JAP&T
TPA-Timişoara

Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2016, 22(2), 108-113

Journal of Agroalimentary Processes and Technologies

Study on thermo-oxidative stability of soybean oil during convective heating at simulated frying temperature

Mariana-Atena Poiana[1*], Teodor Trasca[1], Diana Moigradean[1], Cristina Gaita[1]

[1]Banat`s University of Agricultural Sciences and Veterinary Medicine "King Mihai I of Romania" from Timisoara, Faculty of Food Processing, Calea Aradului 119, Timisoara 300645, Romania

Received: 05 May 2016; Accepted: 31 June 2016

Abstract

The main goal of this study was to investigate the thermo-oxidative stability of soybean oil subjected to convective heating at simulated frying temperature of 185±5°C up to 4h. The lipid oxidation induced in soybean oil was assessed on the base of peroxide value (PV), para-anisidine value (pAV), conjugated dienes and trienes, the inhibition of oxidation (IO) and TOTOX value. Also, total phenolic content (TP) was evaluated in response to heating to estimate their losses related to the level of lipid oxidation. Our results have proved that soybean oil exposure at high temperature resulted in important increases in PV, pAV and TOTOX values. Moreover, the content of conjugated dienes and conjugated trienes monitored by absorbance values at 232 nm and at 270 nm recorded also, significant increases in response to heating. The addition of BHT in soybean oil samples exposed to high temperature limited the lipid oxidation processes, evidenced by decreases in the values of monitored parameters (PV, pAV, TOTOX, K232 and K270). The results obtained by performing of this study suggested that the evaluation of multiple quality parameters is a necessary approach for assessing the lipid stability in the course of heat treatment.

Keywords: soybean oil, convective heating, thermo-oxidative stability, primary and secondary oxidation

1. Introduction

Soybean oil is one of the most popular and largely edible oils used in the word for cooking, baking and salads preparation. This vegetable oil is rich in polyunsaturated and monounsaturated (PUFA, MUFA) fatty acids and low in saturated fatty acids and trans fatty acid - free [1,2]. Soybean oil is considered healthier than other edible oils because of its variety of essential fatty acids needed to the health diet. Moreover, soybean oil contains a number of plant sterols with a wide variety of health benefits. Also, phenolic compounds existing in soybean oil are very important for the oxidative stability of the polyunsaturated fatty acids of this oil [3]. Although soybean oil retains its natural antioxidant compounds and has a good nutritional profile due to the high level of unsaturated fatty acids, it is very susceptible to lipid oxidation, especially during processing at high temperature, specific to some food thermal applications [4, 5].

Lipid oxidation represents main way of oil quality deterioration because of rancid and undesirable flavors as well as due to the generated reactive oxygen species which are an important role in induction of carcinogenesis, cardiovascular diseases and aging processes [1, 6]. The lipid oxidation of edible oils influences their chemical, nutritional and sensory properties, having a significant role in determining the shelf-life of edible oils and, eventually, influences their uses [7].

The chemistry of lipid oxidation processes occurring at high temperatures is very complex because of both thermal and oxidative reactions. During oil heating at frying temperature various chemical reactions such as

Corresponding author: *e-mail: atenapoiana@yahoo.com*

oxidation, hydrolysis, thermal decomposition and polymerization takes place [3, 5]. As a result of deep-oil frying, occurs decreases in unsaturated fatty acids and increases of the polar compounds.

Phenolic compounds found in plant oils have the ability to improve the stability and nutritional characteristics of the vegetable oils and they may prevent the oil deterioration by scavenging of free radicals responsible for lipid oxidation [8, 9]

Considering all above mentioned information, the aim of this study was to examine the high-temperature stability of soybean oil (with and without addition of BHT) as a function of heating time in simulated frying conditions (185±5°C). The oxidative degradation of soybean oil samples was monitored by many methosa that included the determination of peroxide value (PV), para-anisidine value (pAV), UV absorption characteristics (K232 and K270), as a measure of conjugated dienes and trienes, the inhibition of oil oxidation (IO, %) and total oxidation (TOTOX) value.

2. Materials and Method

Heat treatment of soybean oil samples

20.0±0.5 g refined soybean oil samples with 200 ppm BHT, respectively without antioxidant (control) were weighed into Pyrex Petri dishes (10 cm inner diameter) and then heated without lids for 30, 60, 120, 180 and 240 min in a forced-air oven (electric convection) (Esmach/Italy, 1200W) at simulated frying temperature of 185±5°C. The oil samples temperatures has been monitored using a calibrated chromel-alumel thermocouple (HI 935009, Hanna Instruments). After heating, the oil samples were rapidly cooled at room temperature, stored in glass bottles and then they were placed in a refrigerator (4-6ºC) until analysis.

Analytical determinations

The lipid oxidation induced by heat exposure was monitored by measuring of analytical indices as follows: peroxide value (PV), para-anisidine value (pAV) as well as conjugated dienes and trienes [10]. Also, the inhibition of oil oxidation (IO, %) and total oxidation (TOTOX) were evaluated.

PV (expressed in meq/kg oil) was iodometrically determined according to standard methods for oils analysis [11].

pAV value was evaluated by AOAC official method using the UV-VIS spectrophotometer (Analytic Jena Specord 205) [11]. This index represents a measure of the carbonyl content in the oil samples.

The content of conjugated dienes and conjugated trienes was monitored on the base of absorbances at 232 nm and at 270 nm. The changes in UV absorption characteristics (K232 and K270) were determined according to the International Standard Organization method [12]. K232 and K270 extinction coefficients were calculated from the absorption values at 232 and 270 nm, respectively, read by an UV spectrophotometer (Specord 205, Analytic Jena, Germany), using a 1% solution of the soybean oil in cyclohexane and 1 cm cellpath length.

IO value was calculated with the formula (1) [13]:

$$IO\ (\%) = \left(1 - \frac{\text{increase in PV of oil sample}}{\text{increase in PV of control}}\right) \times 100 \quad (1)$$

TOTOX value was calculated according to formula (2) [14]:

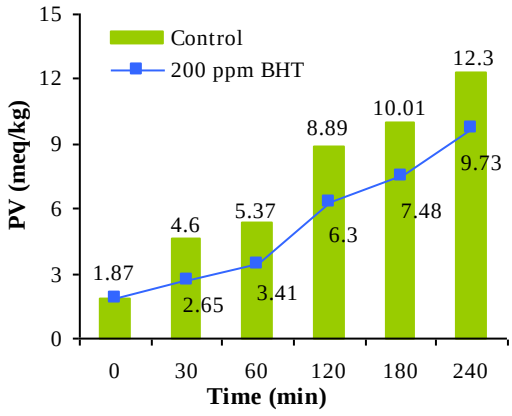
$$\text{TOTOX value} = 2 \times PV + pAV \quad (2)$$

Total phenolic content (TP) of soybean oil samples was analyzed following the Folin-Ciocalteu method [15]. The extraction of phenolic compounds from oil was performed as follows: 2 mL soybean oil sample was mixed with 20 mL of 70% aqueous ethanol solution (v/v) by sonication at 20°C for 30 min. After centrifuged for 10 min at 5000 rpm the supernatant was separately and used for TP analysis on the base of calibration curve by measuring the absorbance at 750 nm. TP content was expressed as μM gallic acid equivalents (GAE) per mL oil. The calibration curve was prepared using standard solution of gallic acid in the range 0.5-5 μM GAE/mL.

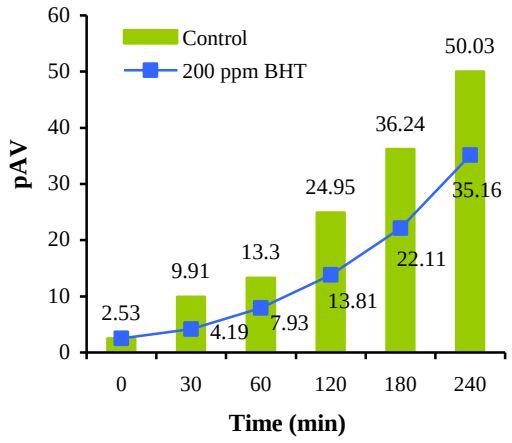
3. Results and discussion

Data submitted in Figure 1 (a) express the evolution of PV recorded during the heating of soybean oil at simulated frying temperature. The peroxides measurement can be used as an index for highlighting the early stages of the lipids oxidation.

It can be seen a continuous increase in this indicator throughout heating, which highlights that the rate of hydroperoxides formation was vastly superior to that of their degradation.



(a)



(b)

Figure 1. Changes induced in PV (a) and pAV (b) during soybean oil heating

It may be noted a decrease in the content of hydroperoxides in oil samples supplemented by synthetic antioxidant BHT to a level of 200 ppm, compared to the control sample. Along with PV, IO is used to highlight the primary oxidation process developed in oil samples subjected to thermal stress [16].

The measurement of hydroperoxides is limited because of their transient nature, representing a potential risk for subsequent formation of unpleasant sensory compounds. PV increases only when the rate of peroxides formation exceeds the rate of their decomposition [16].

Hydroperoxides, the products of the primary oxidation process are decomposed during high temperature exposure to secondary oxidation products such as aldehydes, aliphatic ketones, alcohols, acids and hydrocarbons. The latter are more stable during heating and they are the main products responsible of rancid smell of vegetable oils [2, 3].

To ensure a better monitoring of lipid oxidation during heating is required the simultaneous detection of primary and secondary products of lipid oxidation. pAV is a reliable indicator of the levels of undesirable secondary products formed in the lipids oxidation processes [17].

The values recorded for pAV presented in Figure 1(b) reveal that by extending the soybean oil samples exposure to elevated temperature is becoming more evident the formation of secondary oxidation products. During the heat treatment there is an increase from 2.53 to 50.03 in the control sample, respectively at 35.16 in oil with addition of BHT.

The Figure 2 shows the potential of synthetic antioxidant BHT to inhibit the formation of hydroperoxides in soybean oil, as a result of primary lipid oxidation.

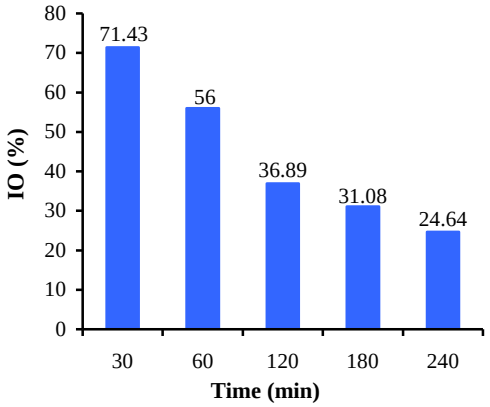


Figure 2. The efficiency of BHT to inhibit lipid oxidation during soybean oil heating

The inhibitory effect of BHT against primary lipid oxidation developed in soybean oil subjected to heat treatment, registered its maximum value after 30 minutes and decreased with increasing of the exposure time to high temperature up to 4 hours.

The values obtained for IO reveal the close connection between this indicator and PV value. It can be said that BHT had inhibitory potential over 50% against primary lipid oxidation in the first 60 min of heat exposure at high temperature.

Figure 3 presents the overall picture of lipid oxidation induced as a result of thermal stress applied to soybean oil samples. Thus, the lipid degradation developed in soybean oil by 4h of heat exposure, can be characterized by an increase in the TOTOX value up to about 75 in the case of control and 55 in oil sample with BHT to a level of 200 ppm.

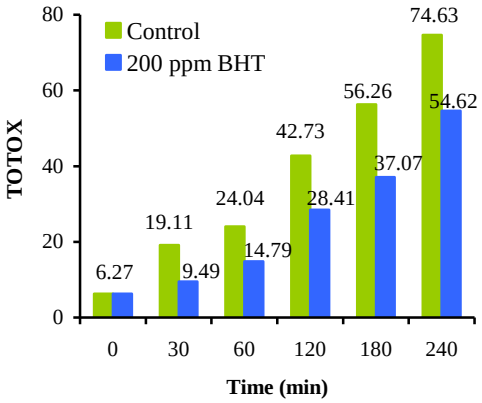


Figure 3. Changes in TOTOX value induced by high-temperature heating of soybean oil

The oxidation of polyunsaturated fatty acid in response to heating resulted in the formation of hydroperoxides. After their formation, these specific compounds of the primary lipid oxidation, the conjugated double bonds from unsaturated fatty acids of soybean oil suffer a structural rearrangement generating conjugated dienes that absorb in UV at 232 nm [18]. When the polyunsaturated fatty acids with three or more double bonds (e.g., linoleic acid) are subjected to oxidation, the conjugation can be extended to another double bond, resulted in formation of a conjugated trienes, which absorb UV light with a wavelength of 270 nm.

The changes occurring in the absorbance values recorded at 232 and 270 nm, quantified by K232 and K270 were used as significant indicators for monitoring the lipid oxidation. The quantification of conjugated dienes and trienes reveals the progress of the thermo-oxidative lipid degradation since these compounds remain in the oil, they are not thermolabiles as hydroperoxides, or volatile like secondary oxidation compounds [15,18].

Data presented in Figure 4 show the increasing of conjugated dienes and trienes monitored on the base of K232 and K270 with advancing of lipid oxidative processes.

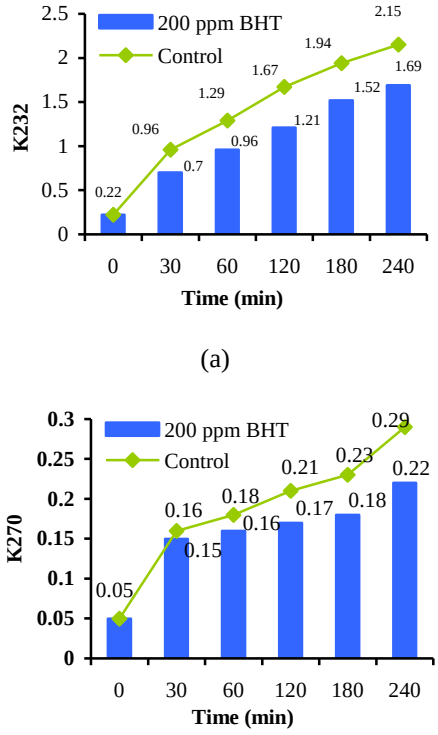


Figure 4. Changes in UV absorption characteristics (a: K232; b: K270) during soybean oil heating

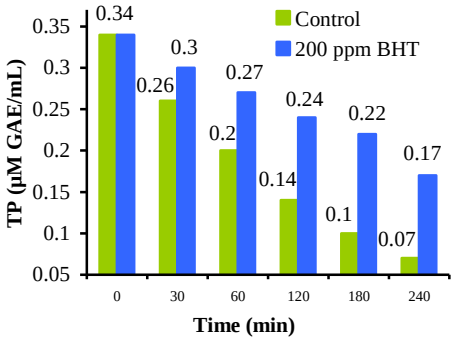


Figure 5. Changes in TP content of oil samples in response to high temperature heating

Figure 5 depicts the changes recorded in total phenolics content during during soybean oil samples heating.

It can be noted an alteration of these compounds as a result of thermal stress. Thus, at the end of heating, TP content decreased from 0.34 to 0.07 in control sample, respectively up to 0.17 in oil sample with BHT to a level of 200 ppm. TP compounds significantly contributed to oxidative stability oil soybean oil in the heating time. Our data are consistent with those reported by Chantzos and Georgiou [9] regarding the finding that the lipid oxidation is more advances in oil sample with lower antioxidant compounds

4. Conclusions

Oil samples exposure to convective heating at simulated frying temperature of 185±5°C up to 4 h resulted in significant alterations of soybean oil quality, quantified by formation of hydroperoxides and secondary oxidation products. By increasing the duration of soybean oil heating, it was noted the increases in hydroperoxides and secondary oxidation products, evidenced by increased in both PV and pAV values. It was noted increasing in the content of conjugated dienes and trienes with the progress of lipids thermo-oxidative degradation. As a result, the TOTOX value, used to describe the overall process of lipid oxidative degradation in soybean oil, recorded increases in response to heating at The addition of BHT, as a synthetic antioxidant, in soybean oil samples subjected to thermal stress, inhibit the primary and secondary oxidation of lipid. Phenolic compounds in soybean oil were significantly decreased in response to high temperature exposure. As a result, TP content of soybean oil samples is closely related to the lipid oxidative deterioration. Our results highlighted that the lipid oxidative stability during soybean oil heating at simulated frying temperature can be successfully monitored on the base of multiple quality parameters.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

References

1. Anwar, F.; Chatha, S. A.S.; Hussain, A.I., Assessment of oxidative deterioration of soybean oil at ambient and sunlight storage, *Grasas Y Aceites* **2007**, *58(4)*, 390**–**395.
2. Sarkar, A.; Golay, P.-A.; Acquistapace, S.; Craft, B.D. Increasing the oxidative stability of soybean oil through fortification with antioxidants, *International Journal of Food Science & Technology* **2015**, *50(3)*, 666–673.
3. Marinova, E.M.; Seizova, K.A.; Totseva, I.R.; Panayotova, S.S.; Marekov, I.N.; Momchilova, S.M., Oxidative changes in some vegetable oils during heating at frying temperature, *Bulgarian Chemical Communications* **2012**, *44(1)*, 57–63.
4. Steenson, D.F.; Min, D.B., Effect of β-carotene and lycopene thermal degradation products on the oxidative stability of soybean oil, *Journal of the American Oil Chemists' Society* **2000**, *77*, 1153–1160.
5. Nzikou, J.M.; Matos; Moussounga, J.E.; Ndangui C.B., Pambou-Tobi, N.P.; E.M. Bandzouzi, E.M.; A. Kimbonguila, A.; Linder M., Desobry, S., Study of oxidative and thermal stability of vegetable oils during frying, *Research Journal of Applied Sciences* **2009**, *4(2)*, 94–100.
6. Pezzuto, J.M.; Park. E.J., Autoxidation and antioxidants, in Swarbrick J, Boylan JC, (Eds.), Encyclopedia of Pharmaceuticals Technology, (vol. 1, 2nd ed.) 97–113, Marcel Dekker Inc., New York, **2002**.
7. Dobarganes, M.C.; Márquez-Ruiz, G., Oxidized fats in foods, C*urrent Opinion in Clinical Nutrition and Metabolic Care* **2003**, *6*, 157–163.
8. Siger, A.; Nogala-Kalucka, M.; Lampart-Szczapa, E., The content and antioxidant activity of phenolic compounds in cold-pressed plant oils, *Journal of Food Lipids* **2008**, *5(2)*, 137–149.
9. Chantzos, N.V.; Georgiou, A.C. Monitoring lipid oxidation events at frying temperatures through radical scavenging assays, *Chemical Industry and Chemical Engineering Quarterly* **2007**, *13*, 163–166.
10. Gómez-Alonso, S.; Salvador, M. D.; Fregapane, G., Evolution of the oxidation process in olive oil triacylglycerol under accelerated storage conditions (40–60°C), *Journal of the American Oil Chemists' Society* **2004**, *81(2)*, 177–184.
11. AOCS (American Oil Chemists' Society). Official methods and recommended practices of the AOCS. 5th edition, editor Firestone D., AOAC Press, Champaign Illinois, USA, **1998**.
12. ISO 3656. Animal fats and vegetable, Determination of ultraviolet absorbance expressed as specific extinction in ultraviolet light, **2002**.

13. Mariod, A.A.; Matthäus, B.; Eichner, K.; Hussein H.I., Antioxidant activity of extracts from *Sclerocarya birrea* kernel oil cake, *Grasas Y Aceites* **2006**, *57*, 361–366.
14. Pereira de Abreu, D.A.; Paseiro Losada, P.; Maroto, J., Cruz, J.M., Evaluation of the effectiveness of a new active packaging film containing natural antioxidants (from barley husks) that retard lipid damage in frozen Atlantic salmon (*Salmo salar* L.), *Food Research International* **2010**, *43*, 1277–1282.
15. Singleton, V.L.; Orthofer, R.; Lamuela-Raventos, R.M., Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent, *Methods in Enzymology* **1999**, *299*, 152–178.
16. Poiana, M.A., Enhancing oxidative stability of sunflower oil during convective and microwave heating using grape seed extract, *International Journal of Molecular Sciences* **2012**, *13(7)*, 9240–9259.
17. Zhang, Y.; Yang, L.; Zu, Y.; Chen, X., Wang, F.; Liu, F., Oxidative stability of sunflower oil by carnosic acid compared with synthetic antioxidants during accelerated storage, *Food Chemistry* **2010**, *118*, 656–662.
18. Kim, R.; Labella, F., Comparison of analytical methods for monitoring autoxidation profiles of authentic lipids, *The Journal of lipid Research* **1987**, *28*, 1110–117.