peroxide values than the accelerated aging test. However, in the summer period simulation of the cyclic aging, the peroxide values of seeds packed in uncoated raffia increased by 32% (OL5), 9% (He250) and 90% (He 253). Laminated raffia showed a slightly higher performance than uncoated for seed preservation. The results found in this study show that storage at constant temperature and humidity conditions does not reproduce the sequence of degradation reactions which occurs due to the daily cyclic variation in temperature and humidity. This highlights, the importance of carrying out studies in laboratory conditions closer to reality for studying seed aging.

1. Introduction

1.1. Background

In 2000–2010 decade oil crop production has been among the most vibrant activities in world agriculture. The sector grew by almost 5 percent per annum; the major part as a vegetable oil. This expansion is of oils with high protein content which also produces oilmeals employed as feed. Sunflower seed is among the four most important oil crops: oil-palm, soybean and rapeseed that account for approximately 75 percent of world production (FAO, 2013).

Sunflower planting has grown in various parts of the world that have warm weather to semi arid as it has good drought resistance and a relatively short growing season, ranging from 90 to 160 days. It also adapts to a wide variety of soils (FAO, 2010).

Brazilian production of sunflower seed (*Helianthus annuus L.*) has grown significantly in recent years. Between 2005 and 2013, there was an increase of about 80% when 109,000 tons were produced. This growth is due mostly to planting in the Center-West region of Brazil, currently responsible for 83% of the country's production (IBGE, 2015).

The National Program of Biodiesel Production and Use—NPBP which has been in operation in Brazil since 2005, is based on the possibility of producing biodiesel from different oleaginous sources (ANP, 2014). Sunflower seeds, due to their high oil content, are

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among the raw materials cited by NPBP with potential use for the production of biodiesel. Most biodiesel is produced using soybean through a complex solvent extraction process. Sunflower oil production is much simpler with just pressing required. As sunflower can be grown in varied soil and climatic conditions, small farmers have the advantage of a cheap biodiesel production source for their machinery and sell off the surplus for extra income (Porte et al., 2010).

1.2. Sunflower seed storage studies

Due to the high content of lipids, these seeds are more sensitive to deterioration than other non-oil seeds (Balešević-Tubić et al., 2010). Considering also the seasonality of any biomass, it is extremely important to know the stability of this raw material during storage. The deterioration of seeds with loss of their germination over time is a well-known fact. Understanding the mechanisms that lead to this deterioration has been studied by many researchers, since the efficiency of germination is of great economic importance. Walters (1998) states that the factors that determine the rate of this "aging" are temperature, moisture content and the intrinsic quality of seeds.

High temperature (45 °C) and high humidity (100% RH) inhibit seed germination and seedling sunflower (Corbineau et al., 1988). Bailly et al. (1996) suggest that sunflower seed deterioration during accelerated aging (45 °C and humidity between 76 and 100% RH) is closely related to a decrease in activities of detoxifying enzymes and to lipid peroxidation.

Aging experiments with maize and sunflower seed (15, 20 and 25% RH, and afterwards maintenance at 40 °C for periods from 0 to 96 h) showed a greater loss of germination the higher the humidity (Stan, 1997).

Few changes in the content of lipids, in the proportion of saturated and unsaturated fatty acids, and in the percentage of free fatty acids were observed in sunflower seeds undergoing priming (7 days, 15 °C, solution of polyethylene glycol) or accelerated aging (5 days, 45 °C, water, 100% RH). Electron microscopy of these seeds, however, revealed that lipid bodies became smaller and more dispersed throughout the cytoplasm during priming and aging (Walters et al., 2005).

A study on the effect of storage conditions on the quality of sunflower seeds for the purpose of preservation of germplasm was carried out by José et al. (2010), a group of researchers at Embrapa. Seeds dried by various drying processes (chamber at 22 °C and 18% RH) and silica gel up to final moisture values ranging between 2.1 and 10.2% were stored in liquid nitrogen (−196 °C) and a freezer (−20 °C). All seeds showed high levels of germination after three months of storage. It was found that seeds stored in normal atmosphere (peroxide value between 14.16 and 24.06 mEq kg^{-1}) had a higher degree of oxidation than those stored in liquid nitrogen (peroxide value between 2.6 and 12.7 mEq kg^{-1}) probably due to the larger concentration of oxygen in the chamber atmosphere. In this work, although large variations in peroxide value were observed it was not possible to correlate them with high or low moisture content of the seeds.

Sunflower seed (cv. BRS 122) kept in paper and vacuum-sealed plastic bags at three different temperatures (10, 25 and 30 °C), and up to four months of storage, maintained its physiological quality. After this period seed quality decreased. Oil content, enzyme reduction and disintegration of cellular components were observed. The best preservation condition was Kraft paper sacks kept at 10 °C (Lins et al., 2014).

Aging of sunflower seed at 35 °C and moisture contents (MC) ranging from 0.04 to 0.48 g H_2O g^{-1} dry matter showed that seed viability is affected by MC and is related to accumulation of hydrogen peroxide and changes in energy metabolism (El-Maarouf-Bouteau et al., 2011). These authors proposed the following mechanism for seed death: when the moisture content of seed increases, lypoxygenase, an enzyme that produces free radicals is activated and respiration resumes at 0.08 g H_2O. These events produce ROS (radical oxygen species) which leads to lipid peroxidation by-products, inducing factors for PCD (controlled programmed cell death) through DNA alteration and mitochondrial dysfunctioning.

These studies reveal that there is still no complete understanding of the mechanisms that lead to the deterioration of stored seeds, but there is a general consensus that the moisture content and temperature conditions of storage play key issues in these processes.

Another aspect that is important to consider is the availability of water in the seeds to promote any subsequent reaction. Labuza (1971) demonstrates that the degradation of various foods is closely linked to water activity and their moisture content. The oxidation of lipids is faster in both low ($0 \sim a_w$) and high water activity ($a_w > 5$) than in intermediate situations ($0.2 < a_w < 0.5$).

The influence of humidity on the properties of cellulose fibers is well known and has been studied for many purposes. The moisture content of cellulose increases with relative humidity which affects many fiber properties such as dimension, stiffness, strength, stretch, water dependent reactions, exudation and shelf life, among others. When water penetrates into the fibers, it breaks the secondary interactions between cellulose macromolecules and is absorbed into the cell walls by hydrogen bonds, causing swelling of the fibers and loss of mechanical resistance (Rostic et al., 2008), and consequently, changing the permeation and solubility properties of its walls. The kinetic of absorption depends on the water content and the temperature. Irreversible mechanisms occur when the fibers are dried and re-humidified for long periods, such as in the processes that occur in natural environments (Baley et al., 2005). In the cellulose packaging area, the phenomenon of creep deformation is well known. Creep is affected by environmental conditions and only laboratory cyclic variations in humidity and temperature (accelerated creep test), within natural limits, can reproduce the types of failures found for packaging in real conditions. The deformations obtained after cycles of humidity and temperature exceed those in any condition of constant humidity (Alfthan et al., 2002).

Considering the results of these previous studies and with the aim of evaluating the storage stability of three genotypes in two different ambient conditions, the following experimental design was selected. The seeds were kept in two different packaging materials under two storage conditions that could be used by the industrial biodiesel sector. Low cost storage conditions and packaging materials were selected in order to avoid significant impact on the costs of biodiesel production.

2. Materials and methods

2.1. Seeds evaluated

The three seeds with genotypes identified as OL5, He 250 and He 253, shown in Fig. 1, were selected from a previous study (Regitano Neto et al., 2013), based on their profiles of fatty acid composition. These seeds were produced during the 2011/2012 crop season (sowed in December 2011, harvested in April 2012). Sunflower OL5 is a triple way cross hybrid—high oleic acid content from Atlantica Seeds and He250 and He 253 are single cross hybrids, standard fatty acid profile, from Heliagro Seeds.

2.2. Storage conditions

Two conditions were selected to study the behavior of seeds in this study. The first was a cyclic accelerated aging designed to