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The High Dose Irradiation Affect the Quality Parameters of Edible Oils

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Abstract: The quality of edible oil or fat is usually determined in term of its quality constants/parameters. The change in these parameters would change the quality of the oil. There are some factors that affect by decreasing or increasing the level of quality parameters from the control and consequently change the market acceptable level. In this study sunflower, soybean and red palm oils were selected and the change in physico-chemical constants i.e. Color, Refractive Index, Free Fatty Acid, Peroxide Value, Iodine Value, Anisidine Value and β-Carotene were determined. The influencing factor was gamma radiation. The three oils samples were radiated with gamma rays using Cobalt-60 source (ISSLEDOVATEL, CIS) at the rate of 0.01539 kGy min^{-1} with doses of 1, 5, 10, 15 and 20 kGy. The non-radiated oils samples were used as a control. The free fatty acids, peroxide and anisidine values increase and iodine values decrease with the high doses of radiation. The red palm oil was found to contain 533 ppm of β-Carotene and thus show maximum stability. The level of β-Carotene in the sunflower and soybean was lesser and consequently show little radiolytic stability. It was found that the red palm oil is more resistant to radiation as compared to the soybean oil, while the sunflower shows less resistant than both soybean and red palm oils.

Key words: Carotenoids, edible oils, irradiation, radiolytic stability

INTRODUCTION

The term ionizing radiation referred to those radiations, which have the properties of ionization when pass through matter. This means that ions or excited molecules are the first species formed when the matter absorbs it. Gamma radiation being ionizing radiations have strong penetrating power and are usually obtained from Cobalt-60 sources, measured in the units of Gray or Rad. Gamma radiation can be used for the preservation of different foodstuffs. But the major difficulty in the application of high-energy radiation of food is the development of unpleasant flavors. The ionizing radiation (gamma radiation) especially affects the quality of oils by increasing its oxidation rate. It may also produce active species like free radicals, which initiate certain chemical reactions and thus result in the rancidity of the oils or fats. Several investigators suspected the lipid fraction as a major contributor to the irradiation odor of complex fat containing foods[1]. Beef fat or pork fat, for example, if irradiated under vacuum, gives rise to an off-odor. The irradiated fat odor produced in beef and pork fats was detectable at 2 Mrad and was more intense at higher doses. Alkanes, alkenes and alkadienes were major radiolytic products in these sample[2]. The increase in free fatty acid and total acidity, concomitant with pH decrease was observed in beans starch irradiated in the range of 2.5-20 kGy. ESR spectra of irradiated beans starch after 9 and 11th months storage (-40°C) showed the presence of long life radicals[3]. The effect of temperature, light and gamma irradiation on the soybean, sunflower, corn and palm products was observed. Determination of peroxide and cholesterol values after 5 months revealed there was significant increase in peroxide values of the samples exposed to fluorescent light at room temperature than those in refrigerator[4]. Radiation produces changes in the composition of oils and fats and it was found that most volatile components such terpene hydrocarbons are resistant to irradiation[5]. The effect of ionizing radiation on fatty acid composition of natural fats and on lipid peroxide formation revealed that peroxide value of fats and oils increase with radiation[6]. Different plant nuts were radiated with gamma rays of 0.5, 1.0 and 1.5 kGy. The lipids were extracted from the seed and were analyzed for various parameters. It was found that peroxide, anisidine and FFA values were higher in the irradiated samples[7]. Many attempts have been conducted to investigate the effect of irradiation at lower doses on the different edible

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oils[8,9], however the comparative radiolytic stability study at higher doses, of the edible oils particularly sunflower, soybean and red palm oils with respect to their physico-chemical constants is limited.

The objective of the present study was to determine the effect of ionizing radiation of higher doses on the quality parameters/physico-chemical constants of selected edible oils such as sunflower, soybean and red palm oils.

MATERIALS AND METHODS

Sample collection: The common edible oils i.e. sunflower and soybean oils were purchased from the local market at Peshawar, while the red palm oil was obtained from the PORIM's (Palm Oil Research Institute of Malaysia) regional office at Karachi. The oil samples were kept in the 50ml caped test tubes for irradiation.

Irradiation: All the three oil samples were then radiated with gamma rays using cobalt-60 source (ISSLEDOVATEL, CIS) at the rate of 0.01539 kGy min^{-1} (20°C) with the doses of 1, 5, 10, 15 and 20 kGy. A non-irradiated oil samples were placed outside of the irradiation chamber to have the same environmental temperature effect as the irradiated sample and consider as control.

Quality Parameters Study: After irradiation the oils samples were kept for six days in the refrigerator at (4°C in order to complete the oxidation started by the irradiation. The quality constant of oil i.e. Peroxide Value (POV) and Unsaturation or Iodine Value (IV) were determined by the AOCS methods[10] and Free Fatty Acid (FFA) was measured according to method of AOAC[11]. The color (Optical Density) was determined as absorbance (index of color development at 420 nm) using 50% v/v solution oil in iso-octane, with the help of Shimadzu UV-160 spectrophotometer. Anisidine value (AV) was measured spectrophotometrically at 350 nm, based on the reactions of aldehydic compounds and para-anisidine, in the presence of acetic acid. The β-carotene in the oil was determined by accurately weighed the oil in a 25 ml volumetric flask. Test portion in each flask was dissolved with a few ml of solvent and dilute to the mark. Then transfer to 1cm cuvette and absorbance was measured at 446 nm against solvent used with the help of Shimadzu UV-160 spectrophotometer.

All the parameters were determined in triplicates. Statistical analysis was carried out using Computer software SPSS[12] to compare differences among mean values. The values of all parameters are given in tabulated form, is the mean of triplicate readings.

RESULTS AND DISCUSSION

Color: Pure fats, fatty acids, esters and the other usual lipid derivatives are color less and essentially transparent to visible light (400-700 mμ). All natural fats and oils however, contain pigments that partially absorb transmitted light. The color of most of the oils and fats are due to presence of carotene pigments. Color of oils increase with increase in the pigments content. Color of present oils was determined in terms of the optical density (Table1). The results show increasing trend being in the range of (0.091 to 0.097) for sunflower oil and for soybean oil the trend is in the range (0.120 to 0.170) for the control to 20 kGy radiation doses. The red palm oil has descending trend from 0.022 to 0.005. It is clear from the findings that by increasing the radiation doses increase the color of sunflower and soybean oils, while decreasing for red palm oil. The increase in color is due to the colored products formed during radiolytic oxidation in SFO and SBO, whereas the decrease in the color of red palm oil is because of the splitting of colored carotene pigments. No significant effect on lipid oxidation or color in irradiated cooked pork sausage between vacuum and carbon dioxide packaging was found[13].

Refractive index: The refractive index of fats and fatty acids is an important characteristic for determining the purity or quality of substances. Refractive index values of sunflower, soybean and red palm oils are presented in the Table 2 which described that the increase in the radiation doses does not have significant effects on the refractive index of soybean oil, its value however change slightly by 0.0001 for sunflower oil. Earlier researcher had found out the value of refractive index for butter fat in the range of 1.453 to 1.456[14].

Free fatty acid: The free fatty acids of the oil samples were determined before its exposure to the gamma radiations, which were considered as control values for the irradiated oil samples (Table 3). The results indicate that sunflower oil is affected more due to high doses of gamma radiation and the values ranges from 0.2102 to 0.4840%. The soybean oil is less affected, with values ranges from 0.198 to 0.4415 %. Free fatty acids in red palm oils are in the range of 0.385-0.466% and this increase is smaller as compared to other two oils. It is thus found that high doses of radiations increases the amount of free fatty acids, which is due to the conversion of triglyceride to free fatty acids, as reported by Nawar[15]. Iqbal *et al.*[16] studied the fatty acid composition and purity of some cooking oils available in the market.

Table 1: The effect of high dose irradiation on the Optical density of sunflower and soybean and red palm oils

Radiation doses (kGy)	Color/Optical Density Sunflower oil	Soybean oil	Red palm oil
Control	0.091	0.120	0.022
1	0.088	0.129	0.012
5	0.089	0.134	0.0097
10	0.091	0.155	0.0065
15	0.093	0.159	0.0059
20	0.097	0.17	0.005

Table 2: The effect of high dose irradiation on the Refractive Index of sunflower and soybean and red palm oils

Radiation doses (kGy)	Refractive index Sunflower oil	Soybean oil	Red palm oil
Control	1.4713	1.4708	1.4638
1	1.4712	1.4709	1.4640
5	1.4713	1.4709	1.4641
10	1.4715	1.4710	1.4642
15	1.4716	1.4710	1.4640
20	1.4716	1.4709	1.4641

Table 3: The effect of high dose irradiation on the Free Fatty Acid of sunflower and soybean and red palm oils

Radiation Doses (kGy)	Free fatty acids Sunflower oil	Soybean oil	Red Palm oil
Control	0.2102	0.198	0.385
1	0.2823	0.2658	0.402
5	0.3889	0.3155	0.413
10	0.4037	0.347	0.425
15	0.4693	0.417	0.447
20	0.484	0.4415	0.466

Table 4: The effect of high dose irradiation on the Peroxide Value of sunflower and soybean and red palm oils

Radiation doses (kGy)	Peroxide value (meq kg^{-1}) Sunflower oil	Soybean oil	Red palm oil
Control	4.5	6.49	10.59
1	8.51	7.36	11
5	10.4	7.09	11.6
10	13.5	8.32	12.26
15	13.2	8.41	12.7
20	14.09	12.27	13.6

Table 5: The effect of high dose irradiation on the Anisidine Value of sunflower and soybean and red palm oils

Radiation doses (kGy)	Anisidine value Sunflower oil	Soybean oil	Red palmoil
Control	4.96	3.65	4.8
1	8.39	3.8	7.54
5	9.23	3.98	8.37
10	9.45	4.19	9.98
15	10.45	4.24	10.03
20	12.13	4.43	10.06

Table 6: The effect of high dose irradiation on the Iodine Value (Unsaturation) of sunflower and soybean and red palm oils

Radiation doses (kGy)	Unsaturation level (g 100^{-1} g^{-1}) Sunflower oil	Soybean oil	Red palm oil
Control	123.47	127.23	58.59
1	99.17	100.12	57.64
5	91.62	73.5	56.02
10	91.70	68.73	54.79
15	85.66	64.26	53.67
20	82.62	60.8	48.80

*The values were determined in triplicate

Peroxide value: The free fatty acids and the triglycerides are oxidizable by auto oxidation or by enzymes called lipo-oxygenases. The oxidation is concerned primarily with the unsaturated fatty acids, of which oleic, linoleic and linolenic acids are the most important. The oxidation of oils produces peroxides or hydro-peroxide that results in the rancidity of oils and fats determined as peroxide value (POV). The Table 4 shows the peroxide values of sunflower, soybean and red palm oils. It is clear from data that peroxide value increases with increasing radiation doses. Sunflower oil shows greater oxidation than soybean oil as its POV ranges from 4.50 to 14.09 meq kg^{-1} while this parameter starts from 6.49 for control and reaches 12.27 meq kg^{-1} for 20 kGy in soybean oil. Red palm oil shows lesser oxidation to radiation, its peroxide value ranges from 10.59 to 13.60 meq kg^{-1}. The increasing trend in the peroxide value of the oils indicates its deterioration towards high doses of radiation and sunflower oil is oxidized more than the soybean oil. Other investigators[8,17] reported increasing trend in POV values of some oil/fats due to irradiation.

Anisidine value: Lipid hydro-peroxides formed as a result of oxidation are very unstable and break down to an alkoxy free radical, which decomposes mainly by cleavage on either side of the carbon bearing the oxygen atom. Aldehydes are among the secondary reaction products, which give rise to flavors that are described as ranging from sweet, pungent to oxidized milk. The results regarding anisidine values are shown by the Table 5. From the data that anisidine value of all the three oils increases with increasing radiation doses. The result for sunflower oil shows that it is more rancid because of the high level of Anisidine, while the soybean oil is more resistant to oxidation induced by radiation. Ahmad *et al.*[7] reported that anisidine level of some nuts oil increases with low dose of irradiation.

Unsaturation value: The unsaturation of oil or fat can be determined by halogenation of the double bond present in the fatty acids. The most important halogenation method for the oil and fat is the Iodine value. The iodine values obtained are given in Table 6. According to the results, the decrease in the iodine value of sunflower oil in the range of 123 to 82 g 100^{-1} g^{-1} oil, while soybean oil shows a decreasing trend in the range of 127 to 60 g 100^{-1} g^{-1} from the control to 20 kGy radiation doses, respectively. The decrease in unsaturation is more in SFO

Table 7: The effect of high dose irradiation on the β-carotene level of sunflower and soybean and red palm oils

Radiation doses (kGy)	Carotene level (ppm) Sunflower Oil	Soybean oil	Red palm oil
Control	24.65	22.13	585.33
1	15.57	14.21	532.30
5	15.10	12.38	448.90
10	11.38	7.38	367.30
15	7.00	3.09	337.30
20	2.93	1.98	254.70

*The values were determined in triplicate

and SBO as compared to red palm oil. Some investigators[18,19] find out that iodine value decrease when oil is treated with low dose gamma radiation.

β-carotene: β-carotene is the precursor of vitamin A and is mostly present in all natural fats and oils. It acts as a strong natural antioxidant. High level of β- carotene offer greater stability to the oil toward rancidity. Data regarding the β- carotene values are presented by the Table 7. The results show that β- Carotene content of sunflower and soybean oils decrease with increase in radiation doses and reach to the lowest level. Red palm oil contains the highest amount of carotene i.e. 585.33 ppm and a similar decreasing trend was observed which indicate that the carotene level falls to 254.70 ppm. The gamma radiation split up the molecule of β-carotene and thus the level of carotene decrease. Increasing the radiation doses thus decrease in the carotene level, which result in lowering the stability of oil and fat and occurrence of rancidity[20].

It is clear from the results of this investigation that the sunflower oil is less resistant to the exposure of high radiation doses as compared to the soybean oil and red palm oil; although red palm oil shows stability for irradiation doses up to 15 kGy due to the presence of high level of carotene. It is therefore recommended that both the sunflower and soybean oils should not be irradiated by doses above 10 kGy.

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