Li Y, Cao Y, Xu F, Zhao H (2012) Quality preservation of soybeans stored at low-oxygen conditions. In: Navarro S, Banks HJ, Jayas DS, Bell CH, Noyes RT, Ferizli AG, Emekci M, Isikber AA, Alagusundaram K, [Eds.] Proc 9th. Int. Conf. on Controlled Atmosphere and Fumigation in Stored Products, Antalya, Turkey. 15 – 19 October 2012, ARBER Professional Congress Services, Turkey pp: 144-155

QUALITY PRESERVATION OF SOYBEANS STORED AT LOW-OXYGEN CONDITIONS

Yanyu Li *, Yang Cao, Fuping Xu, Huiyi Zhao

Academy of State Administration of Grain, №11 Baiwanzhuang Street, Beijng, 100037, P.R. China, Tel: 86-10-68623707. Fax: 86-10-58523599
*Corresponding author's e-mail: *lyy@chinagrain.org*

ABSTRACT

A pilot-scale experiment for the evaluation of the effect of different low oxygen concentrations (2%, 4%, 6%, 8% and 21%) on the quality of stored soybean was carried out. The various oxygen concentrations were tested at temperatures of 20°C and 30°C. Monthly samples were taken for testing the quality parameters of soybeans stored at low oxygen conditions. The test results showed that: the low oxygen concentration in the system could be controlled within ±0.3% accuracy. The brightness of soybean powder did not change at different temperatures and oxygen concentrations; lightness remained between 67 and 69, hue -1.4 and -1.8, and chroma 15 and 17. The acid value of soybeans increased as the oxygen concentration increased and/or the storage time prolonged. Peroxide value of soybean increased with increase in oxygen concentration. The activity of the urea enzyme decreased; with temperature, oxygen concentration and storage time. The total protein, moisture and oil content remained constant, 38.57%, 8.50% and 20.87%, respectively. The results indicated that at 30°C, low oxygen could partly delay the change in soybean quality and at 20°C, the oxygen concentration should be sufficiently low to keep the soybean quality.

Key words: Argentina soybean, quality, storage, low oxygen

INTRODUCTION

Soybean is an important oil crop with a high nutritional value. To meet the increasing demand, soybean production has been increasing year by year in China. The different storage methods and storage time have obvious effect on the quality of soybean (Cao and Cui, 2005; Liu and Su, 2003; Lu, 1999). Because soybean is rich in protein (35%-40%) and fat (17%-22%), the storage stability is poor due to moisture absorption, mold development, increase in free fatty acids, and germination loss during storage. Compared with other crops, soybean storage needs more attention to prevent spontaneous heating for quality preservation (Cao and Cui, 2005). To meet the demand for high quality of food and without the use of chemicals, the storage technology of control atmosphere (CA) has reached the historic moment. CA storage technology is a green grain storage technology, which is an economic and effective method developed in P.R. China and abroad for commercial applications. There are several methods for generating modified atmospheres (MA), among them are; by the biological consumption of oxygen, oxygen absorption, catalytic converters that results in the alteration of the ratio of oxygen, nitrogen or carbon dioxide concentration in the grain bulk. Such MA leads to the control of pests and inhibits mould activity for retaining food quality during storage (Li, 2006). The objective of this investigation was to determine the quality parameters of soybeans stored under nitrogen atmosphere.

MATERIALS AND METHODS

Materials
Soybean imported from Argentina.

Reagents
Hydrogen gas, purity ≥99.995%; Helium gas, purity ≥99.995%; Aspartic acid, purity ≥99%, Ethyl ether, ethanol, acetic acid, methanol, petroleum ether, chloroform, strong sulfuric acid, strong hydrochloric acid, potassium iodate, potassium iodide, potassium hydroxide, sodium hydroxide, sodium thiosulfate, potassium dihydrogen phosphate, dipotassium hydrogen phosphate, sodium chloride, sodium molybdate, sulfuric acid hydrazine, phenolphthalein, anthrone, perchloric acid, trichloride ferric. All above were analytical reagents, obtained from Beijing chemical works. Deionized water was chemical pure.

Equipments and apparatus
FOSS 2055 crude fat radiomete, FOSS 2300 automatic protein radiometer (Denmark FOSS TECATOR company); PL403-IC electronic balance (accuracy 0.001 g), ML204/02 electronic balance (accuracy 0.0001 g)(METTLER TOLEDO (Shanghai) instrument Co., LTD.); THZ-D desktop constant temperature oscillator (HUAMEI biochemical instrument factory, Taicang); RJ-TDX-50A centrifuge (RUN JIANG company, Jiangsu); LAMBDA35 ultraviolet-visible spectrophotometer (PerkinElmer instrument Co., LTD., USA); CR-400 brightness instrument (KONICA MINOLTA Co., Japan).

Experimental Methods
The oil content, crude protein, water-soluble protein, fatty acid value, peroxide value and moisture content were determined according to GB/T14488.1-2008, GB/T5511-2008, NY-T1205-2006, GB5510-85, GB/T 18868-2002 and GB/T 5497-1985, respectively. The color was analyzed by color meter.

Low oxygen atmosphere storage of soybeans
The volume of the gas tank was 200 L, equipped with the sampling port, air inlet and air outlet, and sensor connecting port for detecting oxygen concentration (a monitoring system with recorder), and temperature-humidity(Safestore$^{@}$ made in USA). The sensor could record the change of the oxygen, temperature and humidity in the system at real-time. Tank gas tightness was tested by half-life pressure decay time, in which pressure from 300 Pa to 150 Pa was longer than 5 min. .

Soybeans were stored at two temperatures, 20°C and 30°C, in climate controlled chambers for testing the bean qualities under MA.

The moisture content of the stored soybeans was 8.5% wet basis. The corresponding equilibrium relative humidity of the beans was 40% (20°C) and 50% (30°C). To ensure prevent moisture loss during storage, the relative humidity of the filled nitrogen was also kept in the range of the corresponding equilibrium relative humidity.

A machine produced nitrogen based on membrane-separation system (MSS) with maximum flow of nitrogen (N_2) 35 m^3/h and maximum N_2 concentration 99% (v/v%). According to the operation procedures, it takes 5 min to establish a constant concentration of

N_2 at the outlet. When the O_2 is stable, the gas could be used. For example for a target O_2 concentration of 2%: the N_2 concentration is adjusted to 98%; the top and bottom valves of the soybean tanks are kept open; then connect the vent hose of MSS to the top valve and at the same time observe the O_2 concentration on the recorder. When the concentration is stable within 2%±0.3%, remove the vent hose, and quickly close the top and bottom valves of the tanks. If there is no change for 10 min in gas concentration, we can assume that gas filling has been completed, otherwise, repeat the process, until the concentration of the gas in the tanks are stable.

The tested groups with different O_2 concentrations were of 4%, 6% and 8%.

RESULTS AND DISCUSSION

Chroma analyses of soybean stored at low-oxygen

Generally, color is considered as one of the parameters to determine quality changes of stored soybeans. In addition, the color of the oil affects the fat quality (Li, 2006). Figures 1 to 6 show the change in color of soybean at different temperature and oxygen storage conditions.

Figures 1 to 6 show that storage temperature, storage time and oxygen concentration had no significant effect on the chromaticity of soybeans. The lightness (L) was between 67.5 and 68.5, chromaticity (a) was -1 and -1.8, saturation (b) was 15 and 17.5.

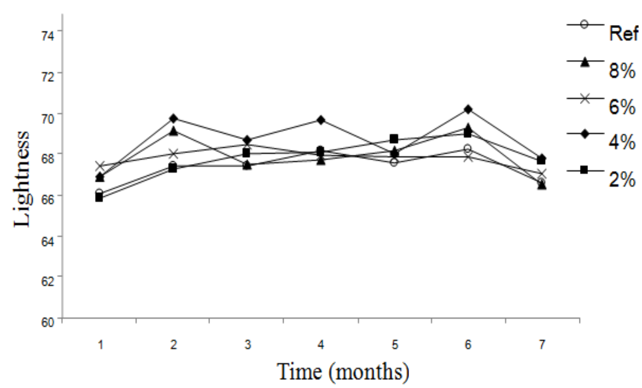

Fig. 1- The lightness (L) of the soybeans under different oxygen concentration conditions at 20°C.

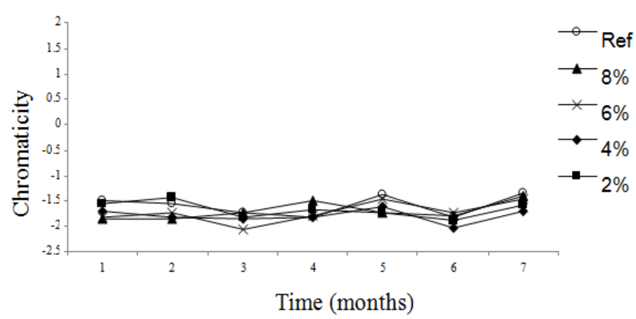

Fig. 2- The chromaticity (a) of the soybeans under different oxygen concentration conditions at 20°C.

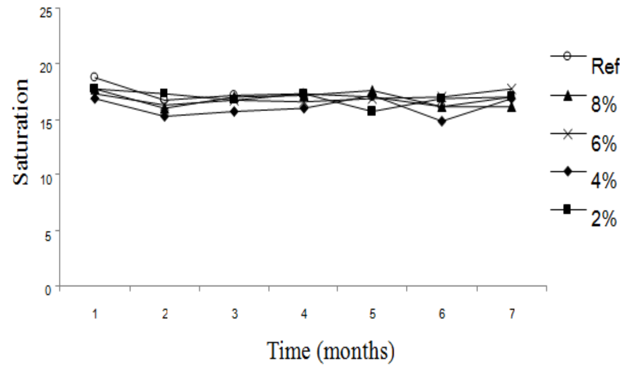

Fig. 3- The saturation (b) of the soybeans under different oxygen concentration conditions at 20°C.

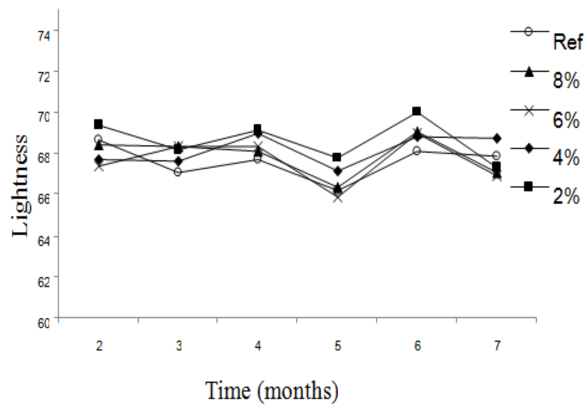

Fig. 4- The lightness (L) of the soybeans under different oxygen concentration conditions at 30°C.

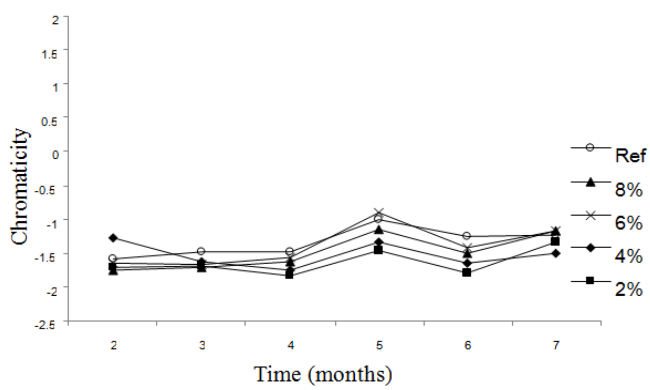

Fig. 5- The chromaticity (a) of the soybeans under different oxygen concentration conditions at 30°C.

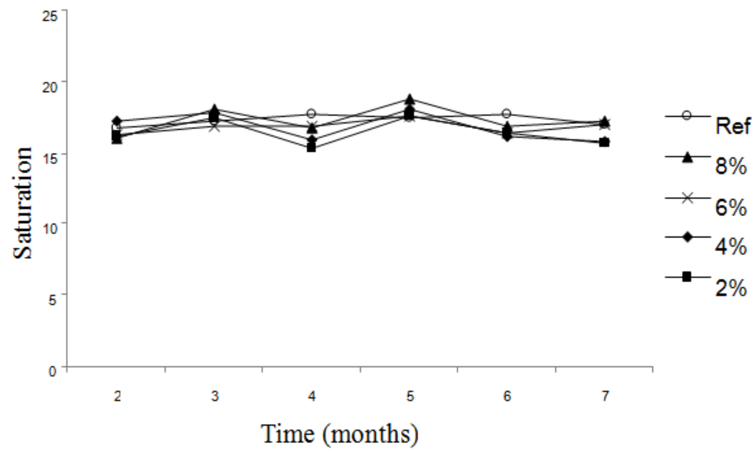

Fig. 6- The saturation (b) of the soybeans under different oxygen concentration conditions at 30°C.

Acid value analyses of soybean stored at low-oxygen

Acid value is a very sensitive index to decide the soybean oil quality; it directly influences the soybean oil grade. The higher acid value indicates free fatty acid development caused by the activity of oil hydrolysis. Figures 7 and 8 show the effects of different temperatures and low-oxygen storage conditions at different storage times on the changes of acid values.

From results in Fig. 7, we can conclude that at 20°C and low-oxygen storage conditions, the acid value of soybeans have no significant changes in the first 4 months, but from the fifth month, the changes in the acid values are significant. Between 21% to 4% oxygen concentrations, the acid value increased as the oxygen level increased. However, the acid value at 2% oxygen concentration is higher than 4%. The result indicated that low oxygen was adverse for soybean storage and 4% low oxygen concentration is more favorable for preserving soybean acid value.

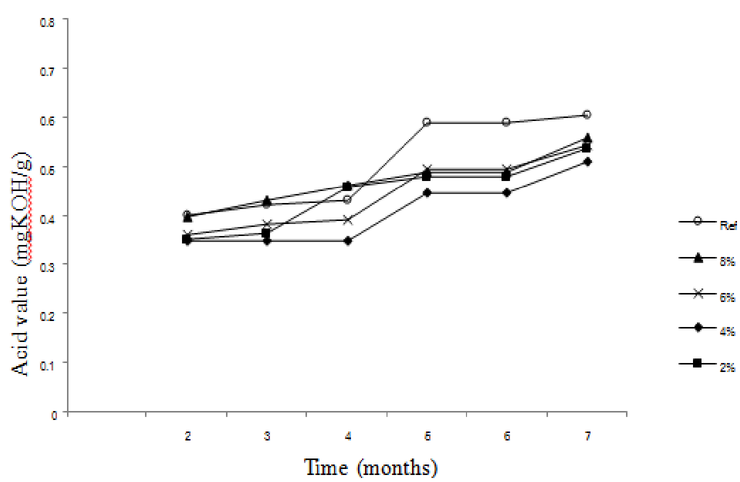

Fig. 7- The acid value of the soybeans under different oxygen concentration conditions at 20°C.

Results in Fig. 8 show that at 30°C, the trend in acid value change was in agreement with that at 20°C. At relatively high temperature conditions, low oxygen better prevented change in acid value. The acid value was in agreement with that at lower temperature (20°C) conditions.

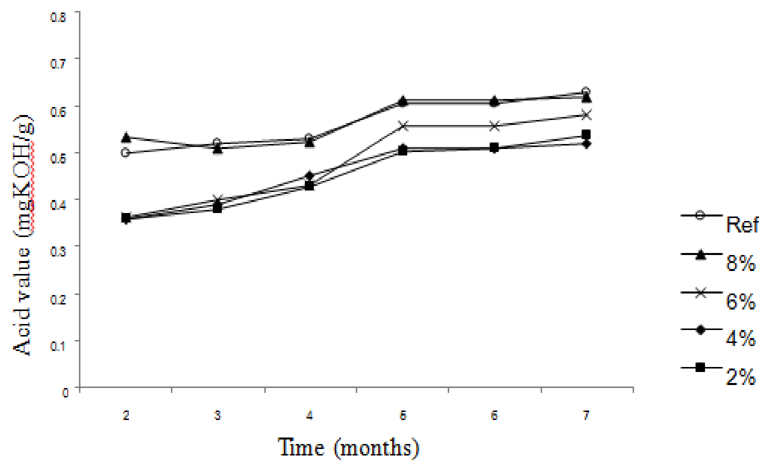

Fig. 8- The acid value of the soybeans under different oxygen concentration conditions at 30°C.

Storage at 4% oxygen appears appropriate for maintaining soybean quality, because on the one hand, the soybean acid value change could be delayed, on the other hand, in term of the efficiency of making nitrogen from the MS, 4% low oxygen concentration is relatively easy to achieve and the efficiency is also the highest. At high temperatures, reducing oxygen concentration appears an option to inhibit the change in the soybean acid value.

Peroxide value analyses of soybean stored at low-oxygen

Peroxide value is an index to measure how much unsaturated fatty acid was oxygenized and how much the double bond was oxidized. The small molecules, such as aldehydes, ketones and acids produced by hydrogen peroxide decomposition have strong pungent smell on the product. If the small molecules are further oxygenized, the produced level 2 dioxide is hard to be metabolized in the human body. Determining the degree of the fat oxidation is very important (Li, 2006). Figures 9 and 10 show the changes in peroxide value of soybeans at low-oxygen and storage time.

From Figures 9 and 10, we could see that the effect of storage time on the peroxide value is not significant. Low temperature and low oxygen environment helped reducing fat oxidation. The lower the oxygen concentration, the lower was the peroxide value. The results suggested that the low oxygen affected the soybean to be a stable environment; it restricted soybean respiration, slowed synthesis and metabolism of soybeans, and delayed the rise of peroxide value. To prevent oxidation of the soybean products and the soybean oil, quality preservation of the soybean in storage should be ensured. In addition to the drying after harvest, low temperature and low oxygen storage is needed to prevent fat oxidation.

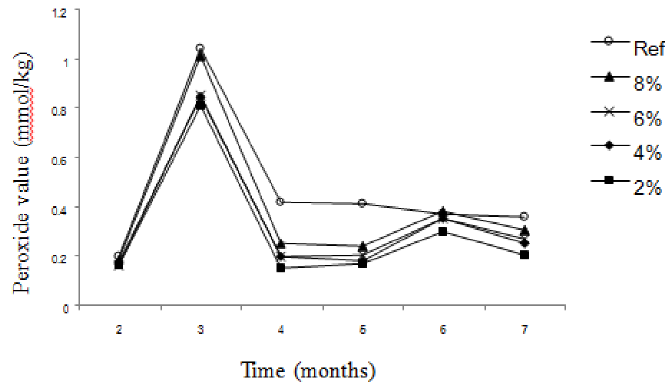

Fig. 9- The peroxide value of the soybeans under different oxygen concentration conditions at 20°C.

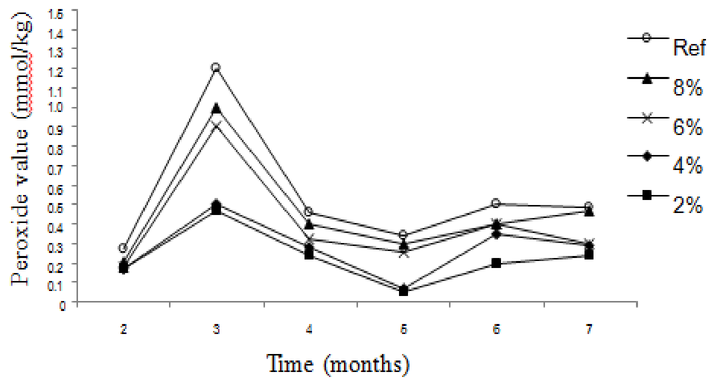

Fig. 10- The peroxide value of the soybeans under different oxygen concentration conditions at 30°C.

Urea enzyme activity of soybean stored at low-oxygen

The raw soybean not only is rich in protein, fat, carbohydrate and nutrition ingredients, but also contains a variety of anti-nutritional factors which could be damaged by heat. Anti-nutritional factor is a floorboard of the substances which was produced from plant metabolism and had an anti-nutrition effect on animals and in different mechanism, such as anti-trypsin factor, anti-vitamin factor and so on. Among them, the effect of anti-trypsin factor on animals is predominant. Anti-trypsin factor, which can disturb the function of the protein digestive enzymes in the small intestine, plays the role of protein decomposing enzyme in the inhibitory substance. These anti-nutritional factors not only affect the palatability, but also affect the nutrition value of animal feed, the digestion and absorption of the substances and some physical processes in the body, and accordingly present some threat to animal health. The enzyme called urea is one of the several natural enzymes contained in the soybean meal. Urea enzyme is not the anti-nutritional factor, but its content in the soybean meal is proportional to the content of anti-trypsin factor. Because of the activity of the urea enzyme is easy to determine, compared to anti-trypsin factor, the method of determining the activity of urea enzyme, Kauai, was usually adopted to evaluate the quality of the soybean. Under the low-oxygen storage conditions, the change of the urea enzyme activity of soybeans with the change of the storage time was shown in Figures 11 and 12.

These results indicated that with the extension of the storage time, the activity of the soybean urea enzyme has a trend of decreasing. There were no significant differences between different storage temperatures and low oxygen levels. Accordingly, low temperature and low oxygen were not enough to inhibit the activity of urea enzyme.

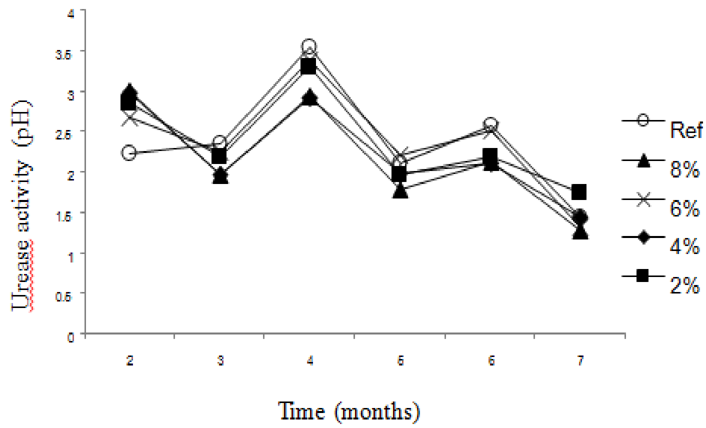

Fig. 11- The urease activity of the soybeans Urea enzyme under different oxygen concentration conditions at 20°C.

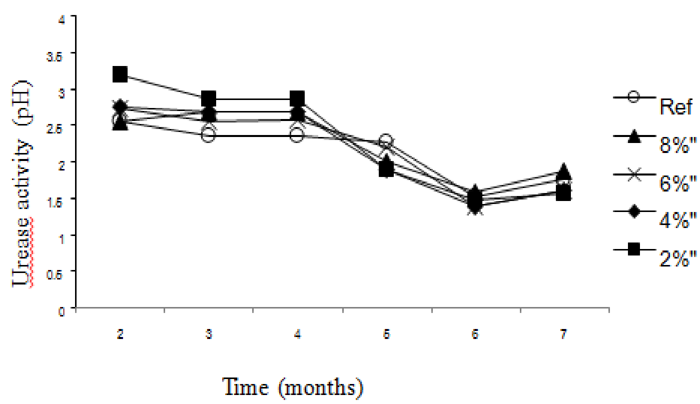

Fig. 12- The urease activity of the soybeans Urea enzyme under different oxygen concentration conditions at 30°C.

Total protein content analyses of soybean stored at low-oxygen

Under the low-oxygen storage conditions, the peroxidizing degree of soybeans with the change of the storage time was shown in Figures 13 and 14.

The results show that, at low-oxygen, the total protein content is maintained between 38.5% - 39.5%, and didn't change by storage time at different oxygen concentrations.

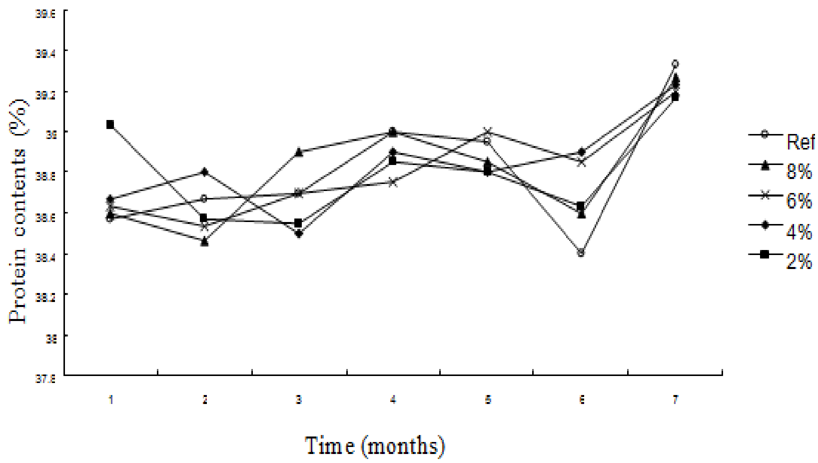

Fig. 13- The crude protein content of the soybeans under different low-oxygen concentration conditions at 20°C.

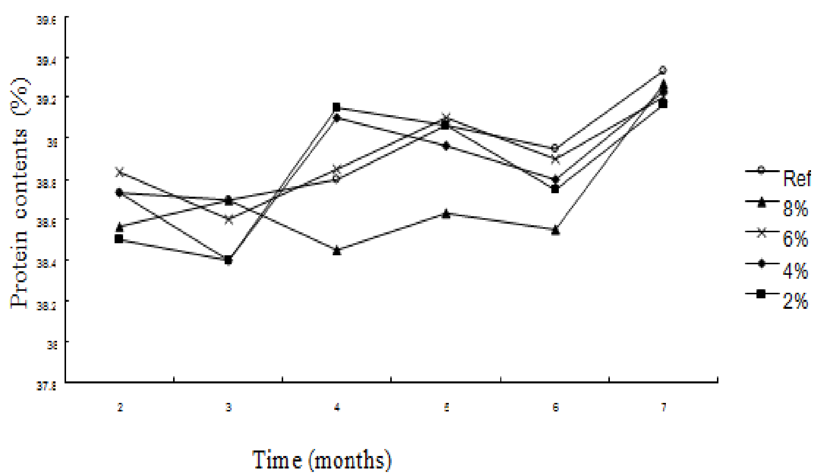

Fig. 14- The crude protein content of the soybeans under different low-oxygen concentration conditions at 30°C.

Oil content analyses of soybean stored at low-oxygen

One of the main usages of stored soybean is producing oils and fats (phospholipids). After a period of storage, the amount of oil extracted, is an important parameter to evaluate storage technology. Under the low-oxygen storage conditions, the change of oil content of soybean with the change of storage time was shown in Figures 15 and 16.

The results show that, the changes of the crude fat content with time are not significant and they remained between 20% and 21%. Therefore, the conditions of low-oxygen have no significant effect on the content of crude fat in the process of soybean storage.

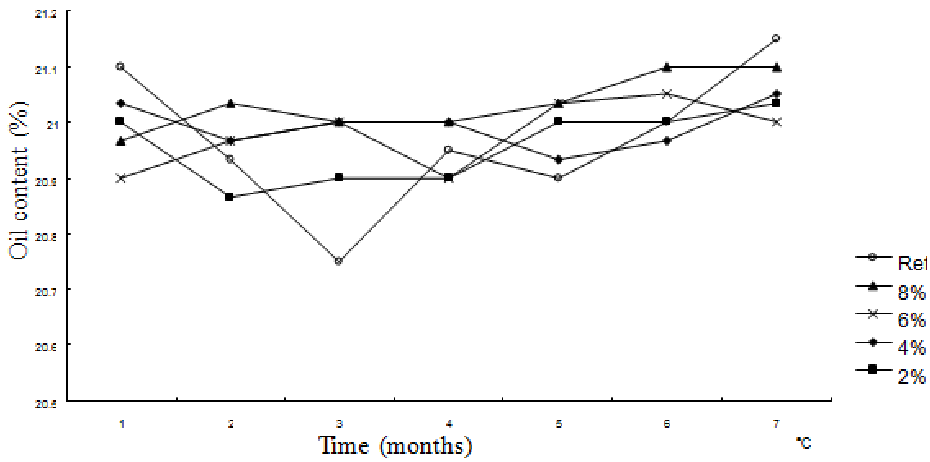

Fig. 15- The oil content of the soybeans under different low-oxygen concentration conditions at 20^{o}C.

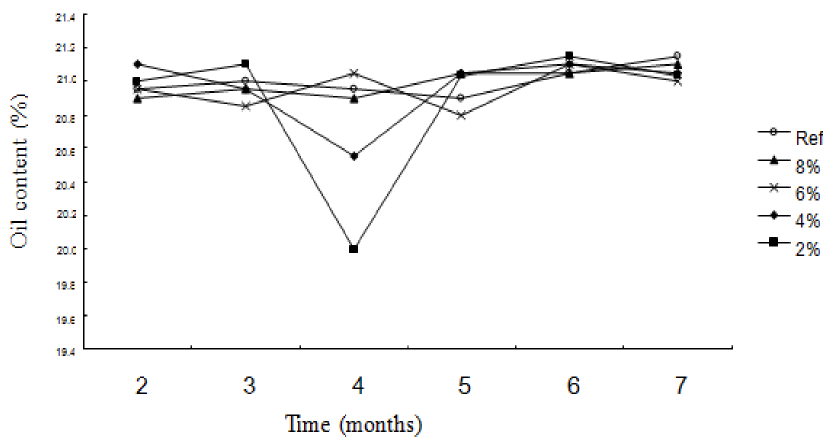

Fig. 16- The oil content of the soybeans under different low-oxygen concentration conditions at 30^{o}C.

Moisture content of soybean stored at low-oxygen

Under the low-oxygen storage conditions, the changes in moisture content of soybean with storage time are shown in Figures 17 and 18.

The results show that storage time, did not significantly influenced the changes in moisture content. During the nitrogen purge process, controlling the relative humidity of the gas was sufficient to avoid water loss of soybean.

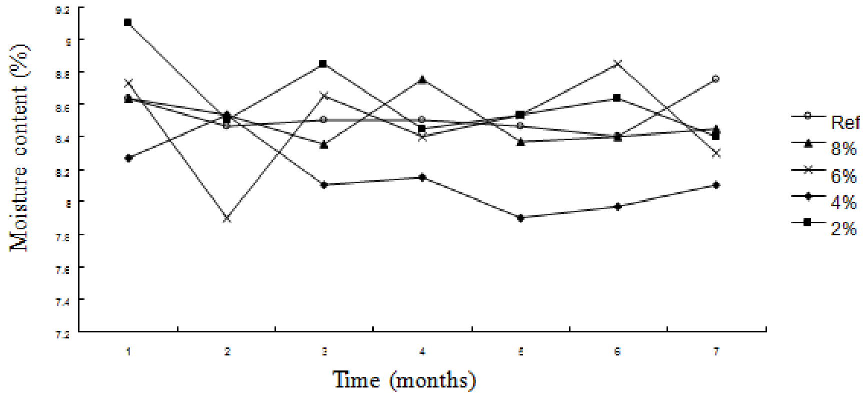

Fig. 17- The moisture content of the soybeans under different low-oxygen concentration conditions at 20°C.

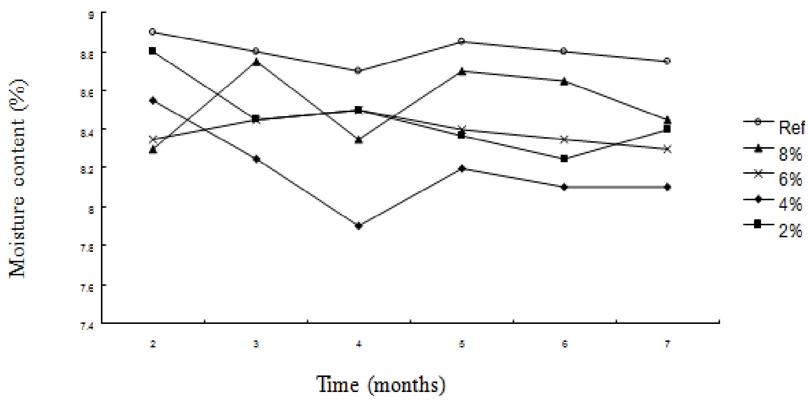

Fig. 18-The moisture content of the soybeans under different low-oxygen concentration conditions at 30°C.

CONCLUSIONS

Quality of soybean stored at different temperatures and low oxygen concentrations was compared with that stored under conventional storage condition. Results showed that the soybean chroma, oil content, total protein and moisture content did not change significantly as storage time prolonged. Acid value, peroxide value and the activity of the urea enzyme had a trend to be influenced as oxygen content increase; especially at high temperature conditions, low oxygen could play the important role on mitigating the negative changes in the soybean quality. Since the moisture of the tested soybean was low, the influence of low oxygen to ensure soybean quality was not significant. In the future, the effect of low oxygen technology on the quality of soybean stored at high moisture will be studied.

REFERENCES

Li G (2006) Inspection and analysis of fuel oil. Chemical Industry Press, Beijing.
Lu Q (1999) Grain and oil storage. Chinese Financial & Economic Publishing House, Beijing.
Cao Y, Cui G (2005) Review about safe storage technology of soybean. Grain Storage, 3: 17-23.
Liu Z, Su L (2003) A perception on green grain storage. Liangyou Cangchu Keji Tongxun, 2: 23.